SVEA HOVRÄTT
Patent- och marknadsöverdomstolen
Rotel 020109

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ÖVERKLAGAT AVGÖRANDE
Patent- och marknadsdomstolens dom 2019-07-26 i mål PMT 6829-17, se bilaga A

PARTER

Klagande
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SAKEN
Bättre rätt till patentsökt uppfinning

Patent- och marknadsöverdomstolens domslut, se nästa sida.

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DOMSLUT

1. Patent- och marknadsöverdomstolen ändrar Patent- och marknadsdomstolens dom, punkterna 1 och 2 i domslutet, samt

a) fastställer att C-Rad Imaging AB har bättre rätt än Beamocular AB i konkurs till hälften av den eller de uppfinningar som specificeras i patentkraven i den amerikanska patentansökan med publiceringsnummer US 2016/0259065 A1 i dess lydelse vid tidpunkten när det sökta patentet beviljades och patentkraven i den europeiska patentansökan med publiceringsnummer EP 3265852 i dess lydelse efter den ändring som gjordes när ansökan fullföljdes hos det europeiska patentverket, och

b) befriar Beamocular AB i konkurs från skyldigheten att ersätta C-Rad Imaging AB för rättegångskostnad i Patent- och marknadsdomstolen och förordnar att vardera parten ska svara för sin rättegångskostnad där.

2. Vardera parten ska svara för sin rättegångskostnad i Patent- och marknadsöver-domstolen.

3. Patent- och marknadsdomstolens sekretessförordnande, punkten 3 i domslutet, ska inte längre bestå.

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YRKANDEN M.M.

Beamocular AB i konkurs (Beamocular) har yrkat att Patent- och marknadsöverdomstolen ska ogilla C-Rad Imaging AB:s (C-Rad) talan i dess helhet. Beamocular har vidare yrkat att Patent- och marknadsöverdomstolen ska befria bolaget från skyldigheten att ersätta C-Rad för dess rättegångskostnad i Patent- och marknadsdomstolen och i stället förplikta C-Rad att ersätta Beamocular för rättegångskostnad där.

C-Rad har motsatt sig att Patent- och marknadsdomstolens dom ändras. C-Rad har dock i Patent- och marknadsöverdomstolen ändrat både förstahands- och andrahandsyrkandet på så sätt att ”och samtliga patentansökningar och patent dessa må resultera i” har frånfallits. Vidare har C-Rad förtydligat att yrkandena avser att bolaget har bättre rätt *än Beamocular* till den eller de uppfinningar som framgår av yrkandena.

Parterna har yrkat ersättning för rättegångskostnader i Patent- och marknadsöverdomstolen.

PARTERNAS TALAN

Parterna har åberopat samma grunder och utvecklat sin talan på i huvudsak samma sätt som i Patent- och marknadsdomstolen.

UTREDNINGEN

Utredningen är densamma som i Patent- och marknadsdomstolen. Parterna har åberopat samma skriftliga och muntliga bevisning som åberopades där. Den muntliga bevisningen har lagts fram genom uppspelning av de förhör som hölls i Patent- och marknadsdomstolen.

DOMSKÄL

Inledning

C-Rads talan avser bättre rätt, helt eller delvis, till den uppfinning eller de uppfinningar som specificeras i patentkraven i en amerikansk patentansökan och i en europeisk patentansökan. Den europeiska ansökan har vilandeförklarats i avvaktan på utgången i detta mål, medan behandlingen av den amerikanska ansökan fortsatt och sedermera lett till att patent meddelats i USA. Patentkraven i det beviljade patentet skiljer sig från dem som fanns i patentansökan när den gavs in.

Patent- och marknadsöverdomstolen redogör inledningsvis för ramen för prövningen här med hänsyn till den justering som gjorts av C-Rads yrkanden och för de rättsliga utgångspunkterna för domstolens prövning. Därefter följer domstolens bedömning i sak och slutligen domstolens ställningstagande i fråga om ersättningsskyldigheten för rättegångskostnader i målet.

Ramen för Patent- och marknadsöverdomstolens prövning

Patent- och marknadsdomstolens prövning har utgått från patentkraven i det beviljade amerikanska patentet. C-Rad har i Patent- och marknadsöverdomstolen ändrat sina yrkanden så att de inte längre omfattar beviljade patent. Hänvisningen i yrkandena till patentkraven i den amerikanska patentansökan måste emellertid anses avse patent-kraven såsom de slutligt kom att formuleras under handläggningen av ansökan innan patentet meddelades. En sådan tolkning är också förenlig med det sätt på vilket C-Rad här har fört sin talan. På motsvarande sätt förhåller det sig med hänvisningen till patentkraven i den europeiska patentansökan, bilaga 5 i den överklagade domen. Som framgår av C.D.:s sakkunnigutlåtande ändrades patentkraven när ansökan fullföljdes hos det europeiska patentverket så att de kom att överensstämma med patentkraven för det amerikanska patentet, varefter ärendet på C-Rads begäran vilandeförklarades. Det nu anförda innebär att det sakligt sett inte blir någon skillnad mellan den prövning som ska göras i Patent- och marknadsöverdomstolen och den som gjordes i Patent- och marknadsdomstolen.

Prövningen får alltså även i Patent- och marknadsöverdomstolen göras i förhållande till Beamoculars Ionizing Radiation Detecting Device (IRDD) sådan den kommer till uttryck i patentkraven i den amerikanska patentansökan såsom de slutligen kom att utformas innan patent beviljades och i patentkraven i den europeiska patentansökan med publiceringsnummer EP 3265852 i dess lydelse efter ändringen av ansökan den 27 september 2017, där dessa patentkrav alltså motsvarar patentkraven i det beviljade amerikanska patentet (se bilaga 4 i den överklagade domen).

I det följande talas för enkelhets skull om uppfinningen IRDD. Med detta avses alltså de uppfinningar som omfattas av C-Rads yrkanden.

Rättsliga utgångspunkter

Som Patent- och marknadsdomstolen redovisat tillkommer rätten till en patentsökt uppfinning uppfinnaren eller den till vilken uppfinnarens rätt övergått (jfr 1 § första stycket patentlagen, 1967:837, och artikel 60 (1) i den europeiska patentkonventionen EPC). Om en patentansökan avseende uppfinningen har gjorts av någon annan, kan den som har rätten till uppfinningen få ansökan överförd på sig (se 18 § första stycket och 53 § första stycket patentlagen). Av 18 § framgår att om någon inför patentmyndigheten visar att han eller hon har bättre rätt till en uppfinning som är föremål för patentansökan, ska patentansökan på yrkande överföras på honom eller henne. För den som anser sig ha bättre rätt till en patentsökt uppfinning står också möjligheten till buds att i stället väcka talan om detta vid domstol.

Bättre rätt till en patentsökt uppfinning kan, som Patent- och marknadsdomstolen också redovisat, bero t.ex. på att den som sökt patentet fått kännedom om uppfinningen, eller de idéer på vilka den väsentligen bygger, genom att missbruka uppgifter som uppfinnaren eller dennes rättsinnehavare lämnat i förtroende (se NU 1963:6 s. 219 f., prop. 1966:40 s. 116 f. och RÅ 82 2:69). Det krävs att det finns en överensstämmelse mellan den patentsökta uppfinningen och idéer tillhöriga den som för talan om bättre rätt, att den patentsökta uppfinningen inte har gjorts eller kan ha gjorts oberoende av dessa idéer och att patentsökanden på ett orättmätigt sätt tillgodogjort sig uppfinningen (se Jonshammar, Patentlag, 1967:837, 18 §, Karnov 2020-10-01, JUNO). Den som hävdar bättre rätt till en patentsökt uppfinning har åberopsbördan för dessa omständigheter.

En särskild fråga är vad som ska anses innefattas i uttrycket idé i detta sammanhang. Förarbetena ger inte någon närmare ledning i denna fråga. Enligt Patent- och marknadsöverdomstolen måste idén ha utvecklats och konkretiserats på ett sådant sätt att den utan större svårighet kan identifieras. Samtidigt kan det inte ställas alltför höga krav i detta avseende. Det kan exempelvis inte krävas att det måste vara fråga om en idé som har övervägts eller utvärderats närmare. Vidare bör även en idé, som uppfinnaren i sitt utvecklingsarbete av något skäl valt att inte gå vidare med, kunna åberopas till grund för bättre rätt.

När det sedan gäller var bevisbördan bör placeras i ett mål om bättre rätt till patentsökt uppfinning är den naturliga placeringen, enligt Patent- och marknadsöverdomstolen, att låta bevisbördan vila på den som påstår sig ha bättre rätt till uppfinningen. En sådan placering är i överensstämmelse med ordalydelsen i 18 § patentlagen, enligt vilken den som inför patentmyndigheten visar sig ha bättre rätt till patentsökt uppfinning har rätt att få ansökningen överförd på sig. (Se även Domeij, Patent och företagshemligheter, 2019, s. 38.)

Som framgått ovan, och som också Patent- och marknadsdomstolen konstaterat, är grunden för talan om bättre rätt till en patentsökt uppfinning sammansatt av flera olika omständigheter av omedelbar betydelse för rättsföljden, dvs. rättsfakta. Patent- och marknadsdomstolen har bedömt att bevisbördan för omständigheten att den patentsökta uppfinningen utvecklats oberoende av idéer från den som hävdar bättre rätt till uppfinningen bör vila på patentsökanden eftersom denne har bäst möjligheter att säkra bevisning om omständigheten. Patent- och marknadsöverdomstolen konstaterar dock att, om den som påstår sig ha bättre rätt till uppfinningen lyckas visa att uppfinningen motsvarar idéer som tillhör honom eller henne, talar redan detta förhållande starkt för att uppfinningen inte har gjorts oberoende av dessa idéer. Därtill kommer att den som påstår sig ha rätt till idéerna måste anses ha bäst möjligheter att säkerställa och lägga fram bevisning om hur motparten har fått eller kan ha fått del av idéerna på sådant sätt att uppfinningen inte kan anses ha utvecklats oberoende av dessa. En annan sak är att patentsökanden då givetvis har möjlighet att förringa värdet av denna bevisning genom att lägga fram egen bevisning om det utvecklingsarbete som har bedrivits av denne. Vid sådant förhållande saknas det, enligt Patent- och marknadsöverdomstolen, skäl till en omkastad bevisbörda för någon av de omständigheter som åberopas till grund för en talan om bättre rätt till patentsökt uppfinning. En placering av bevisbördan på den som hävdar bättre rätt till uppfinningen stämmer också väl överens med regleringen i 7 § första stycket lagen (1949:345) om rätten till arbetstagares uppfinningar, LAU.

Till skillnad från vad som gäller i förhållandet mellan arbetsgivare och arbetstagare enligt 7 § första stycket LAU bedömer Patent- och marknadsöverdomstolen att det för en talan om bättre rätt till patentsökt uppfinning inte finns något förhållande som motiverar att beviskravet ska vara ett annat än vad som gäller inom civilrätten i allmänhet. Den som påstår sig ha bättre rätt till en patentsökt uppfinning ska därmed visa att det finns en överensstämmelse mellan den patentsökta uppfinningen och idéer tillhöriga den som för talan om bättre rätt, att den patentsökta uppfinningen inte har gjorts eller kan ha gjorts oberoende av dessa idéer och att patentsökanden på ett orättmätigt sätt tillgodogjort sig uppfinningen. Patent- och marknadsöverdomstolen prövar frågorna i den ordningen.

Patent- och marknadsöverdomstolens bedömning i fråga om C-Rad har bättre rätt än Beamocular till uppfinningen

Hur förhåller sig IRDD till idéerna hos C-Rad?

Inledningsvis konstaterar Patent- och marknadsöverdomstolen att IRDD utgör en vidareutveckling av tekniken i C-Rads patenterade uppfinning X-Ray Detector (bilaga 2 i den överklagade domen) och att det på ett övergripande plan finns stora likheter mellan X-Ray Detector och IRDD. Vissa skillnader finns dock, vilket parterna också är ense om. De skillnader som är aktuella här, liksom i Patent- och marknadsdomstolen, är de tekniska särdrag som i korthet kan benämnas konverter med flerlagerstruktur (S1), beläggning av blindhålens yta med ett isolerande material (S2), placeringen av GEM-hålen (S3) och segmenteringen av GEM-folien (S4).

När det gäller särdragen S1, S3 och S4 gör Patent- och marknadsöverdomstolen inte några andra bedömningar än de som Patent- och marknadsdomstolen har gjort i fråga om att särdragen har sin motsvarighet i idéer som tagits fram inom C-Rad. I frågan om särdraget S2 uppvisar en sådan motsvarighet gör Patent- och marknadsöverdomstolen dock följande bedömning.

Av patentkrav 1 i IRDD framgår att ett isolerande materiallager, som enligt beskrivningen kan vara exempelvis parylene, används för att täcka insidan av blindhålen förutom ett område som lämnas frilagt. Det frilagda området har till funktion att kunna attrahera och neutralisera positiva joner och kan exempelvis placeras på botten av varje blindhål (se bilaga 4 till den överklagade domen, kolumn 4, rad 37–50 respektive kolumn 8, rad 40–42). Som Patent- och marknadsdomstolen funnit har detta särdrag inte någon motsvarighet i X-Ray Detector. I X-Ray Detector är blindhålens väggar eller botten belagda med ett fotoelektriskt material. Alternativt kan både väggar och botten vara belagda (se bilaga 2 till den överklagade domen, kolumn 8, rad 26–50). Ett sådant lager är inget isolerande lager i patentkravets mening, i synnerhet som ett fotoelektriskt material definieras genom sin egenskap att vid fotoninfall avge fria elektroner, varvid det blir elektriskt ledande.

C-Rad har i detta sammanhang hävdat att syftena med det isolerande materialet i IRDD och det fotoelektriska lagret i X-Ray Detector är väsentligen desamma, vilket Beamocular har bestritt. Patent- och marknadsöverdomstolen gör bedömningen att oavsett om syftena är lika eller inte, så representerar IRDD i detta avseende en annan teknisk lösning.

Frågan är då om särdraget S2 väsentligen uppvisar någon motsvarighet i idéer som fanns hos C-Rad. I ett e-postmeddelande till G.N. den 25 januari 2014 har K.M. nämnt bl.a. att det enligt två artiklar är möjligt att åstadkomma en selektiv beläggning med parylene, och att det i princip borde vara möjligt att undvika att parylene hamnar på insidan av hålen på konvertern. Frågan om en i viss mening selektiv beläggning med parylene har alltså, som Patent- och marknadsdomstolen funnit, diskuterats inom C-Rad. Däremot har det inte genom utredningen framkommit att det inom C-Rad diskuterats eller på annat sätt aktualiserats en specifik selektiv beläggning som är lämplig för att attrahera och neutralisera joner. Till skillnad från Patent- och marknadsdomstolen gör Patent- och marknadsöverdomstolen därför bedömningen att detta särdrag inte kan anses väsentligen bygga på någon idé som fanns hos C-Rad.

Sammanfattningsvis är Patent- och marknadsöverdomstolens slutsats att särdragen S1, S3 och S4 har sin motsvarighet i idéer som tagits fram hos C-Rad, men att så inte är fallet beträffande särdraget S2.

Är IRDD resultatet av en oberoende uppfinnarinsats?

Den patentsökta uppfinningen IRDD utgörs alltså förenklat uttryckt väsentligen av X-Ray Detector med tillägg för de fyra tekniska särdragen som redovisats tidigare. Patent- och marknadsöverdomstolen har i det föregående kommit till slutsatsen att ett av dessa, S2, inte har någon motsvarighet i X-Ray Detector eller i någon idé hos C-Rad. Redan vid detta förhållande får S2 bedömas vara resultatet av en uppfinnarinsats som oberoende utförts av Beamocular.

De övriga tre särdragen – S1, S3 och S4 – har sin motsvarighet i idéer som tagits fram inom C-Rad och det saknar här, enligt Patent- och marknadsöverdomstolen, betydelse att C-Rad, i vart fall såvitt framkommit i målet, inte självt gått vidare med utvecklingsarbetet med en eller flera av dessa idéer. Som angetts tidigare är det C-Rad som har att visa att IRDD beträffande dessa tre särdrag inte är resultatet av en oberoende uppfinnarinsats.

Redan det förhållandet att nämnda särdrag motsvarar utvecklade och konkretiserade id éer som togs fram inom C-Rad under den tid som K.M. arbetade där talar för att särdra gen inte är resultatet av en oberoende uppfinnarinsats. Detta gäller särskilt med beakta nde av att C-Rad hade endast ett fåtal anställda, att verksamheten i bolaget var helt inriktad på att utveckla X-Ray Detector och att K.M. hade en ledande position i bolaget. Av utredningen framgår dessutom att K.M. var involverad i utvecklingsarbete t och att han hade goda kunskaper i tekniska frågor. Det framgår även att K.M. faktiskt hade tillgång till teknisk information rörande bl.a. de nu aktuella särdragen. Därutöver framgår det av utredningen att framtagandet av IRDD gjordes med ambitionen att få fram en produkt som fungerade bättre än X- Ray Detector och att komma tillrätta med vissa problem som X-Ray Detector var behäftad med. Sammantaget talar det som nu anförts med styrka för att särdragen S1, S3 och S4 i IRDD inte är resultatet av en oberoende uppfinnarinsats hos Beamocular.

Det som talar för att Beamocular har tagit fram IRDD med de tre särdragen S1, S3 och S4 oberoende av C-Rad är framför allt de uppgifter som lämnats av K.M. och M.A.. De har båda två beskrivit att M.A. bedrev ett arbete för att utveckla IRDD, vilket det enligt Patent- och marknadsöverdomstolen inte finns skäl att ifrågasätta. Att det i vart fall under början av 2015 utförts ett sådant arbete får också stöd av de anteckningar som M.A. gjort under arbetets gång och det råder inte heller någon tvekan om att M.A. i och för sig hade tillräcklig teknisk kompentens för att utföra det beskrivna utvecklingsarbetet. Som Patent- och marknadsdomstolen har redovisat ger emellertid utredningen inte någon tydlig bild av hur framtagandet av IRDD gick till, bl.a. med avseende på vilken information som K.M. lämnade till M.A. i samband med detta. Uppgiften att K.M. inte skulle ha deltagit i M.A.:s arbete motsägs dessutom av det förhållandet att K.M. ensam hade kontakten med Beamoculars patentombud då bolagets patentansökan utarbetades och att han inledningsvis var angiven som ensam uppfinnare till IRDD. Med hänsyn till detta bedömer Patent- och marknadsöverdomstolen att det som K.M. och M.A. berättat inte förtar styrkan av den bevisning som C-Rad har åberopat.

Vid en sammantagen bedömning finner Patent- och marknadsöverdomstolen att C-Rad har visat att IRDD när det gäller särdragen S1, S3 och S4 inte är resultatet av en oberoende uppfinnarinsats hos Beamocular.

Har Beamocular orättmätigt tillgodogjort sig uppfinningen IRDD?

När det sedan gäller frågan om Beamocular har tillgodogjort sig uppfinningen IRDD på ett orättmätigt sätt är det, som angetts tidigare, C-Rad som ska visa att så är fallet. Eftersom särdraget S2 inte motsvarar någon idé som fanns hos C-Rad har Beamocular inte tillgodogjort sig den delen av uppfinningen på ett orättmätigt sätt. I fråga om särdragen S1, S3 och S4 är det klarlagt att de motsvarar idéer som utvecklats i C-Rad under den tid som K.M. arbetade där och som han senare tog med sig till Beamocular.

Det har visserligen inte lagts fram något sekretessavtal eller motsvarande för K.M.:s anställning som är aktuell i detta mål. Enligt Patent- och marknadsöverdom- stolen sa knas det emellertid skäl att ifrågasätta T.T.:s uppgift om att känsliga uppgifter rörande forsknings- och utvecklingsarbete skulle hållas inom företaget. E.H. redogörelse för hur sekretess tillämpades inom C-Rad föranleder inte någon annan bedömning.

Av utredningen framgår att det inom C-Rad har funnits en öppenhet så till vida att X-Ray Detector – efter det att patentansökan getts in – presenterats på en bransch- mässa och i kontakter med externa aktörer utan att det då ställts krav på sekretess. Dessa presentationer har emellertid, såvitt framkommit, rört produkten som sådan. Det finns inte något stöd i utredningen för att C-Rad skulle ha offentliggjort uppgifter i patentansökan eller uppgifter om någon av de idéer hos bolaget på vilka särdragen S1, S3 och S4 väsentligen byggt. Inte heller ger utredningen stöd för att K.M. skulle haft rätt att använda sådana uppgifter på något annat sätt än vad som följde av hans anställning.

Mot denna bakgrund finner Patent- och marknadsöverdomstolen att särdragen S1, S3 och S4 i uppfinningen IRDD har tillkommit genom information som K.M. fick del av inom ramen för sin anställning i C-Rad och som han inte fick sprida till utomstående. Beamocular har därmed tillgodogjort sig den del av uppfinningen IRDD som utgörs av särdrag S1, S3 och S4 på ett orättmätigt sätt.

Har C-Rad helt eller delvis rätt till uppfinningen?

Patent- och marknadsöverdomstolen har alltså kommit fram till att uppfinningen IRDD delvis väsentligen bygger på idéer som härrör från C-Rad och delvis är resultatet av arbete hos Beamocular som utförts oberoende av C-Rad. Den del som tagits fram av Beamocular, dvs. S2, kan enligt Patent- och marknadsöverdomstolen inte ses som en oväsentlig del i IRDD.

Uppfinningen som specificeras i patentkraven i patentansökningarna för IRDD är således delvis ett resultat av arbete som utförts hos Beamocular. En konsekvens av detta är att C-Rad inte kan tillerkännas bättre rätt till hela uppfinningen eftersom det skulle medföra att C-Rad fick bättre rätt till en uppfinning trots att bolaget inte ensamt tagit fram den och att Beamocular helt utesluts från rätten till en uppfinning som man delvis står bakom.

Enligt Patent- och marknadsöverdomstolen går det utifrån utredningen i detta fall inte att med tillräcklig säkerhet göra någon bedömning av hur stor del av den patentsökta uppfinningen som vardera parten kan anses ha bidragit med och därmed bör ha rätt till. En rimlig utgångspunkt bör i ett sådant fall vara att parterna har rätt till lika stor del av uppfinningen, dvs. hälften var (jfr 1 § lagen, 1904:48 s. 1, om samäganderätt). Det har enligt Patent- och marknadsöverdomstolen inte framkommit skäl att avvika från detta.

Patent- och marknadsöverdomstolens slutsats är alltså C-Rad och Beamocular har rätt till hälften vardera av uppfinningen IRDD.

Sammanfattande bedömning

Patent- och marknadsöverdomstolens bedömningar och ovan redovisade slutsatser innebär att C-Rads förstahandsyrkande inte ska bifallas, men att andrahandsyrkandet ska bifallas på det sättet att C-Rad förklaras ha bättre rätt än Beamocular till hälften av uppfinningen IRDD.

Av domslutet måste tydligt framgå vilken eller vilka uppfinningar som C-Rad får bättre rätt till. Som tidigare redovisats får C-Rads andrahandsyrkande anses avse den eller de uppfinningar som specificeras i den amerikanska patentansökan med publiceringsnummer US 2016/0259065 A1 med den slutliga lydelse som kraven getts när patentet beviljades samt, när det gäller den europeiska patentansökan med publiceringsnummer EP 3265852, i dess lydelse när ärendet vilandeförklarades hos det europeiska patentverket efter att ansökan fullföljts där. Dessa förhållanden ska återspeglas i domslutet.

Patent- och marknadsdomstolens dom, punkten 1 i domslutet, ska ändras i enlighet med detta.

Rättegångskostnader

Patent- och marknadsöverdomstolens ställningstagande i huvudsaken innebär att C-Rad och Beamocular är ömsom vinnande, ömsom förlorande i såväl Patent- och marknadsdomstolen som Patent- och marknadsöverdomstolen. Vad Beamocular har anfört om att C-Rads ändring av yrkandena ska påverka fördelningen av rättegångskostnadsansvaret föranleder inte någon annan bedömning. Vardera parten ska därmed svara för sina rättegångskostnader i båda instanserna.

Sekretess

Ingen av parterna har längre begärt att sekretess ska gälla för någon handling som åberopats i målet. Det finns därför inte skäl att låta Patent- och marknadsdomstolens sekretessförordnande bestå.

Överklagande

Det saknas skäl att göra undantag från huvudregeln att Patent- och marknadsöverdomstolens domar inte får överklagas (se 1 kap. 3 § tredje stycket lagen, 2016:188, om patent- och marknadsdomstolar). Denna dom får därför inte överklagas.

I avgörandet har deltagit hovrättsråden Ulrika Beergrehn och Göran Söderström, referent, tf. hovrättsassessorn Viktor Kamlin och de tekniska experterna Håkan Sandh och Anders Hansson.

STOCKHOLMS TINGSRÄTT
Patent- och marknadsdomstolen

DOM
2019-07-26
Meddelad i
Stockholm

Mål nr
PMT 6829-17

PARTER

Kärande
C-Rad Imaging AB, 556643-6043
Bredgränd 18
753 20 Uppsala

Ombud: Advokaterna P.O. och C.I
Baker & McKenzie Advokatbyrå KB
Box 180
101 23 Stockholm

Svarande
Beamocular AB i konkurs, 556976-7972
c/o K. M.

Ombud: Advokat M.T. och Jur. kand. F.E.
Next Advokater KB
Box 7641
103 94 Stockholm

DOMSLUT

1. Patent- och marknadsdomstolen fastställer att C-Rad äger bättre rätt till den eller de uppfinningar som specificeras i patentkraven i den amerikanska patentansökan med publiceringsnummer US 2016/0259065 A1 samt i den europeiska patentansökan med publiceringsnummer EP 3265852 och samtliga patentansökningar och patent dessa må resultera i.

2. Beamocular AB i konkurs ska ersätta C-Rad Imaging AB för rättegångskostnader med 1 530 128 kr, varav 1 418 783 kr utgör ombudsarvode jämte ränta enligt 6 § räntelagen från denna dag till dess betalning sker.

Postadress	Besöksadress	Telefon	Telefax	Expeditionstid
Box 8307 104 20 Stockholm	Rådhuset, Scheelegatan 7	08-561 654 70		måndag – fredag 08:00–16:00

E-post: stockholms.tingsratt@dom.se
www.stockholmstingsratt.se

3. Sekretessen enligt 36 kap. 2 § offentlighets- och sekretesslagen (2009:400) ska, i den mån uppgifterna inte tagits in i denna dom, bestå för uppgifterna i Patent- och marknadsdomstolens aktbilaga 41, 42 och 124 med undantag för uppgifterna på sidan 8.

BAKGRUND

C-Rad AB med dotterbolag bedriver forskning, utveckling, tillverkning och försäljning av lösningar och utrustning inom området avancerad strålterapi. All forskning och utveckling bedrivs i dotterbolagen, bl.a. i C-Rad Imaging AB (C-Rad). Dotterbolagen innehar ett antal patent och patentansökningar på det aktuella området, bl.a. uppfinningen X-Ray Detector som C-Rad patentsökte den 4 september 2013 (US 2015/0060685 A1 fortsättningsvis benämnd ’685), domsbilaga 1. Patent beviljades på X-Ray Detector i USA den 26 december 2017 (US 9851452 B2 fortsättningsvis benämnt ’452), domsbilaga 2. C-Rads registrerade verksamhetsändamål är att bedriva utveckling, tillverkning och försäljning av utrustning och system för användning inom diagnostik och strålterapi.

Beamocular AB i konkurs (Beamocular) är ett bolag vars registrerade verksamhetsändamål är att bedriva utveckling och marknadsföring av utrustning för användning inom det medicinsktekniska området. Verksamheten består mer precist i att utveckla och marknadsföra lösningar inom området avancerad strålterapi.

K. M. anställdes inom C-Rad-koncernen under 2005. I mars 2013 blev han verkställande direktör för C-Rad. K. M. sade den 29 augusti 2014 upp sig från C-Rad med sista arbetsdag den 29 september 2014. Bekräftelse på uppsägningen ingicks mellan K. M. och C-Rad den 3 september 2014.

K. M. är sedan oktober 2014 styrelseledamot och verkställande direktör i Beamocular. Bolaget hade under 2015 tre anställda, bl.a. K. M. och M. A. Beamocular patentsökte den 2 mars 2015 uppfinningen Ionizing Radiation Detecting Device (IRDD) med K. M. som angiven uppfinnare (US 2016/0259065 A1 fortsättningsvis benämnt ’065), domsbilaga 3. Patent beviljades för IRDD i USA den 30 januari 2018 (US 9880291 B2 fortsättningsvis benämnt ’291), domsbilaga 4. Ansökan om patent för IRDD har, med ’065 som prioritetsgrundande dokument, även lämnats in till den europeiska patentmyndigheten EPO som PCT/EP

2016/054429 och fullföljts som EP 3265852 (fortsättningsvis benämnt ’852), domsbilaga 5. Ansökan har förklarats vilande i avvaktan på utgången av förevarande tvist.

Beamocular försattes den 8 januari 2018 i konkurs. Konkursboet har inte inträtt i rättegången.

YRKANDEN OCH INSTÄLLNING

C-Rad har i första hand yrkat att Patent- och marknadsdomstolen fastställer att C-Rad äger bättre rätt till den eller de uppfinningar som specificeras i patentkraven i den amerikanska patentansökan med publiceringsnummer US 2016/0259065 A1 samt i den europeiska patentansökan med publiceringsnummer EP 3265852 och samtliga patentansökningar och patent dessa må resultera i.

C-Rad har i andra hand yrkat att Patent- och marknadsdomstolen fastställer att C-Rad äger bättre rätt till en andel uppgående till 9/10 – eller den mindre andel som domstolen må finna – av den eller de uppfinningar som specificeras i patentkraven i den amerikanska patentansökan med publiceringsnummer US 2016/0259065 A1 samt i den europeiska patentansökan med publiceringsnummer EP 3265852 och samtliga patentansökningar och patent dessa må resultera i.

Beamocular har bestritt käromålet i dess helhet.

Parterna har yrkat ersättning för sina rättegångskostnader.

GRUNDER

C-Rad

Förstahandsyrkandet

K. M. var verkställande direktör för C-Rad, tillika projektledare för GEMini-projektet från mars 2013. K. M. sade upp sig från sin anställning, som under inga förhållanden avslutades före den 3 september 2014.

K. M. har inom ramen för sin anställning ägnat sig åt utvecklingen av det s.k. GEMini-projektet som bedrivits av C-Rad och han står tillsammans med den hos C-Rad anställde G. N. som uppfinnare av den av C-Rad den 4 september 2013 patentsökta uppfinningen X-Ray Detector. Både K. M. och G. N. har överlåtit sina rättigheter till X-Ray Detector till C-Rad.

I tiden efter patentansökan av X-Ray Detector har både G. N. och K. M. ägnat sig åt vidareutvecklingen av X-Ray Detector och GEMini-projektet hos C-Rad.

Beamocular, ett bolag som K. M. är delägare i samt verkställande direktör för, har den 2 mars 2015 patentsökt uppfinningen IRDD.

Uppfinningstanken i X-Ray Detector utgör en konverterenhet och detektor som reducerar elektron- och fotonspridning och som möjliggör hög skärpa i bilder av inkommande strålning. I IRDD utgör uppfinningstanken en konverterenhet och detektor som reducerar spridda (laterala) elektroner och som möjliggör en ökad noggrannhet och upplösning i bilder av inkommande strålning.

Mellan X-Ray Detector och IRDD föreligger mycket stora likheter. Patentansökan avseende uppfinningen IRDD uppvisar i huvudsak följande tre tillägg i förhållande till X-Ray Detector.

1. Konverterstrukturen kan vara uppbyggd av flera lager som är isolerade från varandra. De olika lagren kan ha olika potentialer (spänningssättning). Flerlagerstrukturen utvecklades av C-Rad – främst av G. N. – under tid som K. M. var anställd hos C-Rad. Att de olika lagren kan ha olika potential konstaterades av C-Rad redan 2013. Detaljen om spänningssättning i tillägget är hur som helst så be-gränsad att väsentlig identitet mellan uppfinningarna under alla förhållanden föreligger.

2. Metallytor kan beläggas med Parylene. Detta tillägg definierar att ytan för varje blindhål är täckt med en isolator förutom en del som är exponerad för att kunna attrahera och neutralisera joner. Att använda Parylene som isolator är en idé som togs fram hos C-Rad av G. N. under den tid som K. M. var anställd hos C-Rad. Detaljen i tillägget – att endast delar av blindhålet isoleras för att påverka mäng-
den elektroner som lämnar blindhålet – tjänar samma syfte som den princip som kommer till uttryck i X-Ray Detector (se krav 4 och sid. 11 rad 24 i WO 2015/034419 A1, vilket motsvarar krav 4 och stycke [0073] i ’685, domsbilaga 2); där det fotoelektriska konverterlagrets syfte är att styra konverteringseffektivitet för valda fotonenergier, vilket betyder att beläggning, helt eller delvis, kommer att påverka mängden elektroner som lämnar konverterenhetens blindhål. Med andra ord är syftena med isolator i IRDD och det fotoelektriska konverterlagret i X-Ray Detector väsentligen desamma, dvs. att helt eller delvis belägga blindhålet för att påverka mängden elektroner som lämnar konverterenhetens blindhål, även om det sker via olika mekanismer. Detaljen i tillägget om att endast isolera delar är hur som helst så begränsad att väsentlig identitet mellan uppfinningarna under alla förhållanden föreligger.

3. Gem-hål kan placeras så att grupperna centreras mot det större konverterhålet. Detta tillägg framgår av X-Ray Detector och motsvarar väsentligen särdraget i

patentkrav 1 i ’452 (domsbilaga 2), som anger att åtminstone en del av de genomgående hålen är upplinjerade med blindhålen. Detta framgår även från beskrivningen. Upplinjeringen är en idé som togs fram hos C-Rad – främst av G. N. – under tid som K. M. var anställd hos C-Rad. Detaljen i tillägget som endast framgår i krav 5 i ’065 (domsbilaga 3) är oväsentligt och hur som helst så begränsad att väsentlig identitet mellan uppfinningarna under alla förhållanden föreligger.

De tillägg som IRDD uppvisar i förhållande till X-Ray Detector bygger på idéer och tekniska lösningar som tagits fram hos C-Rad, främst av G. N., under vidareutvecklingen av X-Ray Detector. Mellan X-Ray Detector och de idéer och tekniska lösningar som tagits fram hos C-Rad å ena sidan och uppfinningen IRDD å den andra föreligger i allt väsentligt uppfinningsidentitet. Om ansökan för IRDD skulle beviljas skulle patentet komma att utgöra ett beroendepatent under kraven i X-Ray Detector.

K. M. har erhållit information om dessa idéer och tekniska lösningar i förtroende inom ramen för sin anställning som verkställande direktör hos C-Rad. Beamocular har inte oberoende av den information om X-Ray Detector, och de idéer som tagits fram av C-Rad under vidareutvecklingen av X-Ray Detector, gjort eller kunnat göra uppfinningen IRDD och patentsöka denna med K. M. som angiven uppfinnare. IRDD är alltså inte resultatet av någon från X-Ray Detector, och de idéer som tagits fram hos C-Rad under vidareutvecklingen av X-Ray Detector, oberoende eller fristående uppfinningsverksamhet.

K. M. har agerat illojalt eller i vart fall missbrukat den information han i förtroende erhållit i sin tidigare anställning genom att Beamocular, i vilket bolag K. M. är verkställande direktör, orättmätigt har kunnat tillgodogöra sig uppfinningen genom att patentsöka IRDD.

Beamocular, genom K. M., har känt till att informationen om X-Ray Detector och vidareutvecklingen av X-Ray Detector härrörde från C-Rad samt att patentansökan avseende X-Ray Detector inte var offentlig vid tidpunkten för Beamoculars patentansökan av IRDD samtidigt som K. M. hade överlåtit sin andel av X-Ray Detector till C-Rad.

Om K. M. skulle anses vara uppfinnare av IRDD, har Beamocular patentsökt uppfinningen med K. M. som angiven uppfinnare inom sex månader från det att K. M. slutade sin anställning hos C-Rad.

Nyttjandet av uppfinningen IRDD faller inom C-Rads verksamhetsområde och äger samband med sådan forsknings- och uppfinnarverksamhet som varit K. M:s huvudsakliga uppgift i anställningen. Alternativt innefattar uppfinning IRDD lösningen av K. M. i tjänsten förelagd närmare angiven uppgift.

Det råder presumtion för att uppfinningen IRDD har tillkommit under K. M:s anställning.

C-Rad inträder som rättighetshavare med avseende på uppfinningen IRDD i förhållande till K. M. och äger därmed bättre rätt till uppfinningen än Beamocular.

Andrahandsyrkandet

Grunden för andrahandsyrkandet är densamma som för förstahandsyrkandet, dvs. att C-Rad har förvärvat X-Ray Detector i sin helhet samt resultaten av G. N:s intellektuella prestationer som resulterat i IRDD, vilka enligt C-Rad i vart fall utgör en andel av 9/10 av IRDD. I sista hand får domstolen pröva hur stor andel som rätteligen tillkommer C-Rad genom C-Rads förvärv av X-Ray Detector från K. M. och G. N. samt förvärvet av G. N:s del i utvecklingen av de tre särdragen.

Beamocular

Med start i april 2013 anställdes K. M. som verkställande direktör i C-Rad; en tjänst som inbegrep sedvanliga arbetsuppgifter för en verkställande direktör i ett dotterbolag till ett börsnoterat företag.

Inom ramen för C-Rad koncernens verksamhetsområde kom dock K. M. att på eget initiativ och utan samband med hans huvudsakliga arbetsuppgifter att uppfinna X-Ray Detector vilken patentsöktes i september 2013. K. M. var den huvudsaklige upphovsmannen till aktuell uppfinning, medan G. N. bidrog som meduppfinnare i begränsad omfattning.

Det bestrids att C-Rad, genom G. N. eller annan anställd, under tiden som K. M. var anställd i bolaget eller därefter, kom att uppfinna de särdrag i förhållande till X-Ray Detector som IRDD uppvisar. Följaktligen bestrids såväl att särdragen utgjort C-Rads företagshemliga information, som att C-Rad genom avtal eller med stöd av lagen om rätten till arbetstagares uppfinningar av G. N. eller annan har förvärvat rättigheterna till de idéer och tillägg som särskiljer IRDD från X-Ray De-tector.

Det bestrids även att K. M. bedrev med C-Rad konkurrerande verksamhet under sin anställning i bolaget eller att han vidtog åtgärder i syfte att bedriva med C-Rad konkurrerande verksamhet. Det bestrids således också att K. M. i sin roll som verkställande direktör för C-Rad lät en konsult analysera hårddiskar med information från GEMini-projektet i syfte att kunna överblicka vilken information han behövde ta med sig till Beamocular. Analyser av hårddiskar gjordes i syfte att underlätta för C-Rad.

Den 29 augusti 2014 valde K. M. att säga upp sin anställning i C-Rad. K. M. tog anställning som verkställande direktör i Beamocular med start den 1 oktober 2014. M. A. rekryterades under senhösten som forskningsansvarig med start den 1 januari 2015.

Även om domstolen mot förmodan skulle finna att G. N. eller annan anställd, under tiden som K. M. var anställd i C-Rad eller därefter kom att uppfinna de tillägg i förhållande till X-Ray Detector som IRDD uppvisar, vilket som nämnts bestrids, uppfann M. A. under alla omständigheter tre av de fyra specifika egenskaper som särpräglar IRDD oberoende härav utifrån kunskap om teknikens ståndpunkt och allmänt känd forskning. Detta utan att ta del av konfidentiell information tillhörig C-Rad. IRDD är således resultatet av en till C-Rad oberoende upp-finningsverksamhet.

IRDD har vidare en annan uppfinningstanke, och såväl uppfinningshöjd som nyhetsvärde i förhållande till X-Ray Detector. Denna omständighet bekräftas även av att det amerikanska patentverket har ansett att IRDD är patenterbar över X-Ray Detector och andra kända uppfinningar. Att det skulle föreligga väsentlig identitet mellan uppfinningarna är således även det felaktigt i sak och bestrids följaktligen. IRDD uppvisar i huvudsak fyra särskiljande drag i förhållande till tidigare patenterade uppfinningar:

1. En konverter med en flerlagerstruktur. Denna teknik användes regelmässigt av kretskortstillverkare sedan 1960-talet, och föreslogs C-Rad av underleverantören tillika kretskortstillverkaren ELTOS av rent tillverkningstekniska skäl. Aktuell teknik var även känd inom röntgendetektorområdet redan genom US-patentet 3 971 942 från 1970-talet. M. A:s tekniska idé att lagren isolerades i förhållande till varandra med hjälp av Parylene för att möjliggöra en separat spänning med olika elekt-riska potential mellan desamma motiverade dock patenterbarhet. Den tekniken finns inte i t.ex. X-Ray Detector och diskuterades inte heller inom C-Rad som ett intressant och utvecklingsbart alternativ. Tvärtom avfärdade G. N. och C-Rad en lösning med olika spänningar för X-Ray Detector.

2. Tekniken att belägga metallytor med Parylene som isolator kom fram redan på 1940-talet. På röntgendetektorområdet var det dessutom redan allmänt känt genom exempelvis US-patentansökan 2009/0142227 att Parylene är en lämplig isolator. Syftet med användandet av Parylene inom X-Ray Detector var endast att elektriskt isolera konvertern från GEM-folien. M. A. kom dock ensam till insikten att Parylene som ovan nämnts dels kunde användas för att isolera lagren i konvertern i för-hållande till varandra, dels att det i en och samma konverterstruktur behövdes både oisolerade och isolerade metallytor för att fånga in och neutralisera joner samtidigt som elektrontransporten säkerställdes i och med att det isolerade ytskiktet i IRDD placerades på insidan av konverterhålen. Parylene används således för olika syften i X-Ray Detector respektive IRDD. Det fotoelektriskt konverterande ytskiktet i X-Ray Detector gör i sig ingen nytta och har inte Parylene.

3. GEM-hålens placering. Idéen att upplinjera grupper av flera GEM-hål mot varje konverterhål har aldrig diskuterats mellan K. M. och G. N. eller annan inom C-Rad. M. A. är ensam upphovsman till denna idé. I patentansökan för IRDD ingår även att ett visst säkerhetsavstånd krävs mellan GEM-hålens och konverterhålens kanter, vilket inte ingår i X-Ray Detector.

4. Uppdelning av GEM-folien i olika delområden (segment). Segmentering av GEM-folier är i sig allmänt känd teknik, och var så även långt innan korrespondensen mellan K. M. och CERN (Europeiska organisationen för kärnforskning). C-Rad medger självt, att segmenteringstekniken var känd genom korrespondens med CERN. Den allmänt kända segmenteringen tar inte hänsyn till en utformning av GEM-folien där GEM-hålen är upplinjerade mot varje konverterhål. K. M:s främsta bidrag till IRDD var att anpassa segmenteringen till både grupperna av GEM-hål samt även de grövre hålmönstren i konvertern.

Det bestrids att IRDD utgör ett beroendepatent under kraven i X-Ray Detector. Det be-strids vidare att K. M. har agerat illojalt eller att han i något sammanhang obehörigen har missbrukat information han erhöll under sin anställningstid i C-Rad.

M. A. är uppfinnare till de centrala delarna av IRDD och hans uppfinningsarbete har bedrivits utan att ta del av konfidentiell information från C-Rad.

I K. M:s anställningsavtal hos C-Rad har vidare varken funnits någon sekretess- eller konkurrensklausul, och inom C-Rad-koncernen har praxis genomgående varit att patentsökta uppfinningar inte har hållits hemliga, X-Ray Detector inkluderat. Den information som K. M. haft om X-Ray Detector har därför inte utgjort företagshemligheter. Beamocular har inte på ett orättmätigt sätt tillgodogjort sig IRDD.

I den utsträckning domstolen eventuellt skulle finna att K. M. är uppfinnare till IRDD görs följande gällande. K. M. hade inte forsknings- eller uppfinnarverksamhet som sin huvudsakliga arbetsuppgift i sin egenskap av verkställande direktör för C-Rad, och inte heller var han i tjänsten förelagd en närmare angiven uppgift bestående i att lösa de problem som IRDD utgör ett svar på. Det föreligger därför inte en presumtion för att uppfinningen IRDD har tillkommit under K. M:s anställning i C-Rad.

Det bestrids att 8 § lagen (1949:345) om rätten till arbetstagares uppfinningar (”LAU”) direkt eller analogt kan tillämpas på uppfinnaren själv. Arbetstagaruppfinnares skyldighet att iaktta sekretess enligt LAU framgår av 5 § andra stycket och gäller endast under fyramånadersfristen i 5 § första stycket.

Uppfinningen IRDD har inte med stöd av lag övergått från K. M. till C-Rad, och inte heller har aktuella rättigheter övergått från K. M. till C-Rad genom avtal. Det bestrids därmed att C-Rad skulle ha bättre rätt till IRDD.

OMSTÄNDIGHETER

Parterna har utvecklat sin respektive talan i skriftliga sakframställningar.

UTREDNINGEN

På C-Rads begäran har förhör under sanningsförsäkring hållits med verkställande direktören T. T. Vidare har vittnesförhör på bolagets begäran hållits med G. N. och patentombudet H. S.

På Beamoculars begäran har förhör under sanningsförsäkran hållits med K. M. Vidare har på bolagets begäran vittnesförhör hållits med M. A., L. J., E. H., C. K. och R. F. och patentombudet C. D.

Parterna har åberopat omfattande skriftlig bevisning.

DOMSKÄL

Inledande anmärkningar

Ett grundläggande inslag inom patenträtten är att rätten till en patentsökt uppfinning (uppfinnarrätten) tillkommer uppfinnaren eller den till vilken uppfinnarens rätt övergått (jfr 1 § första stycket patentlagen och artikel 60 (1) i den europeiska patentkonventionen EPC).

Om ett patent har sökts eller beviljats för annan än den som är berättigad till uppfinnarrätten kan denne för svenskt vidkommande – efter begäran om detta hos Patent- och registreringsverket eller efter talan vid domstol – få patentansökningen eller patentet överfört på sig (se 18 § första stycket och 53 § första stycket patentlagen). Innehavaren av uppfinnarrätten kan även efter talan vid domstol enligt allmänna förmögenhetsrättsliga principer få fastställt att denne äger bättre rätt till den patentsökta uppfinningen.

Ett av de fall som får anses kunna grunda ett anspråk på bättre rätt till en patentsökt uppfinning är om sökanden fått kännedom om uppfinningen, eller de idéer på vilka den väsentligen bygger, genom att på ett orättmätigt sätt använda uppgifter som uppfinnaren eller dennes rättsinnehavare delat med sig av (se NU 1963:6 s. 219 och RÅ 82 2:69 samt jfr även den skiljaktiga meningen i NJA 2009 s. 695 särskilt s. 712).

En slutats som enligt domstolen kan dras av det ovan anförda är att bifall till en talan om bättre rätt till en patentsökt uppfinning får anses förutsätta att det finns en överensstämmelse mellan idéer och tekniska lösningar till vilka käranden har en rätt och den patentsökta uppfinningen, att uppfinnaren till den patentsökta uppfinningen inte oberoende av idéerna och de tekniska lösningarna har gjort eller kan ha gjort den patentsökta uppfinningen och att sökanden av patentet missbrukat uppgifterna i förhållande till käranden (jfr Stockholms tingsrätts dom den 30 januari 2004 i mål T 6718-00 och T 18975-01, s. 32 samt Patent- och marknadsdomstolens dom den 2 maj 2018 i mål PMT 14315-15, s. 24).

Den civilrättsliga regleringen kring anspråk på bättre rätt till en patentsökt uppfinning skiljer sig från det skydd som uppställs för företagshemligheter i lagen (2018:558) om skydd för företagshemligheter (”FHL”) och tidigare lydelser av lagen. Syftena bakom regleringarna skiljer sig också åt. För att det ska vara fråga om en orättmätig användning av uppgifter framtagna av den som framställt ett anspråk på bättre rätt kan det inte anses nödvändigt att käranden visar att svaranden gjort sig skyldig till ett angrepp på företagshemlig information enligt FHL.

Som framhållits i juridisk doktrin (se Domeij, B., Patentavtalsrätt, andra uppl., s. 111) får bevisfrågor ofta en framträdande plats i en talan som innefattar en prövning av vem som har rätten till en patentsökt uppfinning. Bevisfrågorna, som inte uttryckligen regleras i någon nu relevant civilrättslig regel, kan avse såväl vem av parterna som har bevisbördan för en viss omständighet och vilka beviskrav som ska gälla. Som angetts ovan är det i förvarande mål inte fråga om en tillämpning av FHL och de principer för bevisbörda och beviskrav som kan gälla enligt den lagstiftningen.

Grunden för ett anspråk på bättre rätt till en patentsökt uppfinning är sammansatt av flera omständigheter av omedelbar relevans för målets utgång (rättsfaktum). För en civilrättslig regel som innehåller flera rättsfaktum kan bevisbördan vara delad, dvs. den ena parten har bevisbördan för vissa rättsfaktum medan den andra parten har det för andra rättsfaktum (se Ekelöf m.fl., häfte IV, 7:e uppl., s. 81).

Enligt domstolen ter det sig i förevarande fall som naturligt att C-Rad visar att de idéer och tekniska lösningar IRDD bygger på framtagits inom bolaget och att Beamocular haft tillgång till dem när patent på IRDD söktes den 2 mars 2015. Om C-Rad förmått visa nu redovisade omständigheter bör det ankomma på Beamocular att visa hur den patentsökta uppfinningen, dvs. IRDD, utvecklats och att detta skett oberoende av uppgifter om idéer och tekniska lösningar framtagna inom C-Rad. Att bevisbördan för sistnämnda omständighet åvilar Beamocular framstår för domstolen som rimligt både med hänsyn till att C-Rad i annat fall skulle behöva visa på icke-existensen av en omständighet och att Beamocular är i en bättre position att säkra bevisning avseende den aktuella omständigheten.

En annan central fråga i ett mål av förevarande slag är vilket krav på likhet som ska ställas vid prövningen av om IRDD uppvisar likhet med de idéer och tekniska lösningar C-Rads anspråk grundas på. Härvidlag kan konstateras att de bedömningskriterier som har till ändamål att ligga till grund för prövningen av patenterbarhet och skyddsomfång saknar omedelbar relevans för en prövning av ett anspråk på bättre rätt (jfr NJA 2009 s. 695). Att patent beviljats för IRDD i USA saknar således omedelbar relevans för prövningen i målet. Likaså saknar frågan om ett patent avseende IRDD utgör ett beroendepatent under ett patent på X-Ray Detector omedelbar relevans.

Prövningen är, till skillnad mot bedömningar av intrångs- och ogiltighetsfrågor, således inriktad på en bedömning av om idéer och tekniska lösningar framtagna av käranden har ett innehåll som överensstämmer med svarandens patentsökta uppfinning.

Domstolen prövning kommer ske med utgångspunkt i ovan redovisade ställningstaganden vad avser fördelning av bevisbörda och vilken likhet som krävs mellan de idéer och tekniska lösningar C-Rads anspråk grundar sig på och IRDD.

Domstolen bedömer först vilka skillnader som föreligger mellan X-Ray Detector och IRDD för att därefter gå vidare till att pröva om eventuella skillnader har sin motsvarighet i idéer och tekniska lösningar som framtagits inom C-Rad innan IRDD patentsöktes av Beamocular i USA den 2 mars 2015 samt om K. M. hade vetskap om dem. Blir svaret på denna fråga positivt följer en bedömning av om IRDD är ett resultat av oberoende uppfinnarverksamhet i förhållande till hos C-Rad förekommande uppgifter. Om domstolen kommer till slutsatsen att det inte är fråga om en oberoende uppfinnarverksamhet prövas om det förekommit en orättmätig användning av uppgifterna som framtagits inom C-Rad.

Skillnaderna mellan X-Ray Detector och IRDD

Parterna har redovisat skillnaderna utifrån de i USA beviljade patenten för X-Ray Detector respektive IRDD, dvs. patenten ’452 och ’291 (domsbilaga 2 och 4). Domstolen har funnit det ändamålsenligt att göra på motsvarande sätt. Det beviljade patentet för IRDD ska för övrigt inte rymma någon uppfinning utöver den som redan innefattades i den patentansökan avseende USA som är föremål för C-Rads talan.

Enligt Beamocular finns det väsentligen fyra särskiljande särdrag mellan IRDD och X-Ray Detector. Särdragen i ’291 (domsbilaga 4) som utgör skillnaderna har angetts till följande av Beamocular.

Särdrag S1:

”each perforated accelerator plate provided with an insulating layer to insulate each perforated accelerator plate from one another in order to be able to provide separate potential to each perforated accelerator plate” (patentkrav 1)

Särdrag S2:

“a surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions” (patentkrav 1)

Särdrag S3:

“wherein a longitudinal axis of the center of each of said groups of GEM through holes is aligned with a longitudinal axis of a respective one of said blind holes” (patentkrav 1)

Särdraget kan, enligt domstolen, även delas upp i två särdrag där det första anger att grupperna av GEM-hål har en mittpunkt och det andra att mittpunktens längdaxel är i linje med respektive blindhåls längdaxel. Antalet GEM-hål i en grupp kan enligt patentkrav 1 vara 1–20.

Särdrag S4:

“In a further embodiment of a GEM in accordance with the invention both the conducting coating of the upper major surface of the GEM is divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.” (spalt 8 rad 1–5)

<u>Särdragen S1–S4 i förhållande till X-Ray Detector</u>

Domstolen kan konstatera att de två uppfinningarna X-Ray Detector och IRDD rör samma teknikområde och att de i fråga om särdrag uppvisar betydande likheter. Det föreligger emellertid, vilket är ostridigt i målet, de skillnader mellan IRDD och X-Ray Detector som har redovisats ovan.

C-Rad har vidare gjort gällande att de skillnader Beamocular pekat på är idéer och tekniska lösningar som framtagits inom C-Rad av i första hand G. N. ensam alternativt i förening med K. M. Enligt domstolen går det inte heller i denna del att dra några säkra slutsatser på grundval av den utredning som lagts fram i målet kring vem – G. N. eller K. M. – som står bakom de idéer och tekniska lösningar C-Rad gör gällande har framtagits hos C-Rad under den tid den K. M. var anställd vid bolaget.

Vad gäller frågan om S1–S4 har en motsvarighet i X-Ray Detector gör domstolen följande bedömning.

X-Ray Detector som den beskrivs i ’452 (domsbilaga 2) kan innehålla flera lager acceleratorplattor, som även kan vara av olika metallmaterial, men dessa är inte isolerade från varandra. Särdraget S1 i IRDD har således inte en direkt motsvarighet i X-Ray Detector. Särdraget S1 möjliggör också en potentialskillnad mellan de olika acceleratorplattorna.

Vad gäller särdrag S2 så utnyttjar X-Ray Detector inte ett isolerande lager i blindhålen för att attrahera och neutralisera joner. I X-Ray Detector används ett fotoelektriskt material, som kan läggas på respektive blindhåls botten. Det fotoelektriska lager som används i X-Ray Detector utgörs typiskt av metall, se spalt 8, rad 46 i ’452 (domsbilaga 2) och något isolerande alternativ anges inte. Särdraget S2 i IRDD har således inte en direkt motsvarighet i X-Ray Detector.

I X-Ray Detector anges att flertalet GEM-hål kan vara upplinjerade med flertalet blindhål. Det framgår dock inte av X-Ray Detector vad som avses exakt med sagda upplinjering. Inte heller är GEM-hålen enligt X-Ray Detector grupperade, vilket spelar mindre roll eftersom en ”grupp” enligt IRDD kan innebära endast ett hål. Det framgår emellertid inte av X-Ray Detector att mittpunktens längdaxel i varje grupp av GEM-hål är i linje med respektive blindhåls längdaxel. Detta gäller oavsett om antalet i en grupp utgör 1, 3 eller fler hål. Särdraget S3 i IRDD har således inte en direkt motsvarighet i X-Ray Detector.

Segmentering beskrivs inte i X-Ray Detector och särdraget S4 i IRDD har således inte en direkt motsvarighet. C-Rad nämner att CERN ställer krav på segmentering, vilket skulle kunna betyda att C-Rad anser att detta särdrag är underförstått i X-Ray Detector. C-Rad har dock inte närmare utvecklat påståendet eller lagt fram någon utredning till stöd för varför särdraget skulle anses vara underförstått med hänvisning till vilka krav CERN ställer. Vad C-Rad anfört i denna del medför därför inte att skillnaden mellan IRDD och X-ray detector kan bortses från.

Skillnaderna mellan X-Ray Detector och IRDD i förhållande till idéer och tekniska lösningar hos C-Rad

Domstolen har i föregående avsnitt konstaterat att det föreligger vissa skillnader mellan X-Ray Detector och IRDD. Likheterna mellan patentdokumenten avseende X-Ray Detector och IRDD (domsbilaga 1–4) är dock betydande. C-Rad har gjort gällande att skillnaderna som IRDD uppvisar i förhållande till X-Ray Detector bygger på idéer och tekniska lösningar som framtagits inom C-Rad, och då främst av G. N., vid vidareutvecklingen av X-Ray Detector.

Det föreligger således enligt C-Rad en likhet mellan hos bolaget förekommande idéer och tekniska lösningar, vilka K. M. fått vetskap om under sin tid som anställd hos C-Rad, och särdragen S1–S4 i IRDD. Domstolen gör i denna fråga följande bedömning.

Vad först gäller särdrag S1 framgår av en rapport upprättad av M. P. den 31 mars 2014 att det inom C-Rad har gjorts simuleringar för att utreda om en flerlager-struktur med alternerande koppar och dielektriskt material var acceptabel eller gav negativa effekter. G. N. har även vittnat om att det förekommit gemensamma diskussioner inom C-Rad om flerlagerstrukturer. Vidare så visar ett e-postmeddelande av den 15 oktober 2013 från G. N. till K. M. att simuleringar med flera lager med olika spänning gjordes inom C-Rad. Utredningen visar enligt domstolen att särdraget S1 har sin motsvarighet i en teknisk lösning, som var framtagen hos C-Rad i tiden innan den 2 mars 2015. Utredningen visar också att K. M. fått vetskap om den tekniska lösningen med flerlagerstruktur med olika spänning.

I ett e-postmeddelande från K. M. till bl.a. G. N. den 25 januari 2014 nämns att det är möjligt med selektiv beläggning av Parylene och att det i princip går att undvika att belägga insidorna av konverterarens hål. Detta får enligt domstolen förstås som att det vid normal beläggning med Parylene även kommer att ske oönskad beläggning, men att detta går att undvika. Det nämnda e-postmeddelandet eller annan av C-Rad anförd bevisning nämner inte att det genom selektiv beläggning (dvs. att belägga blindhålen med en isolator förutom på en del) går att åstadkomma attraktion och neutralisering av joner. Av utredningen kan enligt domstolen inte anses framgå att särdrag S2 har en direkt motsvarighet i någon teknisk lösning framtagen inom C-Rad. Däremot kan konstateras att diskussioner förekommit inom C-Rad om selektiv beläggning med Parylene, vilka K. M. haft vetskap om. Denne har också omvittnat att man inom C-Rad sett det som ett problem att insidan på blindhålen blev isolerade när Parylene användes och att man ville undvika detta. IRDD utgår ifrån att det sker en selektiv beläggning med Parylene varför det således finns ett visst, om än försvagat, samband med uppgifterna som förekom hos C-Rad och den vetskap K. M. hade om dem.

Den presentation G. N. redovisade för styrelsen i C-Rad den 26 september 2014 visar en upplinjering mellan blindhål och GEM-hål som motsvarar vad som anges i särdrag S3. I presentationen visas den variant som anges i X-Ray Detector, en variant där GEM-hålen och blindhålen är upplinjerade ett till ett, samt en variant där grupper om tre GEM-hål är i linje med blindhålen. Mittpunkternas längdaxlar är så vitt det går att utläsa i linje med blindhålens längdaxlar.

Vad sedan gäller K. M:s vetskap om lösningen med upplinjering av GEM-hål i förhållande till blindhål har G. N. berättat att det under sommaren 2014 fördes diskussioner inom C-Rad om att centrera hålen och att K. M. var involverad i dessa diskussioner. Att frågan om att försöka optimera antal GEM-hål inom blindhålen har varit aktuell inom C-Rad framgår av vad som anges på sidan 12 i M. P. rapport från den 31 mars 2014. K. M. har bestritt att han med G. N. diskuterat att man behöver tre GEM-hål per blindhål, men förklarat att han är osäker på om de diskuterat användningen av ett GEM-hål per blindhål.

Uppgifterna lämnade av G. N., och M. P. rapport, är alltför allmänt hållna för att det mot K. M:s uppgifter kan anses klarlagt att denne under sin tid som anställd hos C-Rad fått del av någon idé eller teknisk lösning innefat-tande just tre GEM-hål per blindhål. Däremot ger uppgifterna stöd för att diskussioner förekommit om ett GEM-hål per blindhål och att centrera GEM-hålen. Det får mot den bakgrunden anses utrett att K. M. under sin tid som anställd hos C-Rad haft vetskap om att en föredragen lösning är att mittpunkternas längdaxlar för GEM-hålen är i linje med blindhålens längdaxlar, vilket får anses vara den väsentliga bestämningen i särdraget S3 då grupp av GEM-hål kan betyda allt mellan 1–20 hål.

Vad gäller särdraget S4 om segmentering så visar ett e-postmeddelande den 2 juni 2014 med rubriken ”New segmented GEM geometry” från K. M. till Rui De Oliveira en speciellt anpassad segmentering för att undvika urladdningar. Särdrag S4 syftar visserligen till att uppnå effekten av lägre kapacitans. Emellertid så framgår det av IRDD att en stor GEM utgör en kondensator med risk för farliga laddningar. IRDD formulerar också att segmenteringen resulterar i reduktion av risk för urladdningar. Särdrag S4 får därför enligt domstolen anses ha sin motsvarighet i en teknisk lösning som framtagits inom C-Rad och att K. M. fått vetskap om lösningen under sin tid som anställd på C-Rad.

Sammantaget kan således konstateras att de skillnader IRDD uppvisar i förhållande till X-Ray Detector till helt övervägande del har en direkt motsvarighet i idéer och tekniska lösningar som förelegat hos C-Rad i tiden före den 2 mars 2015, dvs. det datum då patentansökan för IRDD lämnades in i USA. Den enda avvikelsen från en fullständig överensstämmelse är särdrag S2, dvs. att det genom att belägga blindhålen med en isolator förutom på en del går att åstadkomma attraktion och neutralisering av joner. Likheterna är, trots detta, enligt domstolen betydande och tillräckliga för att det ska anses föreligga en överensstämmelse mellan X-Ray Detector i förening med de idéer och tekniska lösningar som var framtagna inom C-Rad och den patentsökta uppfinningen IRDD.

Har IRDD tillkommit oberoende av uppgifter från C-Rad?

Utredningen i målet har visat att det föreligger en väsentlig överensstämmelse mellan idéer och tekniska lösningar framtagna inom C-Rad och den patentsökta uppfinningen IRDD. Beamocular, som genom K. M. haft tillgång till uppgifterna när pa-tentansökan på IRDD lämnades in i USA den 2 mars 2015, har därmed att visa att IRDD är ett resultat av en oberoende uppfinnarinsats.

En omständighet parterna har uppehållit sig vid i samband med frågan om IRDD tillkommit genom en oberoende uppfinnarinsats eller inte är om patentansökan avseende X-Ray Detector före den 2 mars 2015 varit allmänt tillgänglig. Beamocular har i denna del gjort gällande att C-Rad haft som praxis att inte hemlighålla patentsökta uppfinningar och att information om X-Ray Detector lämnats till utomstående i tiden före den 2 mars 2015 utan krav på sekretess.

I målet är ostridigt att den i USA inlämnade patentansökan avseende X-Ray Detector inte var offentliggjord av patentverket i USA, eller någon annan patentmyndighet, när patent söktes på IRDD i USA den 2 mars 2015. Att C-Rad inte begärt en tidigareläggning av publiceringen av bolagets ansökan ter sig också enligt domstolen naturligt mot bakgrund av de nackdelar det innebär för en patentsökande att göra detta (se t.ex. Stenvik, A., Patentrett, tredje uppl., s. 78).

Vad K. M., E. H. och L. J. berättat ger visst stöd för vad Beamocular gjort gällande om att C-Rad inte höll sina patentsökta uppfinningar hem-liga utan i marknadsföringssyfte öppet redovisade information om dem. Detta gör även vad R. F. berättat om att han i C-Rads monter på ESTRO-mässan i april 2014, utan krav på sekretess, tog del av en folder med information om X-Ray Detector. På sidan 8 i den nämnda foldern förekommer en bild som enligt domstolen återger vissa grundläggande element i X-Ray Detector. Bilden, och övrigt innehåll i den aktuella foldern, motsvarar emellertid enligt domstolen inte ett offentliggörande av patentansökningen avseende X-Ray Detector. Uppfinningen i hela sitt omfång kan t.ex. inte utläsas ur foldern och den avslöjar inte heller samtliga särdrag i patentkraven eller några andra detaljer i ansökan.

K. M., E. H., och R. F. har inte heller berättat att patent-ansökan för X-Ray Detector som sådan förevisats i något publikt sammanhang eller att ansökan överlämnats till tredje man utan krav på sekretess. I stället har de lämnat allmänt hållna uppgifter om att det rådde en praxis på C-Rad att det gick bra att prata om uppfinningar med personer utanför bolaget så snart en patentansökan var inlämnad och att så också skedde. När det gäller R. F. kan också konstateras att han 2011 lämnade sitt arbete inom C-Rad koncernen och att patentansökan avseende X-Ray De-tector lämnades in 2013.

Domstolen finner sammantaget att Beamocular visserligen förmått visa att det inom C-Rad funnits en praxis att tala öppet om patentsökta uppfinningar, men inte att patentansökan avseende X-Ray Detector offentliggjorts innan den publicerades av patentmyndigheten i USA.

M. A. och K. M., som båda var delägare i Beamocular under den i målet relevanta tidsperioden, anges i patent ’291 (domsbilaga 4) som uppfinnare till IRDD. Enligt Beamocular är det M. A. som står för den helt övervägande delen av uppfinnarinsatsen. Frågan i målet blir därför om Beamocular har styrkt att dessa två, oberoende av innehållet i de idéer och tekniska lösningar som var fram-tagna inom C-Rad före det att K. M. lämnade sin anställning hos bolaget, gjort uppfinningen.

Vad Beamocular anfört att IRDD är resultatet av en oberoende uppfinnarinsats stöds främst av vad M. A. och K. M. uppgett. Deras berättelser vinner visst stöd av de anteckningar M. A. gjort under sitt arbete på Beamocular under januari-februari 2015. Vad C. D. omvittnat om förekomsten av detektorer av det slag som beskrivs i ’452 och ’291, dvs. teknikens ståndpunkt, får också an-ses ge visst stöd för Beamoculars ståndpunkt. Det finns emellertid ett antal omständigheter som talar i en annan riktning, dvs. att uppfinningen inte tillkommit oberoende av uppgifter som var framtagna inom C-Rad.

Inledningsvis kan konstateras att de inom C-Rad förekommande idéerna och tekniska lösningarna, som lagts till grund för bolagets anspråk på bättre rätt, får väsentligen an-ses innehålla en teknisk beskrivning av den uppfinning som avses med den av Bea-mocular sedermera gjorda patentansökan. I målet är klarlagt att K. M. hade tagit del av nämnda idéer och tekniska lösningar innan patentansökningen av IRDD gjordes samt att han hade tillgång till utkast till patentansökningen på X-Ray Detector.

Beamocular har framhållit M. A:s insatser för tillkomsten av IRDD och anfört att han står bakom merparten av uppfinnarinsatsen. Trots detta är det först efter drygt två år från det att ansökan lämnades in, och efter det att denna rättegång inletts, som Beamocular ser till att han antecknas som uppfinnare till IRDD. Orsaken till detta var, enligt vad K. M. berättat, att det var först efter patentmyndigheten i USA granskat ansökan som det blev klarlagt vad som var patenterbart.

Ett beviljat patent får inte avse någon annan uppfinning än den som redan finns angiven i patentansökan. Detta, liksom vikten av att samtliga uppfinnare anges i en patentansökan, måste Beamocular ha varit införstått med. K. M:s förklaring till varför inte M. A. angavs som uppfinnare av Beamocular när patentansökan lämnades in framstår mot denna bakgrund som mindre trolig.

En annan omständighet som inte är förenlig med vad Beamocular gjort gällande om M. A:s uppfinnarinsats är att han inte involverades i arbetet med en patentansökan. Både M. A. och K. M. har berättat att den först-nämnde inte ens kände till att en patentansökan tagits fram och lämnats in till patent-myndigheten i USA. Det trots att K. M. berättat att grunden för patentansökan var de insikter han fått av rapporter lämnade av M. A.

M. A. har med hänvisning till av honom förda anteckningar under tiden januari och februari 2015 utvecklat hur han gått tillväga för att komma fram till uppfinningen. Härvidlag kan noteras att den första anteckningen är införd den 12 januari 2015 och den sista anteckningen den 4 februari 2015. Ur anteckningarna framträder enligt domstolen inte vad som kan anses utgöra en mer detaljerad beskrivning av uppfinningens faktiska tillkomst. Den 2 mars 2015 lämnas sedan ansökan om patent på IRDD in i USA. På mindre tid en än månad tar alltså Beamocular fram en patentansökan genom K. M. och detta sker utan att denne överhuvudtaget har någon kontakt med M. A. angående ansökan. Givet förutsättningarna framstår denna tidsrymd för domstolen som ytterst kort. Någon utredning om hur arbetet med patentansökan avseende IRDD framskred, som kunde ha kastat ett ljus över uppfinningens tillkomst, har inte heller lagts fram av Beamocular.

Det rör sig också om en förhållandevis kort tid från det att M. A. inleder sitt arbete hos Beamocular till när en patentansökan lämnas in. Tiden får anses som kort även om hänsyn tas till att M. A., som han uppgivit, ”tjuvstartade” sitt arbete under oktober 2014 och att han får anses tekniskt kompetent för att göra uppfinningen. Några detaljer om det närmare innehållet i det arbete som bedrevs före årsskiftet har M. A. inte heller lämnat och den av Beamocular åberopade anteckningsboken omfattar inte heller denna tidsperiod.

Vad gäller vilken information som M. A. fått inför starten på sitt arbete hos Beamocular har K. M. berättat att han pratat allmänt med M. A. om problemen med jonkammare, GEM och konverterare, men däremot inte gett honom några direktiv. M. A. har å sin sida omvittnat att han fått upp-gifter från K. M. om att C-Rad inte fått det att fungera. Både K. M.
och M. A. medger således, i vart fall på ett mer allmänt plan, att de haft diskussioner av en natur som synes nära anknyta till det arbete som bedrevs inom C-Rad, de idéer och tekniska lösningar som förekom där samt att de inte fått någon lös-ning att fungera. Det kan också noteras att M. A. vittnat om att han, såvitt han är medveten om, inte fått några konfidentiella uppgifter från C-Rad. Det kan såle-des inte uteslutas att M. A. fått sådana uppgifter från K. M. utan att vara medveten om att det var fråga om just konfidentiella uppgifter.

Mot bakgrund av vad som anförts ovan får det anses föreligga en viss osäkerhet kring om IRDD tillkommit oberoende av idéer och tekniska lösningar framtagna hos C-Rad. Den av Beamocular framlagda bevisningen är enligt domstolen inte tillräcklig för un-danröja osäkerheten varför bolaget inte kan anses ha styrkt att IRDD tillkommit obero-ende av uppgifter om idéer och tekniska lösningar framtagna hos C-Rad.

Har Beamocular orättmätigt tillgodogjort sig idéer och tekniska lösningar som tillkommer C-Rad?

Parterna har haft olika uppfattningar om vem det är av G. N. och K. M. som stått för den huvudsakliga uppfinnarinsatsen vad avser X-Ray Detector. Den utredning som lagts fram i målet ger enligt domstolen inte någon närmare vägled-ning för att bedöma omfattningen av deras respektive uppfinnarinsatser varför domstolen tar sin utgångspunkt i att de varit jämbördiga.

Vad gäller patentansökan på IRDD så lämnades den in till patentmyndigheten i USA den 2 mars 2015 med K. M. som uppgiven uppfinnare. Ansökan låg sedan till grund för den patentansökan (domsbilaga 5) som lämnades in till det europeiska patentverket. Dennes anställning hos C-Rad upphörde den 29 september 2014. Patent söktes således på IRDD inom sex månader från det att K. M. slutade sin an-ställning hos C-Rad.

För s.k. tjänsteuppfinningar enligt 3 § första stycket LAU gäller enligt 7 § första stycket i samma lag under vissa förutsättningar en presumtion för att en patentansökan som lämnas in inom sex månader från det en arbetstagare slutat sin anställning tillkommit under anställningen.

För att en uppfinning ska ha karaktären av en s.k. tjänsteuppfinning krävs enligt 3 § första stycket LAU att forsknings- eller uppfinnarverksamhet är arbetstagarens huvudsakliga arbetsuppgift och att uppfinningen tillkommit väsentligen som ett resultat av denna verksamhet. Under begreppet forsknings- eller uppfinnarverksamhet faller enligt förarbetena till LAU allt konstruktions- och utvecklingsarbete där man kan tänka sig att uppfinningar framkommer (se Dennemark, S., Om rätten till arbetstagares uppfinningar, s. 32 ff.).

C-Rad har i målet gjort gällande att K. M:s huvudsakliga arbetsuppgift hos C-Rad var forsknings- och uppfinnarverksamhet varför uppfinningar han gjorde kunde tas i anspråk av bolaget enligt 3 § första stycket LAU.

Beamocular har å sin sida hävdat att K. M:s arbetsuppgifter hos C-Rad var sedvanliga uppgifter som ankommer på en verkställande direktör och att de inte huvudsakligen involverade forsknings- och utvecklingsarbete.

För Beamocular ståndpunkt talar de uppgifter som K. M. har lämnat och som har bekräftats av E. H.. Både K. M. och E. H. har emellertid ägarintressen i Beamocular varför deras utsagor måste bedömas med viss försiktighet.

Vidare har det av förhören med T. T. och E. H. framgått att den sistnämnde, i förening med vissa partners, under sommaren 2014 ville förvärva GEMini-projektet och att de la ett indikativt bud på projektet. Budet innefattade även att vissa av nyckelpersonerna i projektet skulle övertas.

Inom C-Rad hade GEMini-projektet, dvs. det projekt som lett fram till uppfinningen X-Ray Detector och vidareutvecklingen av uppfinningen, pågått under G. N:s ledning sedan 2005. Projektet var det enda projektet som bedrevs inom bolaget och det bedrevs med endast ett fåtal anställda. Under april 2012 gick K. M., som arbetat inom C-Rad koncernen ända sedan 2005, in som projektledare för GEMini-projektet för att sedan axla rollen som verkställande direktör.

Det går inte att hämta ledning från något skriftligt anställningsavtal eftersom ett sådant inte funnits avseende tjänsten som verkställande direktör i C-Rad, som K. M. tillträdde under 2013. Det har emellertid varit fråga om ett bolag med ett fåtal anställda och vars verksamhet varit helt inriktat på att utveckla GEMini-projektet, som K. M. varit projektledare för innan han tillträde tjänsten som verkställande direktör.

Den utredning som lagts fram i målet i form av dokumentation över tekniska diskuss-ioner mellan K. M. och G. N. visar på att K. M:s arbetsuppgifter innefattat forsknings- och uppfinningsinriktad verksamhet. Detta är också något som G. N. bekräftat i förhör.

Det finns sammantaget således ett antal omständigheter som talar för att K. M:s förändrade roll från projektledare till verkställande direktör inte medfört några betydande förändringar i inriktningen på hans arbetsuppgifter. Som projektledare för det enda utvecklingsprojekt ett bolag med ett fåtal anställda bedriver får han anses haft som huvudsaklig arbetsuppgift att syssla med forsknings- eller uppfinnarverksamhet. Någon förändring av betydelse kan inte anses ha inträtt i K. M:s arbetsuppgif-ter när han blev verkställande direktör i C-Rad varför han även därefter får anses ha haft forsknings- och uppfinnarverksamhet som huvudsaklig arbetsuppgift i det bolaget.

Domstolen bedömer vidare att hans del i uppfinningen IRDD har tillkommit väsentligen som ett resultat av denna verksamhet.

Patentansökan avseende IRDD är inlämnad inom sex månader från det att K. M:s anställning upphörde. Beamocular har, vilket följer av den slutsats domstolen kommit till vad gäller tillkomsten av IRDD, inte visat att uppfinningen tillkommit efter K. M:s anställning upphörde. C-Rad har alltså enligt 3 § första stycket LAU en rätt att förvärva K. M:s rätt till IRDD. Mot denna bakgrund får Beamocu-lar orättmätigt anses ha använt uppgifter om idéer och tekniska lösningar som framta-gits inom C-Rad.

Sammanfattande slutsats

Patent- och marknadsdomstolen har kommit fram till att det finns en överensstämmelse mellan idéer och tekniska lösningar till vilka C-Rad har en rätt och den patentsökta uppfinningen IRDD, att uppfinnarna till den patentsökta uppfinningen inte oberoende av dessa idéer och tekniska lösningar har gjort eller kan ha gjort den patentsökta uppfinningen och att Beamocular av patentet missbrukat uppgifterna i förhållande till C-Rad. Käromålet ska således bifallas i enlighet med det i första hand framställda yrkandet av C-Rad.

Rättegångskostnader

Beamocular ska ersätta C-Rads rättegångskostnader.

Enligt 18 kap. 8 § första stycket rättegångsbalken ska ersättning för rättegångskostnad fullt ut motsvara kostnaden för rättegångens förberedande och talans utförande jämte arvode till ombud eller biträde, såvitt kostnaden skäligen varit påkallad för tillvaratagande av partens rätt.

C-Rad har begärt ersättning med 1 530 128 kr, varav 1 418 783 kr för ombudskostnader. Beamocular har ifrågasatt skäligheten av kostnaderna för en IT-forensisk undersökning som uppgår till 80 250 kr. I övrigt har bolaget överlämnat till domstolen att bedöma skäligheten av C-Rad yrkad ersättning. Domstolen bedömer att C-Rads kostnader varit skäligen påkallade för tillvaratagandet av bolagets rätt. Beamocular ska därför ersätta kostnaderna fullt ut.

Sekretess

Bestämmelsen i 36 kap. 2 § offentlighets och sekretesslagen (2009:400) bör fortsatt vara tillämplig på uppgifter som har lagts fram vid under syn och förhandling inom stängda dörrar i den mån uppgifterna inte har tagits in i denna dom (se domslutet). Uppgiften på sidan 8 i aktbilaga 124, som är intagen i C. D:s sakkunnigutlå-tande, har lagts fram vid offentlig förhandling i samband med förhöret med C. D. varför bestämmelsen i 36 kap. 2 § offentlighet- och sekretesslagen inte fort-satt kan vara tillämplig på denna uppgift.

För uppgifter i handlingar som inte har lagts fram vid offentlig förhandling eller tagits in i dom eller beslut gäller sekretessregleringen fortsatt utan något särskilt förordnande om detta ska göras i domslutet.

HUR MAN ÖVERKLAGAR, se bilaga 6 (PMT-02)
Överklagande ställt till Patent- och marknadsöverdomstolen, ska ha kommit in till Patent- och marknadsdomstolen senast den 16 augusti 2019.

Rätten har bestått av rådmännen Peter Adamsson och Ulrika Persson samt patentråden Patrik Rydman och Kerstin Roselinger. Avgörandet är enhälligt.

Peter Adamsson — Ulrika Persson

Patrik Rydman — Kerstin Roselinger

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Maad et al.

(54) **CONVERTER UNIT**

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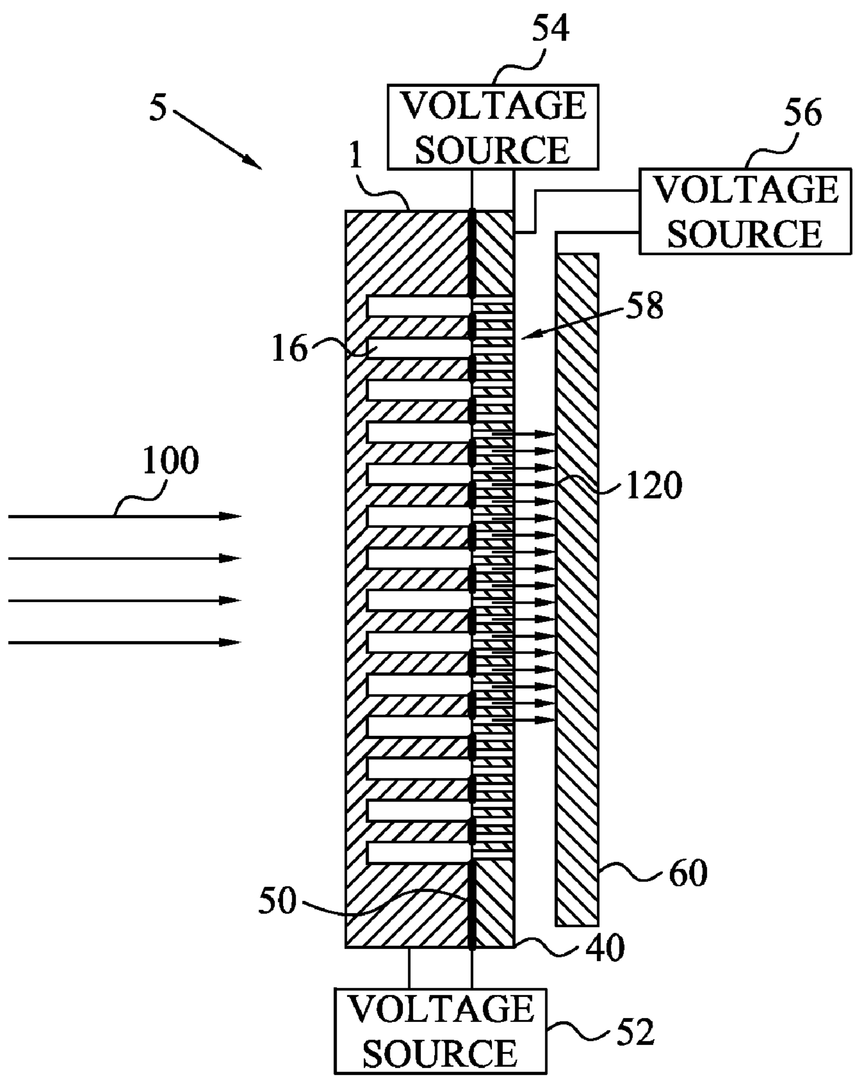
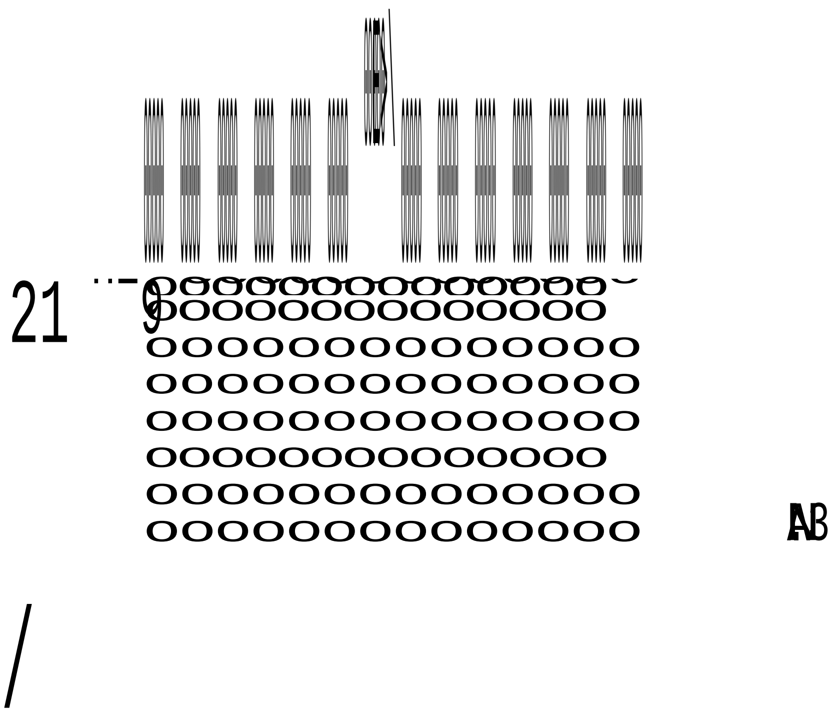
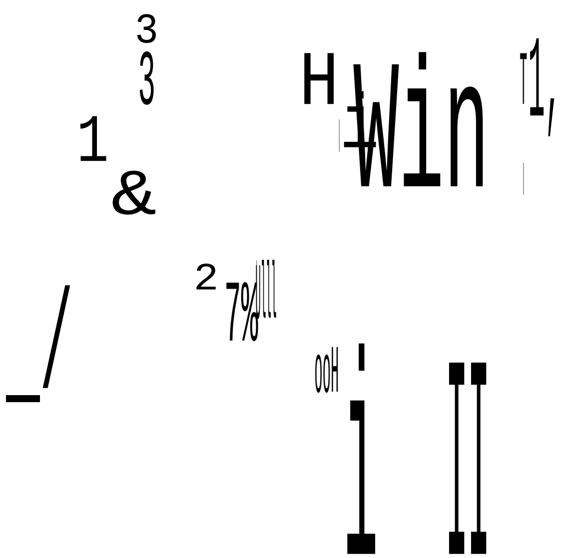
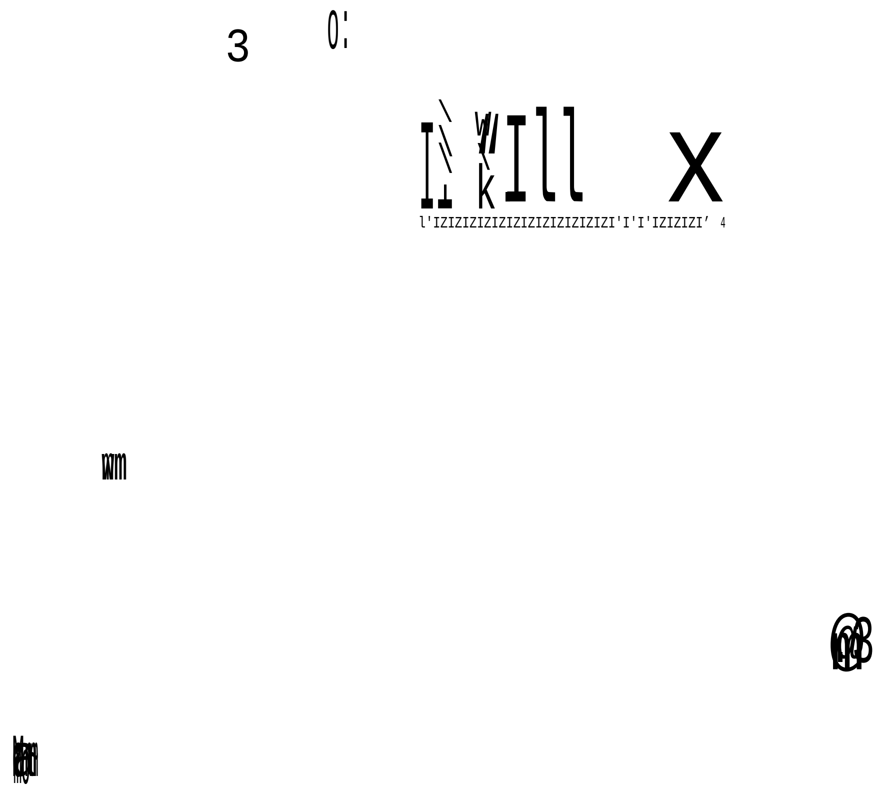
(57) **ABSTRACT**

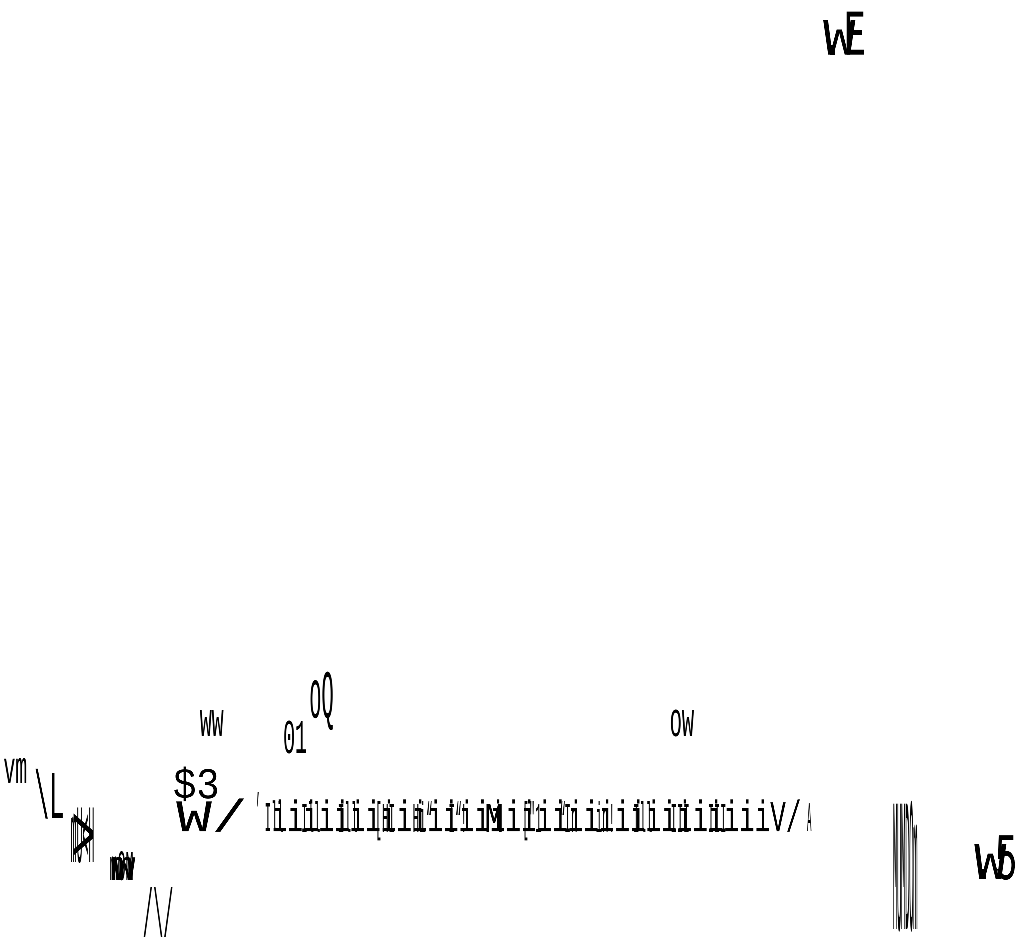
A converter unit configured to convert incident photons into electrons comprises multiple blind holes forming respective ionization chambers. In additional embodiments, the converter unit is arranged in a detector, such as an X-ray detector or absolute radiation dose measurement detector, additionally comprising an electron amplification device and/or a readout device.

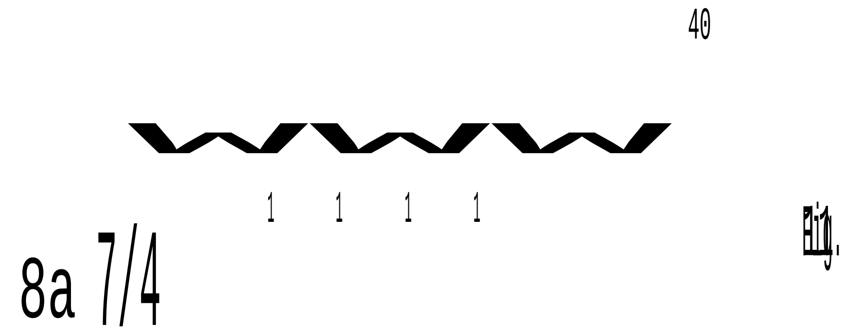


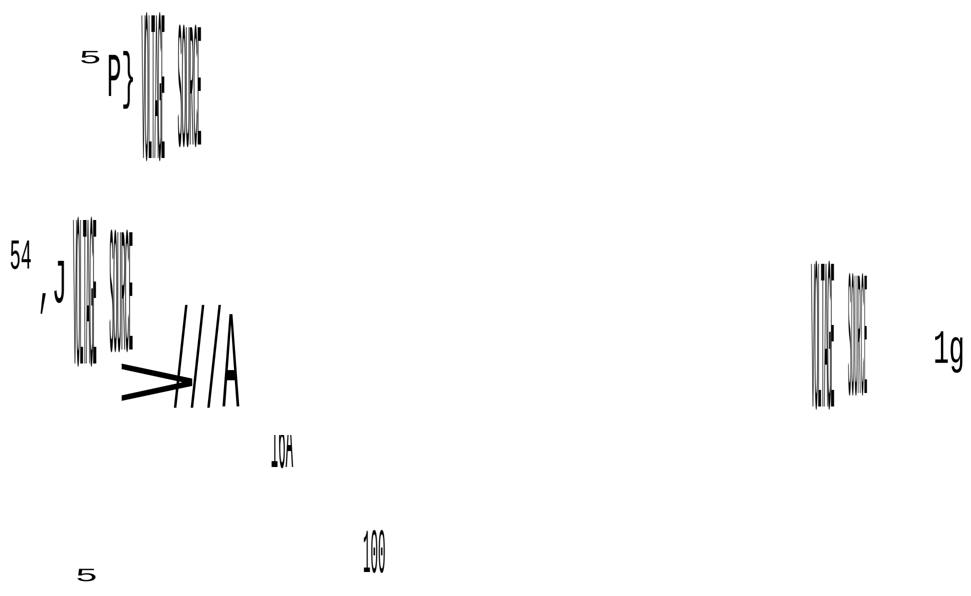












CONVERTER UNIT

TECHNICAL FIELD

[0001] The present embodiments generally relate to a converter unit adapted to convert incident photons into electrons, and to a detector comprising such a converter unit.

BACKGROUND

[0002] X-ray detectors are used to detect radiation and provide spatial mapping of radiation intensity in radiation-based imaging systems. Such systems involve detection of incoming radiation, such as X-rays and gamma photons, in a wide range of different applications, including medical applications.

[0003] Basically, a radiation source generates a beam in the direction of an object to be examined and a detector measures the intensity of the beam after it has passed through the object. The detector outputs information required to produce an image representing attenuation of the radiation resulting from absorption and scattering by the structure through which the beam traveled. Apart from forming an X-ray transmission image of an object an X-ray detector could also be used for measuring radiation doses.

[0004] Many radiation systems involve radiation sources, such as X-ray tubes or radiation treatment machines, associated with a very high MeV photon ?ow during the output pulse. The challenge is to convert as many as possible of the incident high energy photons, while at the same time preserving their spatial information, with a high precision. This makes it very dif?cult to achieve su?icient image quality.

[0005] A detector unit for detecting photons in the energy range 1 keV to 100 MeV is disclosed in a document [1]. The detector unit includes at least two converter layers adapted to interact with incident X-ray photons and to cause electrons to be emitted therefrom. At least one ampli?er is adapted to interact with the emitted electrons and produce a multiplicity of secondary electrons and photons representing a signal proportional to the incident ?uence of X-ray photons.

[0006] A document [2] is directed towards reducing spread of electrons as compared to conventional radiation detectors. The radiation detector comprises a gas electron multiplier (GEM) using interaction between radiation and gas through photoelectric effects. The GEM is arranged in a chamber ?lled with gas and has a single gas electron multiplication foil arranged in the chamber. This gas electron multiplication foil is made of a plate-like multilayer body composed by having a plate-like insulation layer made of a macromolecular polymer material having a thickness of 100-300 um and ?at metal layers overlaid on both surfaces of the insulation layer. The plate-like multilayer body is provided with a through-hole structure.

SUMMARY

[0007] It is a general objective to provide an improved converter unit.

[0008] It is a particular objective to provide a converter unit reducing electron and photon scattering.

[0009] These and other objectives are met by embodiments as de?ned herein.

[0010] An aspect of the embodiments relates to a converter unit con?gured to convert incident photons into electrons. The converter unit comprises multiple blind holes forming respective ionization chambers.

[0011] Another aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and an electron ampli?cation device con?gured to produce further electrons from electrons formed in the converter unit. The electron ampli?cation device is attached to the converter unit with an electrically isolating connection.

[0012] A further aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and a readout device con?gured to generate a signal representative of incident photons.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The embodiments, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

[0014] FIG. 1 is a cross-sectional view of a converter unit according to an embodiment;

[0015] FIG. 2 is an illustration of a converter unit according to an embodiment;

[0016] FIG. 3 is an illustration of a converter unit according to another embodiment;

[0017] FIG. 4 is a cross-sectional view of a converter unit according to another embodiment;

[0018] FIG. 5 is a cross-sectional view of a converter unit according to a further embodiment;

[0019] FIG. 6 is a cross-sectional view of a converter unit according to yet another embodiment;

[0020] FIG. 7 is a cross-sectional view of a detector according to an embodiment;

[0021] FIG. 8 schematically illustrates alignment of blind holes and through holes according to an embodiment;

[0022] FIG. 9 is a cross-sectional view of a detector according to another embodiment;

[0023] FIG. 10 is a cross-sectional view of a detector according to a further embodiment; and

[0024] FIG. 11 is a cross-sectional view of a detector according to yet another embodiment.

DETAILED DESCRIPTION

[0025] Throughout the drawings, the same reference numbers are used for similar or corresponding elements.

[0026] The present embodiments generally relate to a converter unit adapted to convert incident photons into electrons, sometimes denoted primary electrons in the art. The embodiments further relate to a detector comprising such a converter unit.

[0027] The converter unit of the embodiments enables, when implemented as a part of a detector, such as an X-ray detector, high sharpness in the captured picture. Such high sharpness and resolution in the picture is possible even for incident high energy photons.

[0028] Generally, there is a big challenge within X-ray detectors to convert as many as possible of incident high energy photons, while at the same time preserving their spatial information, with a high precision. A prior art solution has typically been to use several separate equidistant converter layers and electron ampli?cation devices that amplify electrons converted from incident photons. However, such an approach generally leads to low sharpness in the formed picture due to open gas layers between the converter layers and electron ampli?cation devices, causing scattering and lateral electron and photon distribution. This in turn leads to blurriness in the captured image.

[0029] The present embodiments have taken a radically different approach as compared to the prior art when constructing the converter unit. The present embodiments therefore relate to a converter unit comprising multiple blind holes, sometimes referred to as bottom holes in the art, forming respective ionization chambers in the converter unit.

[0030] Accordingly, an aspect of the embodiments relates to a converter unit adapted to convert incident photons into electrons. The converter unit comprises multiple blind holes forming respective ionization chambers.

[0031] This means that the blind holes 16 in the converter unit 1 extend through a portion L, see FIG. 1, of a thickness T of the converter unit 1 but do not extend through the whole thickness T of the converter unit 1. This means that there is a portion W of the thickness T of the converter unit 1 into which the blind holes 16 do not extend.

[0032] Various implementation embodiments of the general aspect will now be further described herein with reference to the drawings.

[0033] FIG. 1 is a cross-sectional view of a converter unit 1 according to an embodiment. In this embodiment, the converter unit 1 is in a form of a single, unitary converter plate 10 comprising multiple blind holes 16 extending through a portion L of the thickness T of the converter plate 10 but do not extend through the whole thickness T of the converter plate 10.

[0034] The multiple blind holes 16 are preferably arranged so that they are substantially parallel in the converterplate 10. Hence, the longitudinal axes 17 of the blind holes 16 are preferably substantially parallel with each other.

[0035] In a particular embodiment, the multiple blind holes 16 are arranged in the converter unit 1 to have a respective longitudinal axis 17 substantially parallel to a normal 18 of a main side 12, 14 of said converter unit 1. Generally, this means that the longitudinal axis 17 is at least substantially parallel to a main beam direction of the incident photons 100 hitting the converter unit 1. In a typical approach, the photons 100 are generated by a radiation source, which could be regarded, as seen from the converter unit 1, to be a point source due to that the extension of the radiation source is generally much smaller than the distance between the radiation source and the converter unit 1. Accordingly, the main beam direction will hit the converter unit 1 with an angle of incidence of close to zero relative to the normal 18 of the main side 12 of the converter unit 1. However, some of the photons 100 may in fact hit the converter unit 1 with a non-zero angle of incidence due to radiation distribution and that the radiation source does not have non-zero extension.

[0036] The converter plate 10 generally comprises a ?rst main side 12 adapted to face the incident photons 100 and a second main side 14 opposite to the ?rst main side 12. In a preferred embodiment, the second main side 14 facing away from the incident photons 100 comprises the entrances of the blind holes 16. Hence the blind holes 16 extend from the second main side 14 towards, but not reaching, the ?rst main side 12 of the converter plate 10.

[0037] The converter plate 10, which in the embodiment as shown in FIG. 1, is in the form of a single, unitary piece of the converter unit 1, is preferably made of a metal material capable of converting incident photons 100 into electrons 110 through electromagnetic interaction. Electromagnetic interaction encompasses all physical interactions between photons 100 and the metal material that causes generation of electrons 110, such as through Compton effect, pair-production or photo electric effect.

[0038] Examples of suitable metal materials for the converter plate 10 include tungsten, tungsten alloys, copper, copper alloys, rhenium, rhenium alloys, molybdenum, molybdenum alloys, tantalum, tantalum alloy, chromium, chromium alloys, iron and iron alloys. Particularly, suitable materials are tungsten and tungsten alloys.

[0039] The incident photons 100 will hit the metal material of the solid portion of the converter plate 10 and are there, through the electromagnetic interaction, converted into electrons 110. The design of the converter unit 1 of the embodiments with blind holes 16 extending merely a portion L of the thickness T of the converter unit 1 will be very ef?cient in stopping lateral electrons and photons, i.e. traveling in a direction perpendicular to the thickness T of the converter unit 1 and perpendicular to the longitudinal axes 17 of the blind holes 16. The reason being that these scattered electrons and photons will be stopped in the walls of the blind holes 16. Consequently, the particular design of the converter unit 1 of the embodiments will reduce the amount of lateral or scattered electrons and photons exiting the converter unit 1, i.e. exiting from the second main side 14. This reduction in electron and photon scattering will in turn reduce blurring of a signal representing detected electrons, which is further discussed herein. This means that the converter unit 1 of the embodiments is designed to promote delivery of electrons 110 that are parallel or at least substantially parallel to the longitudinal axes 17 of the blind holes 16 and parallel to the normals of the ?rst and second main sides 12, 14.

[0040] Not only the particular material of the converter plate 10 but also the thickness W of the solid part of the converter plate 10, i.e. the portion between the bottom of the blind holes 16 and the ?rst main side 12 of the converter plate 10 facing the incident photons 100, affects the attenuation of incident low energy photons, so called beam hardening. This is useful in high energy applications in order to reduce the detection of scattered photons, which generally have lower energy, such as up to approximately 300 keV.

[0041] Each blind hole 16 will operate as an ionization chamber in which energetic electrons ejected from the converter plate 10 create a large number of ion pairs, i.e. ions and free electrons. This means that if the blind holes 16 are made deeper, i.e. larger L in FIG. 1, then the available gas volume in the blind holes 16 will increase. Accordingly, a signal, representing free electrons, will increase proportionally. The available gas volume is also dependent on the open area, e.g. diameter, of the blind holes 16.

[0042] FIG. 2 schematically illustrates the converter unit 1 of FIG. 1 as seen from the second main side 14, i.e. the main side comprising the entrances to the blind holes 16. In this embodiment, the blind holes 16 are arranged in a matrix of a number of rows and columns. In an alternative embodiment, which generally enables smaller distances between adjacent blind holes, the blind holes 16 can be arranged staggered relative to each other as indicated in FIG. 3. This embodiment generally has a denser arrangement of blind holes 16 and thereby a lower portion of metal material in the portion of the converterplate 10 occupied by the blind holes 16 as compared to the embodiment of FIG. 2.

[0043] The choice of hole pattern is generally a compromise between open area (active gas volume) and the ability to stop lateral electrons and photons. The hole pattern could also be in?uenced by the available manufacturing methods available for the various metal materials.

[0044] The blind holes 16 advantageously have circular cross-sectional area as shown in FIGS. 2 and 3. However, other cross-sectional con?gurations are also possible and encompassed by the embodiments, such as quadratic, rectangular, pentagon, hexagon, octagon, elliptic, etc.

[0045] Each blind hole 16 in the converter plate 10 can be seen as a gas cylinder having a closed end facing the ?rst main side 12 and an open end at the second main side 14.

[0046] A non-limiting but illustrative example of a converter unit design is to manufacture the converter plate 10 to have thickness T of about 2.5 mm with a blind hole length L of 2 mm and thereby a remaining solid thickness portionW of 0.5 mm. The size ofthe converter plate 10, see FIGS. 2 and 3, could, for instance, be 500x500 mm for height><width. In a particular embodiment, the area of the second main surface 14 occupied by the matrix or pattern of blind holes 16 could be around 400x400 mm. Each blind hole 16 could have an average diameter of about 0.3 mm with an inter-hole distance of about 0.45 mm from center to center (hole pitch). If the embodiment of FIG. 3 is used, i.e. staggered blind holes 16, then a 60° staggered geometry could be used. The above presented numbers should merely been seen as illustrative example of a typical size for a converter unit 1. The embodiments are, however, not limited thereto and other dimensions of the converter plate 10 and the blind holes 16 are possible and within the scope of the embodiments.

[0047] FIG. 4 is a cross-sectional view of another embodiment of a converter unit 2 according to the embodiments comprising multiple blind holes. In this embodiment, the converter unit 2 is not made of a single, unitary converter plate but rather comprises a converter plate 20 with multiple through holes 26 and a solid converter plate 21.

[0048] The through holes 26 in the converter plate 20 are preferably true through holes 26 and thereby preferably extend through the whole thickness of the converter plate 20. The solid converter plate 21 is then attached to the converter plate 20 with through holes 26 as a lid for the multiple through holes 26 to thereby form a converter unit 2 with multiple blind holes. Hence, in this embodiment the portion of the converter unit 2 that contains solid converter material is made up of the solid converter plate 21. The solid converter plate 21 could therefore be regarded as a lid to the through holes 26. The combination of the solid converter plate 21 and the converter plate 20 with through holes 26 will thereby constitute the converter unit 2 with blind holes.

[0049] The solid converter plate 21 comprises a ?rst main side 23 adapted to face the incident photons 100. A second main side 25 of the solid converter plate 21 opposite to the ?rst main side 23 is attached to the converter plate 21 with the through holes 26. This means that the second main side 25 of the solid converter plate 21 is attached to a ?rst main side 22 of the converter plate 20 with the through holes 26. Electrons 110 formed by the converter unit 2 exit from a second, opposite main side 24 of the converter plate 20 with the through holes 26.

[0050] The solid converter plate 21 is preferably attached with an airtight and electrically conducting connection or bond to the converter plate 20 with the through holes 26. The connection is preferably electrically conducting so that the two converter plates 20, 21 together form an electrically conducting structure, to which a voltage source can be connected, which is further discussed herein.

[0051] The connection is furthermore airtight or, more correctly, preferably gas tight. This means that gas present in through holes 26 is prevented from traveling laterally in the interface between the converter plates 20, 21. This in turn reduces the risk of lateral photons and electrons from moving within the converter unit 2 and between adjacent through holes 26. The connection preferably also prevents formation of any gas pockets between the two converter plates 20, 21.

[0052] There are various alternatives and variants that can be used in order to achieve an airtight or gastight but still electrically conducting connection between the converter plates 20, 21. Non-limiting but preferred examples include using a conductive glue, welding and diffusion bonding. It is also possible to use external mechanical ?xtures that tightly interconnect the converter plates 20, 21 and keep them connected in an airtight and electrically conductive manner.

[0053] The two converter plates 20, 21 can be made of a same metal material or different metal materials. The converter plate 20 with the through holes 26 is preferably made of a metal material as previously discussed for the converter plate 10 of FIG. 1, i.e. tungsten, tungsten alloys, copper, copper alloys, rhenium, rhenium alloys, molybdenum, molybdenum alloys, tantalum, tantalum alloy, chromium, chromium alloys, iron and iron alloys. Particularly, suitable materials are tungsten and tungsten alloys. The solid converter plate 21 could also be made of a metal material selected from this group of metals and metal alloys. However, it is alternatively possible to manufacture the solid converter plate 21 from a material selected among aluminum, an aluminum alloy and stainless steel.

[0054] The converter plate 10 with blind holes 16 in FIG. 1 and the converter plate 20 with through holes 26 in FIG. 2 can be manufactured with conventional machining, for instance, using drills and mills. This production method is particularly suitable for standard metals, e.g. copper, aluminum and stainless steel. High aspect ratio holes 16, 26 can be achieved as well as blind holes 16 and through holes 26. Ultrasonic activation of the tools can increase the processing speed and extend the tool life.

[0055] Electro Discharge Machining (EDM) can be used as an alternative to conventional machining. EDM generally have similar advantages and constrains but typically somewhat lower processing speed.

[0056] Particle beam drilling, e.g. using electrons, is also an option for the metal materials.

[0057] Additive layer manufacturing, using metal powder and a laser or an electron beam to form the convert plate structure by precisely, layer by layer, melting the metal powder according to the desired geometry is also possible.

[0058] Laser drilling is also feasible for some of the preferred metal materials. A preferred metal material, i.e. tungsten, is typically difficult to laser drill and suf?cient hole depth may be hard to achieve using a single converter plate 10, 20. One solution is to drill thinner sheets or plates of tungsten and then align and bond the plates together, such as using a diffusion bonding process. Such an approach will be further discussed below in connection with FIG. 5.

[0059] Another manufacture technique that can be applied if using multiple thinner sheets or plates is chemical etching. In order to improve the aspect ratio of the blind or through holes 16, 26 anisotropic etching, e.g. spray etching, could be utilized.

[0060] In the embodiment shown in FIG. 5 the converter unit 2 comprises multiple, i.e. at least two, converter plates

20A, 20B, each of which has multiple through holes 26 extending through the whole thickness of respective converter plate 20A, 20B. These multiple converter plates 20A, 20B are attached together to form a layered structure as shown in the ?gure. The multiple converter plates 20A, 20B are preferably arranged in the resulting layered structure so that the multiple through holes 26 of the converter plates 20A, 20B are aligned.

[0061] This means that the ?nal blind holes of the converter unit 2 are formed by aligned and corresponding through holes 26 in each converter plate 20A, 20B once these are attached to each other in the layered structure as shown in FIG. 5 and the layered structure is attached to the solid converter plate 21.

[0062] As is shown in FIG. 5, the second main side 25 of the solid converter plate 21 faces a ?rst main side 22 of a ?rst converter plate 20A with through holes 26. A second, opposite main side 24 of the ?rst converter plate 20B in turn faces a ?rst main side of second converter plate 20B with through holes 26 and so on until reaching the ?nal converter plate with through holes 26 in the stacked or layered structure.

[0063] The different converter plates 20A, 20B with through holes 26 can be attached to each other using similar techniques that have been discussed in the foregoing in connection with FIG. 4 and attaching the converter plate 20 with through holes 26 to the solid converter plate 20. This means that the connections between the multiple converter plates 20A, 20B with through holes 26 and between the ?rst converter plate 20A with through holes 26 and the solid converter plate 21 are preferably airtight and electrically conducting connections or bonds. Preferred examples, thus, include using a conductive glue, welding and diffusion bonding. It is also possible to use external mechanical ?xtures.

[0064] The multiple converter plates 20A, 20B with through holes 26 could all be made of a same metal material. However, it is in fact possible to use different metal materials for different converterplates 20A, 20B with through holes 26. The metal material(s) for the converter plates 20A, 20B with through holes 26 is(are) preferably selected from the group previously discussed herein in connection with FIG. 4.

[0065] The embodiments of the converter unit 1, 2 shown in FIGS. 1, 4 and 5 have various degrees of freedom with regard to affecting the formation of electrons and reducing the risk of electron and photon scattering. For instance, the converter unit 1 of FIG. 1 can be designed to be adapted to various applications, such as ranging from MeV to keV applications, by the selection of, for instance, the metal material of the converter plate 10; the geometry of the blind holes 16, such as shape, cross-sectional area, length L and overall pattern, including hole pitch (compare FIGS. 2 and 3); and the thickness W of the solid portion of the converter plate 10.

[0066] The converter unit 2 of FIG. 4 has one additional degree of freedom in affecting the operation characteristics of the converter unit 2 since it can use different metal materials for the solid converter plate 21 and the converter plate 20 with through holes 26. The converter unit 2 of FIG. 5 provides further degrees of freedom since it is possible to use different metal materials for different converter plates 20A, 20B with through holes 26.

[0067] Thus, the converter unit 1, 2 of the embodiments can easily be designed to be adapted to the particular characteristics that are wanted for a particular application or use of the converter unit 1, 2.

[0068] FIG. 6 illustrates yet another embodiment of a converter unit 3 according to the embodiments. This embodiment is similar to FIG. 4 but with the difference that the solid converterplate of FIG. 4 is replaced by an anti-scatter grid 31. Hence, the converter unit 3 comprises a converter plate 30 with multiple through holes 36 and an anti-scatter grid 31 attached to the converterplate 30 as a lid for the through holes 36 to thereby form multiple blind holes of the converter unit 3.

[0069] An anti-scatter grid 31 is a device adapted to limit the amount of radiation scatter. It is generally constructed of a series of alternating parallel strips of lead, or another attenuating metal material, and a radiolucent substance, such as a plastic. A primary X-ray beam of photons 100 passes through the radiolucent strips as it travels roughly parallel to them. Scattered radiation, which has deviated from the primary X-ray beam, cannot easily pass through the anti-scatter grid 31 as it encounters the lead strips at an angle and is attenuated or lost from the primary X-ray beam.

[0070] The anti-scatter grid 31 has a ?rst main side 33 adapted to face the incident photons 100 and a second main side 35 opposite to the ?rst main side 33 and attached to a ?rst main side 32 of the converter plate 30. A second main side 34 of the converter plate opposite to the ?rst main side 32 is facing the direction in which electrons 110 exit the converter unit 3.

[0071] The anti-scatter grid 31 is preferably attached to the converter plate 30 with an airtight and electrically conducting connection. This connection can be in the form of any the embodiments discussed in the foregoing with regard to the connection between the solid converter plate and a converter plate with through holes.

[0072] A variant of the converter unit 3 of FIG. 6 is to have the anti-scatter grid 31 and a layered structure of multiple converter plates 30 with through holes 36 as shown in FIG. 5.

[0073] In an embodiment, at least a portion of the walls of the blind holes 16 in the converter unit 1, 2, 3 of the embodiments can be coated with a photoelectric converting layer. In addition, or alternatively, at least a portion of the ?rst main side 23 or the second main side 25 of the solid converter plate 21 in FIG. 4 or 5 could be coated with a photoelectric converting layer. In this latter case, it is generally preferred to provide the photoelectric converting layer on at least a portion of the second main side 25 and in particular to at least the portion of the second main side 25 aligned with the through holes 26. This means that the photoelectric converting layer is preferably provided at the bottom of the blind holes. This approach is also possible with the converter unit 1 as shown in FIG. 1 where the photoelectric converting layer can be applied to the bottom of the blind holes 16 in addition to, or alternatively to, on the walls of the blind holes 16.

[0074] The photoelectric converting layer(s) can be included in the converter unit 1, 2, 3 in order to customize the conversion ef?ciency for selected photon energies.

[0075] The photoelectric converting layer(s) is(are) typically made of a metal selected among alkali, bi-alkali and multialkali metals. Non-limiting, but preferred examples, include CsiI, CsiTe, NaiKiSbiCs, SbiK4Cs, Sbin4Cs and Sb4Cs.

[0076] The converter unit of the embodiments is preferably included as a part of a detector. Various detector embodiments incorporating a converter unit will now be further described herein.

[0077] An aspect of the embodiments relates to a detector comprising a converter unit of the embodiments, such as any of the converter units 1, 2, 3 discussed in the foregoing in connection with FIGS. 1-6. In this aspect, the detector also comprises an electron ampli?cation device con?gured to produce further electrons from the electrons exiting the converter unit. The electron ampli?cation device is attached to the converter unit with an electrically isolating connection.

[0078] FIG. 7 is a cross-sectional view of a detector 4 according to an embodiment. In the ?gure, the converter unit 1 has been exempli?ed by the embodiment as shown in FIG. 1. This should, however, merely be seen as an illustrative but non-limiting example. Any of the other converter unit embodiments, such as shown in FIGS. 4-6 could instead be arranged in the detector 4.

[0079] As is shown in the ?gure the electron ampli?cation device 40 is preferably arranged attached to the main side 14 of the converter unit 1 comprising the entrances of the blind holes 16. Thus, the second main side 14 of the converter unit 1, being opposite to the ?rst main side 12 facing the incident photons 100, is attached to a ?rst main side 42 of the electron ampli?cation device 40. Electrons 120, sometimes denoted secondary electrons in the art, formed in the electron ampli?cation device 40 exit a second, opposite main side 44 of the electron ampli?cation device 40.

[0080] As stated in the foregoing, the converter unit 1 and the electron ampli?cation device 40 are electrically isolated from each other by an electrically isolating connection, bond or layer 50 between these two units. The electrically isolating connection 50 could, for instance, be in the form of an electrically isolating glue or a photo pattemable dry ?lm. Further variants include using polyimides, such as Kapton (4,4'-oxydiphenylamine), or FR-4, which is a composite material composed of woven ?berglass cloth with an epoxy resin binder.

[0081] The electrical isolation 50 between the converter unit 1 and the electron ampli?cation device 40 implies that a voltage source 52 can be connected to the converter unit 1 and the electron ampli?cation device 40. The voltage source 52 is thereby adapted to apply a voltage and electric ?eld across the electrical isolation layer 50 that forces electrons present in the blind holes 16 towards the electron ampli?cation device 40.

[0082] Thus, the voltage source 52 provides the driving force (electric ?eld) that directs electrons converted in the converter unit 1 from the incident photons 100 towards the electron ampli?cation device 40.

[0083] The purpose of the electron ampli?cation device 40 is, as its name indicates, to amplify the electron signal exiting the converter unit 1. Thus, the electron ampli?cation device 40 produces a multiplicity of electrons 120 from the electrons emitted from the converter unit 1. This multiplicity of electrons 120 then represents a signal proportional to the incident ?uence of photons 100.

[0084] A suitable voltage applied by the voltage source 52 could be about 50 V between the converting unit 1 and the electron ampli?cation device 40. However, the actual voltage value depends on various design aspects, such as the depth of the blind holes 16 in the converter unit 1.

[0085] There are various implementation examples of electron ampli?cation devices 40 that can be used in a detector 4 in order to amplify an input electron signal and output an ampli?ed electron signal. A preferred example is a Gas Electron Multiplier (GEM).

[0086] A GEM 40 is, in its most basic design, a thin structure of two metal electrodes with an insulating foil inserted between. The structure is perforated with through holes 46 where the electron multiplication can occur. In a preferred embodiment, a voltage source 54 is connected to the two metal electrodes of the GEM 40 and is adapted to apply a voltage across the metal electrodes. This applied voltage will create large electric ?elds in the through holes 46.

[0087] In typical implementations, the voltage source 54 could provide a voltage within the range of 150-400 V across the two metal electrodes. This should, however, merely be seen as an illustrative but non-limiting example.

[0088] In FIG. 7 the detector 4 has been illustrated with two voltage sources 52, 54, one for providing a voltage across the electrically isolating connection 50, preferably between the converter unit 1 and the metal electrode facing the converter unit 1 and the electrically isolating connection 50, and one for providing a voltage across the metal electrodes of the GEM 40. In an alternative embodiment, a single voltage source is used to provide both these voltages, possible in connection with one or more resistors to get the correct voltage values.

[0089] In an embodiment, the multiple through holes 46 of the GEM 40 are aligned with the multiple blind holes 16 of the converter unit 1 as schematically indicated in FIG. 8. In such an embodiment, the diameter or the cross-sectional area of the through holes 46 in the GEM 40 is typically smaller than the corresponding diameter or cross-sectional area of the blind holes 16 in the converter unit 1.

[0090] It is, however, generally not necessary to align the through holes 46 with the blind holes 16. For instance, by having a GEM 40 with a smaller pitch for the pattern of through holes 46 in the GEM 40 as compared to the converter unit 1 then a certain number of through holes 46 will always match a blind hole 16 in the converter unit 1. This approach thereby reduces the need for any alignment.

[0091] GEMs 40 are well known in the art and there are various documents disclosing GEM examples [1-4].

[0092] In some prior art detectors, a stack of multiple GEMs 40 could be used to even further amplify the electron signal. Such an approach is also possible for detector 4 of the embodiments. In such a case, the multiple GEMs 40 could be separated from each other by a respective electrically insulating layer, similar to the electrically insulating layer 50 between the converter unit and the GEM 40 in FIG. 7. Alternatively, a small gas gap could be present between adjacent GEMs 40.

[0093] Other non-limiting examples of electron ampli?cation devices 40 that can be used in the detector 4 include Micro Channel Plate (MCP), Capillary Plate (CP) and Micro Mesh Gaseous Structure (MicroMegas).

[0094] Generally, a MCP is a slab made from highly resistive material with a regular array of tubes or slots (microchannels) leading from one face to the opposite. These tubes or slots are typically densely distributed over the whole structure. In operation, each microchannel is a continuous-dynode electron multiplier, in which multiplication of electrons takes place under the presence of a strong electric ?eld. An electron or photon entering a microchannel through a small ori?ce is guaranteed to hit the channel wall since the microchannels are angled to the plate and, thus, angled relative to the angle of impact. The impact between the electron or photon and the channel wall starts a cascade of electrons that propagate through the microchannel. Accordingly, an ampli?cation of the original signal by several orders of magnitude is possible depending on the electric ?eld strength and the geometry of the MCP.

[0095] There are variants of MCP in the art that can also be used according to the embodiments, such as chevron MCP and Z stack MCP.

[0096] An example ofa MCP design is disclosed in a document [5].

[0097] A CP is basically a thin plate-like member, in which a plurality of lead glass capillaries constituting a hollow-like shape is integrated. Thin ?lm electrodes are formed on opposite surfaces of the CP. More information of CP design can be found in a document [7].

[0098] In a MicroMegas a gas volume is divided in two by a metallic micro-mesh. An electron or photon passing through the MicroMegas will ionize gas atoms by puling up an electron creating an electron-ion pair. By applying an electric ?eld the electron will drift toward the micro-mesh operating as ampli?cation electrode. When the electron enters close to the micro-mesh it enters an intense electric ?eld. Accelerated by this high electric ?eld, the electron reaches enough energy produce electron-ion pairs that will also ionize the gas causing an avalanche effect.

[0099] In operation, electrons formed in the converter unit 1 and having suf?cient low energy will directly be captured by the electric ?eld and transported towards the electron ampli?cation device 40. An optional photoelectric converting layer on the surfaces de?ning the blind holes 16 increases the amount of such low energy electrons since the preferred alkali, bi-alkali and multialkali metals of the photoconverting layer are ionized at lower energies as compared to the preferred materials of the converter plate(s).

[0100] Electrons with higher energy and photons will typically not follow the electric ?eld but will instead form ion tracks in the gas present in the blind holes forming electron ion pairs. The free electrons of the electron-ion pairs generally have low energy and will therefore be transported by the electric ?eld towards the electron ampli?cation device 40. In this case, the blind holes 16 will operate as ionization chambers and the amount of formed electrons will be substantially proportional to the total gas volume in the blind holes.

[0101] The sum of the low energy electrons generated as described above will be ampli?ed by the electron ampli?cation device 40.

[0102] In an embodiment, the detector 5 also comprises a readout device 60 adapted to generate a signal representative of the incident photons 100 in addition to the previously described converter unit 1 having multiple blind holes 16 and the electron ampli?cation device 40 as shown in FIG. 9.

[0103] The readout device 60 is preferably arranged with a small gas gap 58 between the electron ampli?cation device 40 and the readout device 40. It is, however, also possible to attach the readout device 60 to the main side of the electron ampli?cation device 40 facing away from the converter unit 1. In such a case, an electrically isolating connection is employed, similar to the electrically isolating connection 50 between the converter unit 1 and the electron ampli?cation device 40.

[0104] The small gas gap 58 could be in the range of about one or a few millimeters for most practical implementations.

[0105] In a preferred embodiment, a voltage source 56 is connected to the electron ampli?cation device 40 and the readout device 60. This voltage source 56 is adapted to apply a voltage and thereby generate an electric ?eld across the gas gap 58 to force electrons 120 exiting the electron ampli?cation towards the readout device 60 for detection therein.

[0106] If the electron ampli?cation device 40 is implemented by a GEM 40, the voltage source 56 is preferably connected between the metal layer of the GEM 40 facing the readout device 60 and the readout device 60.

[0107] In FIG. 9 three separate voltage sources 52, 54, 56 have been illustrated. In alternative embodiments, it could be suf?cient to only use one or two voltage sources, possible together with one or more resistors, to provide the correct voltages and electric ?elds across the electrically isolating layer 50, across the electron ampli?cation device 40 and across the gas gap 58.

[0108] In an embodiment, the readout device 60 is con?gured to generate a signal representative of an X-ray transmission image of an object based on detection of electrons 120. In this embodiment, the detector 5 is preferably in the form an X-ray detector 5 that can be used to generate an image of an object, such as a patient or a portion of a patient's body. The input photons 100 could then be from a diagnostic X-ray source or indeed from a therapeutic radiation source to be used to irradiate the patient, e.g. irradiate a tumor in the patient's body. This latter case is generally referred to as portal imaging in the art.

[0109] An example of a readout device 60 that can be used according to the embodiments is a two-dimensional (2D) charge sensitive device. There are various such 2D charge sensitive devices available in the art including, for instance, a thin-?lm transistor (TFT) panel.

[0110] Otherpossible readout devices 60 that can be used in the detector 5 include direct readout, for instance, through metallized pixels and stacked printed circuit boards (PCBs) with edge patterned pixels [6]. Further examples are also discussed in document [4], see for instance section 2.1.4 Electronic readout system.

[0111] In an embodiment, the pattern formed by the blind holes 16 in the converter unit 1, see FIGS. 2 and 3, preferably has at least substantially a same resolution as the readout device 60.

[0112] In the above described embodiment, the detector 5 is preferably in the form of an X-ray detector con?gured to generate a signal representative of an X-ray transmission image based on the incident X-ray beam(s) of photons 100. The embodiments are, however, not limited thereto but can alternatively be used for other detection purposes and detector implementations. For instance, in an embodiment the readout device 60 of the detector 5 is con?gured to generate a signal representative of an absolute radiation dose of the incident photons 100 by detection of electrons 120 exiting the converter unit 1 and the electron ampli?cation device 40. Hence, in this embodiment the detector 5 is employed for measuring radiation doses. The detector 5 could then, for instance, be employed for radiation machine quality assurance as well as veri?cation of treatment plans.

[0113] The detector 6 preferably comprises a detector housing 70 as shown in FIG. 10. In such a case, the detector housing 70 comprises the converter unit 1, the electron ampli?cation device 40 and preferably also the readout device 60. These units 1, 40, 60 could be fully encompassed within the detector housing 70 as shown in FIG. 10. In an alternative approach as shown in FIG. 11, the detector housing 80 of the detector 7 at least partly encloses the converter unit 1, the electron ampli?cation device 40 and preferably the readout device 60. For instance, the ?rst main side of the converter unit 1 facing the incident photons could extend outside of the detector housing 80, which is then typically connected to the end side(s) of the converter unit 1. Correspondingly or alternatively, the main side of the readout device 60 facing away from the incident photons and electrons could be present outside of the detector housing 80.

[0114] It is, however, generally preferred if the detector housing 70, 80 at least encloses portions of the converter unit 1 and the readout device 60 so that the blind holes, the electron ampli?cation device 40 and the gap between the electron ampli?cation device 40 and the readout device 60 will be present within the detector housing 70, 80.

[0115] The detector housing 70, 80 is preferably ?lled with a gas. This means that this gas will be present in the blind holes of the converter unit 1 and preferably also within the through holes of the electron ampli?cation device 40 and in the gap between the electron ampli?cation device 40 and the readout device 60.

[0116] Various gases, including gas mixtures, are possible and can be used according to the embodiments. Non-limiting examples include argon, xenon, carbon dioxide, dimethyl ether (DME) and mixtures thereof. However, other quenching gases or penning mixtures are possible.

[0117] In FIGS. 7, 9-10 the detector 4-7 has been illustrated as comprising the converter unit 1 and an electron ampli?cation device 40 in addition to a preferred readout device 60. In another approach, the electron ampli?cation device 40 could be emitted. Hence, another aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and a readout device con?gured to generate a signal representative of the incident photons. In such an embodiment, the converter unit and the readout device are preferably arranged in a detector, such as at least partly within a detector housing, with a small gas gap between the converter unit and the readout device. A voltage source is preferably connected to the converter unit and the readout device across the gas gap in order to force electrons formed in the converter unit towards the readout device for detection therein.

[0118] Though, this aspect of the detector works it is generally preferred to include an electron ampli?cation device as discussed in the foregoing in order to achieve an ampli?cation of the electrons prior to detection thereof by the readout device.

[0119] The drawings of the converter unit and detector of the embodiments should be regarded as schematic representations of various implementation embodiments. Hence, the drawings are not intended to show the including units and devices in any particular scales or relative sizes.

[0120] The embodiments described above are to be understood as a few illustrative examples of the present invention. It will be understood by those skilled in the art that various modi?cations, combinations and changes may be made to the embodiments without departing from the scope of the present invention. In particular, different part solutions in the different embodiments can be combined in other con?gurations, where technically possible. The scope of the present invention is, however, de?ned by the appended claims.

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1. A converter unit adapted to convert incident photons into electrons, wherein said converter unit comprises multiple blind holes forming respective ionization chambers.

2. The converter unit according to claim 1, wherein said multiple blind holes extend through a portion of a thickness of said converter unit but do not extend through a whole thickness of said converter unit.

3. The converter unit according to claim 1, wherein said multiple blind holes are arranged in said converter unit to have a respective longitudinal axis substantially parallel to a normal of a mains side of said converter unit.

4. The converter unit according to claim 1, wherein at least a portion of walls of said multiple blind holes is coated with a photoelectric converting layer.

5. The converter unit according to claim 4, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of an alkali metal, a bi-alkali metal and a multialkali metal.

6. The converter unit according to claim 4, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of CsiI, CsiTe, NaiKiSb4Cs, SbiK4Cs, SbiniCs and SbiCs.

7. The converter unit according to claim 1, wherein said converter unit is in a form of a single, unitary converter plate comprising said multiple blind holes extending through a portion of a thickness of said converter plate but do not extend through a whole thickness of said converter plate.

8. The converter unit according to claim 7, wherein said converter plate comprises:

a ?rst main side adapted to face said incident photons; and

a second main side opposite to said ?rst main side and comprising entrances of said multiple blind holes.

9. The converter unit according to claim 7, wherein said converter plate is made of a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys.

10. The converter unit according to claim 1, further comprising:

a converter plate with multiple through holes; and

a solid converter plate, wherein said solid converter plate is attached to said converter plate with said multiple through holes as a lid for said multiple through holes to form said multiple blind holes.

11. The converter unit according to claim 10, wherein said solid converter plate comprises:

a ?rst main side adapted to face said incident photons; and

a second main side opposite to said ?rst main side and attached to said converter plate with multiple through holes.

12. The converter unit according to claim 11, wherein at least a portion of at least one of said ?rst main side and said second main side is coated with a photoelectric converting layer.

13. The converter unit according to claim 12, wherein at least a portion of said second main side aligned with said through holes is coated with said photoelectric converting layer.

14. The converter unit according to claim 12, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of an alkali metal, a bi-alkali metal and a multialkali metal.

15. The converter unit according to claim 14, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of CsiI, CsiTe, NaiKiSb4Cs, SbiK4Cs, SbiniCs and SbiCs.

16. The converter unit according to claim 10, wherein said solid converter plate is attached with an airtight and electrically conducting connection to said converter plate with multiple through holes.

17. The converter unit according to claim 16, wherein said solid converter plate is attached to said converter plate with multiple through holes by means of at least one of a group consisting of a conductive glue, welding and a diffusion bonding.

18. The converter unit according to claim 10, wherein

said converter plate with multiple through holes is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys; and

said solid converter plate is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron, iron alloys, aluminium, an aluminium alloy and stainless steel.

19. The converter unit according to claim 10, further comprising multiple converter plates, each converter plate of said multiple converter plates has multiple through holes, wherein

said multiple converter plates are attached together to form a layered structure in which said multiple through holes of said multiple converter plates are aligned, and

said solid converter plate is attached to said layered structure as a lid for said multiple through holes to form said multiple blind holes.

20. The converter unit according to claim 1, further comprising:

a converter plate with multiple through holes; and

an anti-scatter grid, wherein said anti-scatter grid is attached to said converter plate as a lid for said multiple through holes to form said multiple blind holes.

21. The converter unit according to claim 20, wherein said anti-scatter grid comprises:

a ?rst main side adapted to face said incident photons; and

a second main side opposite to said ?rst main side and attached to said converter plate.

22. The converter unit according to claim 20, wherein said anti-scatter grid is attached with an airtight and electrically conducting connection to said converter plate.

23. The converter unit according to claim 22, wherein said anti-scatter grid is attached to said converterplate by means of at least one of a group consisting of a conductive glue and a diffusion bond.

24. The converter unit according to claim 20, wherein said converter plate is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys.

25. A detector comprising:

a converter unit according to claim 1; and

an electron ampli?cation device adapted to produce further electrons from said electrons, wherein said electron ampli?cation device is attached to said converter unit with an electrically isolating connection.

26. The detector according to claim 25, wherein said converter unit comprises:

a ?rst main side adapted to face said incident photons; and

a second main side opposite to said ?rst main side and comprising entrances of said multiple blind holes, wherein said electron ampli?cation device is attached to said second main side.

27. The detector according to claim 25, further comprising a voltage source connected to said converter unit and said electron ampli?cation device and adapted to force electrons present in said multiple blind holes towards said electron ampli?cation device.

28. The detector according to claim 25, wherein said electrically isolating connection is selected from a group consisting of an electrically isolating glue, a photo patternable dry ?lm and a polyimide.

29. The detector according to claim 25, wherein said electron ampli?cation device is selected from a group consisting of a Gas Electron Multiplier, GEM; a Micro Channel Plate, MCP; a Capillary Plate, CP; and a Micro-Mesh Gaseous Structure, MicroMegas.

30. The detector according to claim 29, wherein said electron ampli?cation device is a GEM comprising multiple through holes, at least a portion of said multiple through holes are aligned with said multiple blind holes.

31. The detector according to claim 25, further comprising a readout device adapted to generate a signal representative of said incident photons.

32. The detector according to claim 31, further comprising a voltage source connected to said electron ampli?cation device and said readout device and adapted to force electrons exiting said electron ampli?cation device towards said readout device.

33. The detector according to claim 31, wherein said readout device is arranged with a gas gap between said electron ampli?cation device and said readout device.

34. The detector according to claim 31, wherein said readout device is adapted to generate a signal representative of an X-ray transmission image of an object based on detection of electrons.

35. The detector according to claim 34, wherein said readout device is a two-dimensional charge sensitive device.

36. The detector according to claim 35, wherein said two dimensional charge sensitive device is a thin-?lm transistor, TFT, panel.

37. The detector according to claim 31, wherein said readout device is adapted to generate a signal representative of an absolute radiation dose of said photons based on detection of electrons.

38. The detector according to claim 31, wherein a pattern formed by said blind holes in said converter unit has at least substantially a same resolution as said readout device.

39. The detector according to claim 25, further comprising a detector housing comprising said electron ampli?cation device and at least a portion of said converter unit, wherein said detector housing is ?lled with a gas and said gas is present in said blind holes.

40. The detector according to claim 39, wherein said gas is selected from a group consisting of argon, xenon, carbon dioxide, dimethyl ether or mixtures thereof.

41. A detector comprising:

a converter unit according to claim 1; and

a readout device adapted to generate a signal representative of said incident photons.

* * * * *

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Maad et al.

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(45) **Date of Patent: Dec. 26, 2017**

(54) CONVERTER UNIT

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(73) Assignee: **C-RAD IMAGING AB**, Uppsala (SE)

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(22) Filed: **Sep. 4, 2013**

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G01T 1/18 (2006.01)
G01T 1/185 (2006.01)
G01T 1/29 (2006.01)

(52) **U.S. Cl.**

CPC ***G01T 1/185*** (2013.01); ***G01T 1/2935*** (2013.01)

(58) **Field of Classification Search**

CPC H01J 47/02; H01J 47/06; G01T 1/185; G01T 1/2935; G01T 1/18

See application file for complete search history.

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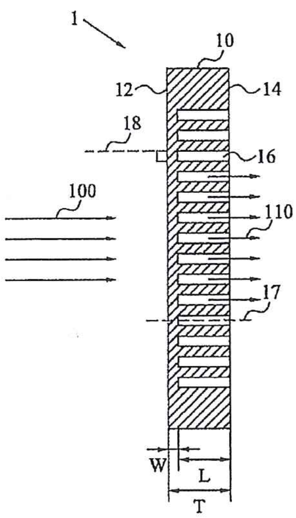
Assistant Examiner — Mamadou Faye
(74) *Attorney, Agent, or Firm* — Porter Wright Morris & Arthur LLP

(57) **ABSTRACT**

A converter unit configured to convert incident photons into electrons comprises multiple blind holes forming respective ionization chambers. In additional embodiments, the converter unit is arranged in a detector, such as an X-ray detector or absolute radiation dose measurement detector, additionally comprising an electron amplification device and/or a readout device.

46 Claims, 5 Drawing Sheets



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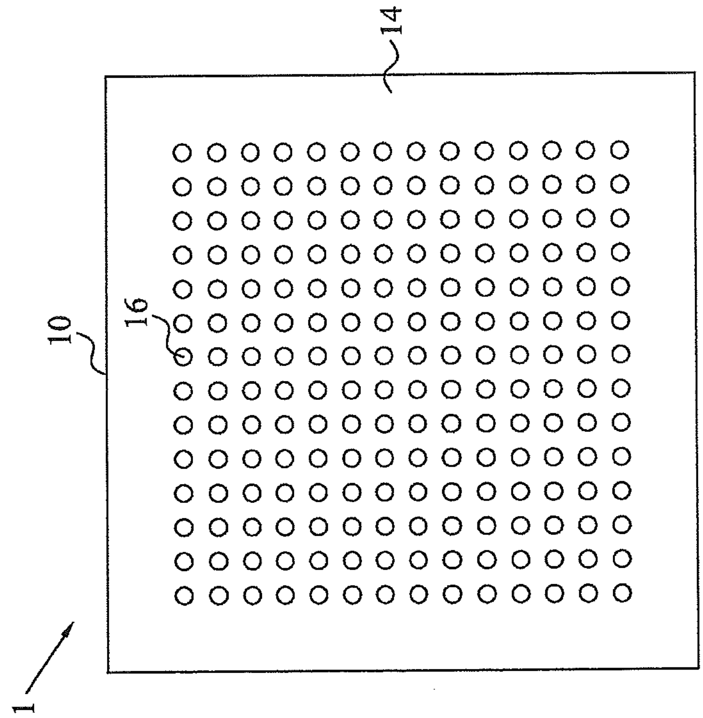

Fig. 2

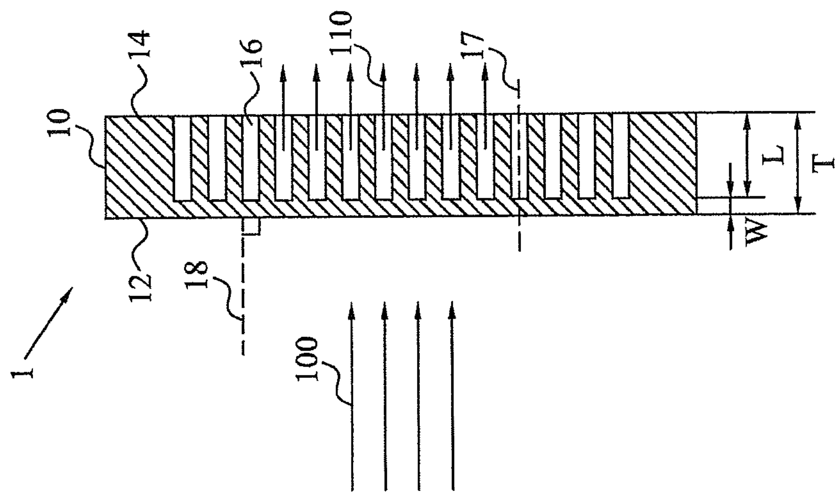

Fig. 1

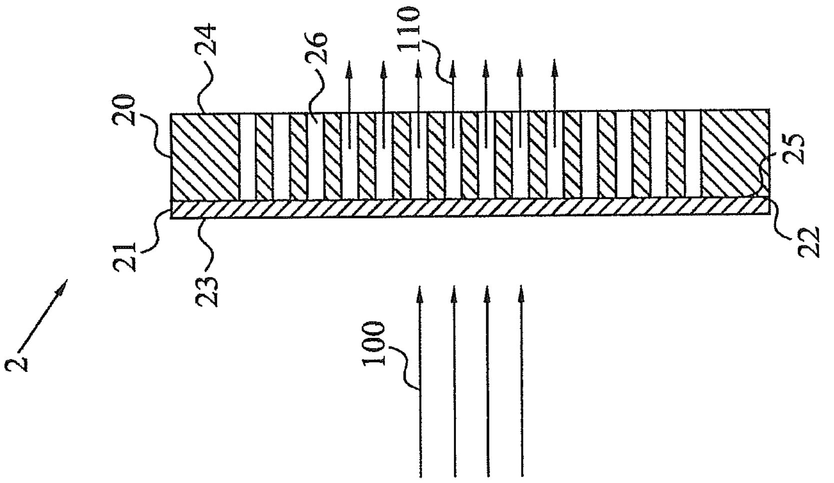

Fig. 4

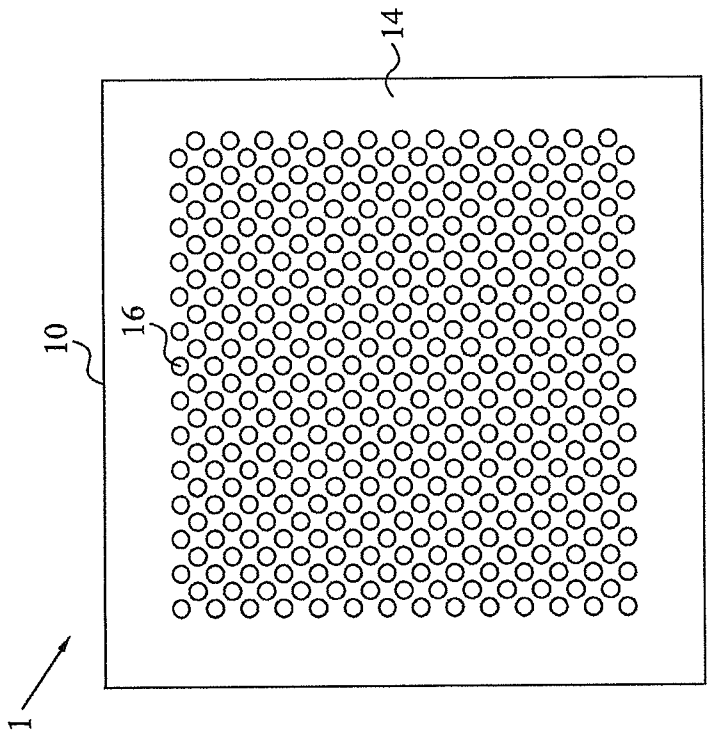

Fig. 3

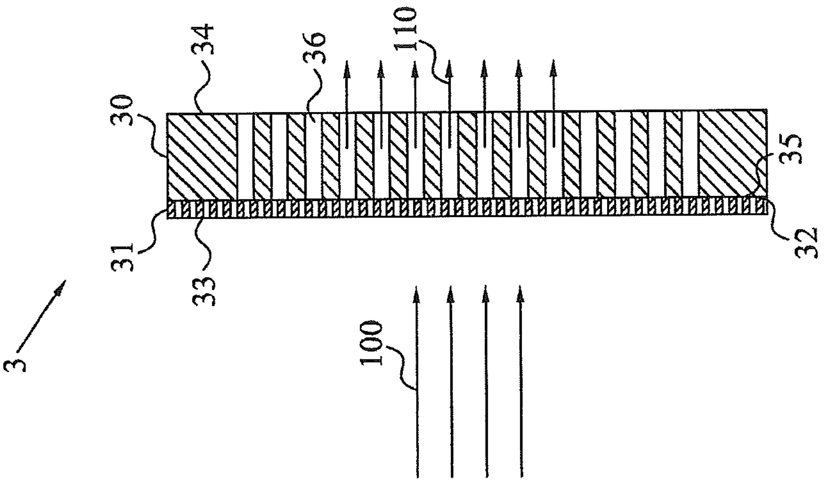

Fig. 6

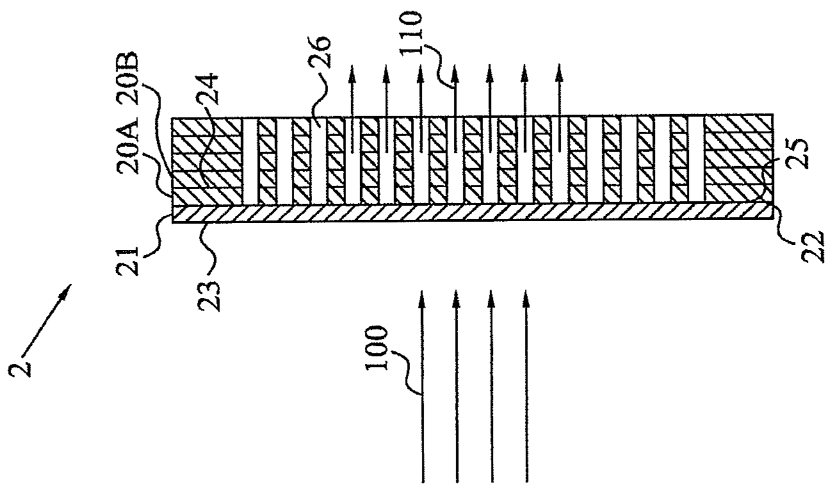

Fig. 5

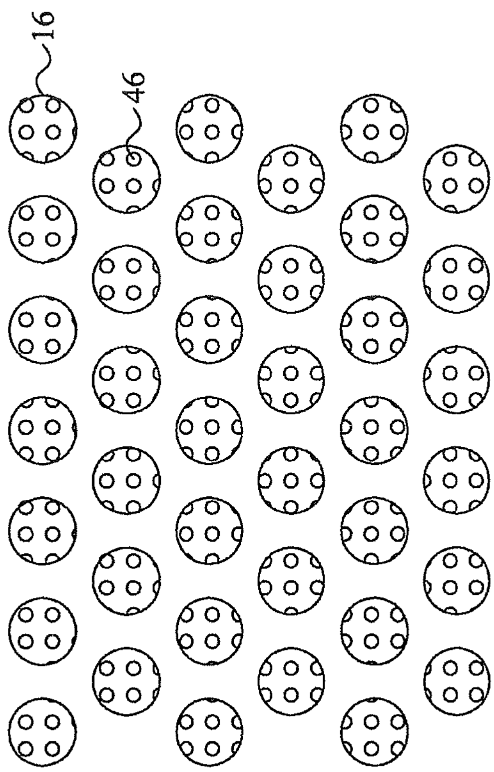
16
46

Fig. 8

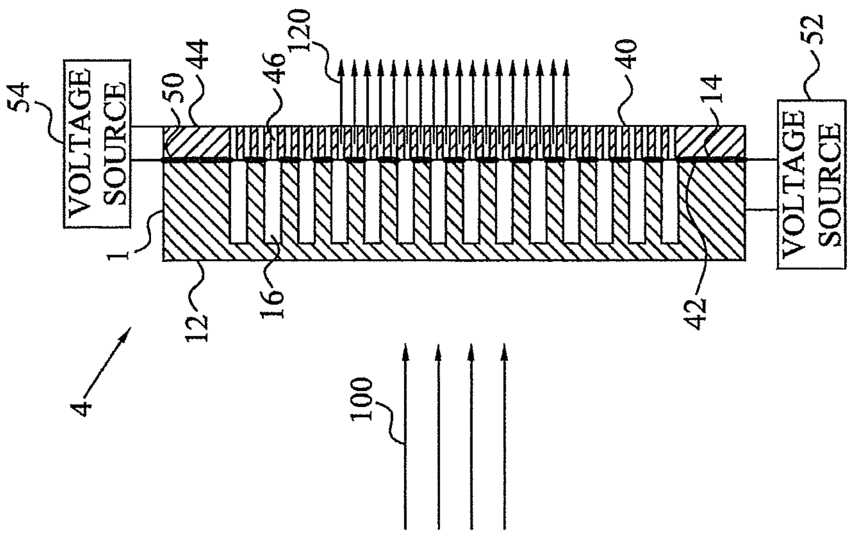
VOLTAGE SOURCE
54
50
44
46
120
40
14
52
VOLTAGE SOURCE
1
12
16
42
4
100

Fig. 7

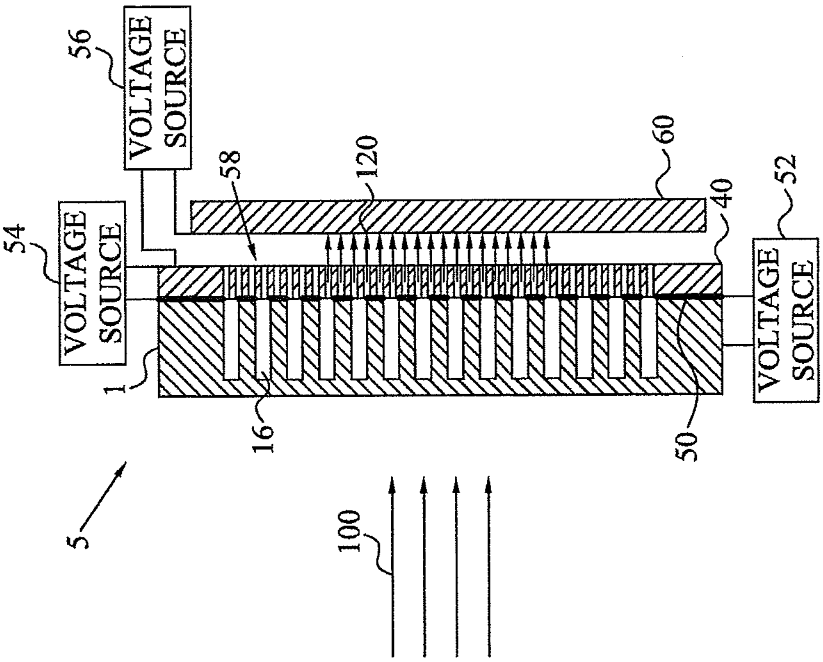

Fig. 9

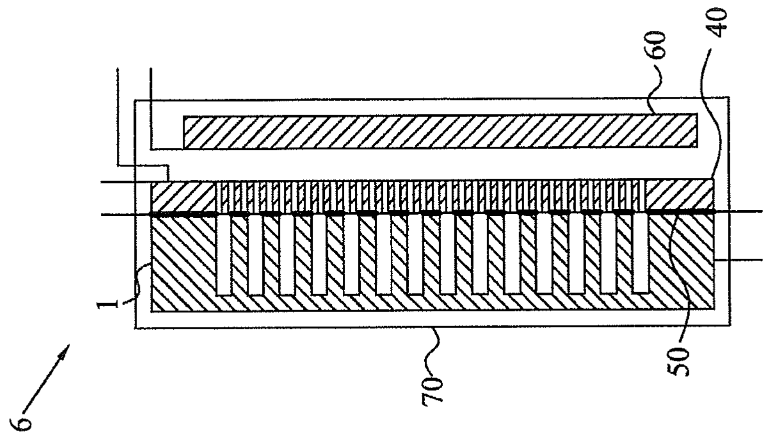

Fig. 10

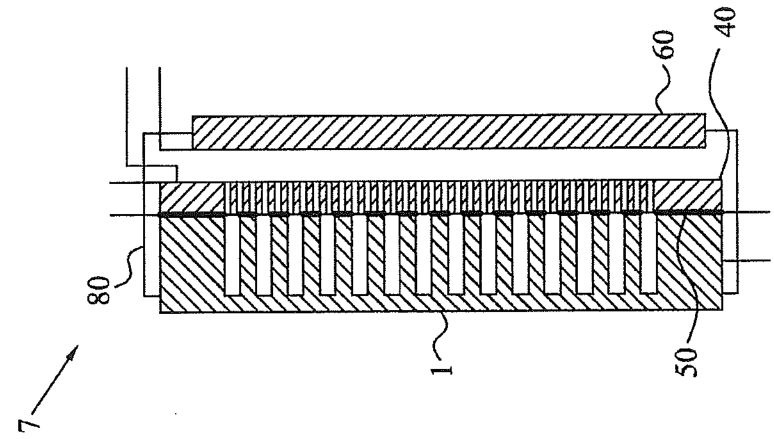

Fig. 11

CONVERTER UNIT

TECHNICAL FIELD

The present embodiments generally relate to a converter unit adapted to convert incident photons into electrons, and to a detector comprising such a converter unit.

BACKGROUND

X-ray detectors are used to detect radiation and provide spatial mapping of radiation intensity in radiation-based imaging systems. Such systems involve detection of incoming radiation, such as X-rays and gamma photons, in a wide range of different applications, including medical applications.

Basically, a radiation source generates a beam in the direction of an object to be examined and a detector measures the intensity of the beam after it has passed through the object. The detector outputs information required to produce an image representing attenuation of the radiation resulting from absorption and scattering by the structure through which the beam traveled. Apart from forming an X-ray transmission image of an object an X-ray detector could also be used for measuring radiation doses.

Many radiation systems involve radiation sources, such as X-ray tubes or radiation treatment machines, associated with a very high MeV photon flow during the output pulse. The challenge is to convert as many as possible of the incident high energy photons, while at the same time preserving their spatial information, with a high precision. This makes it very difficult to achieve sufficient image quality.

A detector unit for detecting photons in the energy range 1 keV to 100 MeV is disclosed in a document [1]. The detector unit includes at least two converter layers adapted to interact with incident X-ray photons and to cause electrons to be emitted therefrom. At least one amplifier is adapted to interact with the emitted electrons and produce a multiplicity of secondary electrons and photons representing a signal proportional to the incident fluence of X-ray photons.

A document [2] is directed towards reducing spread of electrons as compared to conventional radiation detectors. The radiation detector comprises a gas electron multiplier (GEM) using interaction between radiation and gas through photoelectric effects. The GEM is arranged in a chamber filled with gas and has a single gas electron multiplication foil arranged in the chamber. This gas electron multiplication foil is made of a plate-like multilayer body composed by having a plate-like insulation layer made of a macromolecular polymer material having a thickness of 100-300 μm and flat metal layers overlaid on both surfaces of the insulation layer. The plate-like multilayer body is provided with a through-hole structure.

SUMMARY

It is a general objective to provide an improved converter unit.

It is a particular objective to provide a converter unit reducing electron and photon scattering.

These and other objectives are met by embodiments as defined herein.

An aspect of the embodiments relates to a converter unit configured to convert incident photons into electrons. The converter unit comprises multiple blind holes forming respective ionization chambers.

Another aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and an electron amplification device configured to produce further electrons from electrons formed in the converter unit. The electron amplification device is attached to the converter unit with an electrically isolating connection.

A further aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and a readout device configured to generate a signal representative of incident photons.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

FIG. **1** is a cross-sectional view of a converter unit according to an embodiment;

FIG. **2** is an illustration of a converter unit according to an embodiment;

FIG. **3** is an illustration of a converter unit according to another embodiment;

FIG. **4** is a cross-sectional view of a converter unit according to another embodiment;

FIG. **5** is a cross-sectional view of a converter unit according to a further embodiment;

FIG. **6** is a cross-sectional view of a converter unit according to yet another embodiment;

FIG. **7** is a cross-sectional view of a detector according to an embodiment;

FIG. **8** schematically illustrates alignment of blind holes and through holes according to an embodiment;

FIG. **9** is a cross-sectional view of a detector according to another embodiment;

FIG. **10** is a cross-sectional view of a detector according to a further embodiment; and

FIG. **11** is a cross-sectional view of a detector according to yet another embodiment.

DETAILED DESCRIPTION

Throughout the drawings, the same reference numbers are used for similar or corresponding elements.

The present embodiments generally relate to a converter unit adapted to convert incident photons into electrons, sometimes denoted primary electrons in the art. The embodiments further relate to a detector comprising such a converter unit.

The converter unit of the embodiments enables, when implemented as a part of a detector, such as an X-ray detector, high sharpness in the captured picture. Such high sharpness and resolution in the picture is possible even for incident high energy photons.

Generally, there is a big challenge within X-ray detectors to convert as many as possible of incident high energy photons, while at the same time preserving their spatial information, with a high precision. A prior art solution has typically been to use several separate equidistant converter layers and electron amplification devices that amplify electrons converted from incident photons. However, such an approach generally leads to low sharpness in the formed picture due to open gas layers between the converter layers and electron amplification devices, causing scattering and lateral electron and photon distribution. This in turn leads to blurriness in the captured image.

The present embodiments have taken a radically different approach as compared to the prior art when constructing the converter unit. The present embodiments therefore relate to a converter unit comprising multiple blind holes, sometimes referred to as bottom holes in the art, forming respective ionization chambers in the converter unit.

Accordingly, an aspect of the embodiments relates to a converter unit adapted to convert incident photons into electrons. The converter unit comprises multiple blind holes forming respective ionization chambers.

This means that the blind holes **16** in the converter unit **1** extend through a portion L, see FIG. **1**, of a thickness T of the converter unit **1** but do not extend through the whole thickness T of the converter unit **1**. This means that there is a portion W of the thickness T of the converter unit 1 into which the blind holes **16** do not extend.

Various implementation embodiments of the general aspect will now be further described herein with reference to the drawings.

FIG. **1** is a cross-sectional view of a converter unit **1** according to an embodiment. In this embodiment, the converter unit **1** is in a form of a single, unitary converter plate **10** comprising multiple blind holes **16** extending through a portion L of the thickness T of the converter plate **10** but do not extend through the whole thickness T of the converter plate **10**.

The multiple blind holes **16** are preferably arranged so that they are substantially parallel in the converter plate **10**. Hence, the longitudinal axes **17** of the blind holes **16** are preferably substantially parallel with each other.

In a particular embodiment, the multiple blind holes **16** are arranged in the converter unit **1** to have a respective longitudinal axis **17** substantially parallel to a normal **18** of a main side **12**, **14** of said converter unit **1**. Generally, this means that the longitudinal axis **17** is at least substantially parallel to a main beam direction of the incident photons **100** hitting the converter unit **1**. In a typical approach, the photons **100** are generated by a radiation source, which could be regarded, as seen from the converter unit **1**, to be a point source due to that the extension of the radiation source is generally much smaller than the distance between the radiation source and the converter unit **1**. Accordingly, the main beam direction will hit the converter unit **1** with an angle of incidence of close to zero relative to the normal **18** of the main side **12** of the converter unit **1**. However, some of the photons **100** may in fact hit the converter unit **1** with a non-zero angle of incidence due to radiation distribution and that the radiation source does not have non-zero extension.

The converter plate **10** generally comprises a first main side **12** adapted to face the incident photons **100** and a second main side **14** opposite to the first main side **12**. In a preferred embodiment, the second main side **14** facing away from the incident photons **100** comprises the entrances of the blind holes **16**. Hence the blind holes **16** extend from the second main side **14** towards, but not reaching, the first main side **12** of the converter plate **10**.

The converter plate **10**, which in the embodiment as shown in FIG. **1**, is in the form of a single, unitary piece of the converter unit **1**, is preferably made of a metal material capable of converting incident photons **100** into electrons **110** through electromagnetic interaction. Electromagnetic interaction encompasses all physical interactions between photons **100** and the metal material that causes generation of electrons **110**, such as through Compton effect, pair-production or photo electric effect.

Examples of suitable metal materials for the converter plate **10** include tungsten, tungsten alloys, copper, copper alloys, rhenium, rhenium alloys, molybdenum, molybdenum alloys, tantalum, tantalum alloy, chromium, chromium alloys, iron and iron alloys. Particularly, suitable materials are tungsten and tungsten alloys.

The incident photons **100** will hit the metal material of the solid portion of the converter plate **10** and are there, through the electromagnetic interaction, converted into electrons **110**. The design of the converter unit **1** of the embodiments with blind holes **16** extending merely a portion L of the thickness T of the converter unit **1** will be very efficient in stopping lateral electrons and photons, i.e. traveling in a direction perpendicular to the thickness T of the converter unit **1** and perpendicular to the longitudinal axes **17** of the blind holes **16**. The reason being that these scattered electrons and photons will be stopped in the walls of the blind holes **16**. Consequently, the particular design of the converter unit **1** of the embodiments will reduce the amount of lateral or scattered electrons and photons exiting the converter unit **1**, i.e. exiting from the second main side **14**. This reduction in electron and photon scattering will in turn reduce blurring of a signal representing detected electrons, which is further discussed herein. This means that the converter unit **1** of the embodiments is designed to promote delivery of electrons **110** that are parallel or at least substantially parallel to the longitudinal axes **17** of the blind holes **16** and parallel to the normals of the first and second main sides **12**, **14**.

Not only the particular material of the converter plate **10** but also the thickness W of the solid part of the converter plate **10**, i.e. the portion between the bottom of the blind holes **16** and the first main side **12** of the converter plate **10** facing the incident photons **100**, affects the attenuation of incident low energy photons, so called beam hardening. This is useful in high energy applications in order to reduce the detection of scattered photons, which generally have lower energy, such as up to approximately 300 keV.

Each blind hole **16** will operate as an ionization chamber in which energetic electrons ejected from the converter plate **10** create a large number of ion pairs, i.e. ions and free electrons. This means that if the blind holes **16** are made deeper, i.e. larger L in FIG. **1**, then the available gas volume in the blind holes **16** will increase. Accordingly, a signal, representing free electrons, will increase proportionally. The available gas volume is also dependent on the open area, e.g. diameter, of the blind holes **16**.

FIG. **2** schematically illustrates the converter unit **1** of FIG. **1** as seen from the second main side **14**, i.e. the main side comprising the entrances to the blind holes **16**. In this embodiment, the blind holes **16** are arranged in a matrix of a number of rows and columns. In an alternative embodiment, which generally enables smaller distances between adjacent blind holes, the blind holes **16** can be arranged staggered relative to each other as indicated in FIG. **3**. This embodiment generally has a denser arrangement of blind holes **16** and thereby a lower portion of metal material in the portion of the converter plate **10** occupied by the blind holes **16** as compared to the embodiment of FIG. **2**.

The choice of hole pattern is generally a compromise between open area (active gas volume) and the ability to stop lateral electrons and photons. The hole pattern could also be influenced by the available manufacturing methods available for the various metal materials.

The blind holes **16** advantageously have circular cross-sectional area as shown in FIGS. **2** and **3**. However, other cross-sectional configurations are also possible and encompassed by the embodiments, such as quadratic, rectangular, pentagon, hexagon, octagon, elliptic, etc.

Each blind hole **16** in the converter plate **10** can be seen as a gas cylinder having a closed end facing the first main side **12** and an open end at the second main side **14**.

A non-limiting but illustrative example of a converter unit design is to manufacture the converter plate **10** to have thickness T of about 2.5 mm with a blind hole length L of 2 mm and thereby a remaining solid thickness portion W of 0.5 mm. The size of the converter plate **10**, see FIGS. **2** and **3**, could, for instance, be 500×500 mm for height×width. In a particular embodiment, the area of the second main surface **14** occupied by the matrix or pattern of blind holes **16** could be around 400×400 mm. Each blind hole **16** could have an average diameter of about 0.3 mm with an inter-hole distance of about 0.45 mm from center to center (hole pitch). If the embodiment of FIG. **3** is used, i.e. staggered blind holes **16**, then a 60° staggered geometry could be used. The above presented numbers should merely been seen as illustrative example of a typical size for a converter unit **1**. The embodiments are, however, not limited thereto and other dimensions of the converter plate **10** and the blind holes **16** are possible and within the scope of the embodiments.

FIG. **4** is a cross-sectional view of another embodiment of a converter unit **2** according to the embodiments comprising multiple blind holes. In this embodiment, the converter unit **2** is not made of a single, unitary converter plate but rather comprises a converter plate **20** with multiple through holes **26** and a solid converter plate **21**.

The through holes **26** in the converter plate **20** are preferably true through holes **26** and thereby preferably extend through the whole thickness of the converter plate **20**. The solid converter plate **21** is then attached to the converter plate **20** with through holes **26** as a lid for the multiple through holes **26** to thereby form a converter unit **2** with multiple blind holes. Hence, in this embodiment the portion of the converter unit **2** that contains solid converter material is made up of the solid converter plate **21**. The solid converter plate **21** could therefore be regarded as a lid to the through holes **26**. The combination of the solid converter plate **21** and the converter plate **20** with through holes **26** will thereby constitute the converter unit **2** with blind holes.

The solid converter plate **21** comprises a first main side **23** adapted to face the incident photons **100**. A second main side **25** of the solid converter plate **21** opposite to the first main side **23** is attached to the converter plate **21** with the through holes **26**. This means that the second main side **25** of the solid converter plate **21** is attached to a first main side **22** of the converter plate **20** with the through holes **26**. Electrons **110** formed by the converter unit **2** exit from a second, opposite main side **24** of the converter plate **20** with the through holes **26**.

The solid converter plate **21** is preferably attached with an airtight and electrically conducting connection or bond to the converter plate **20** with the through holes **26**. The connection is preferably electrically conducting so that the two converter plates **20**, **21** together form an electrically conducting structure, to which a voltage source can be connected, which is further discussed herein.

The connection is furthermore airtight or, more correctly, preferably gas tight. This means that gas present in through holes **26** is prevented from traveling laterally in the interface between the converter plates **20**, **21**. This in turn reduces the risk of lateral photons and electrons from moving within the converter unit **2** and between adjacent through holes **26**. The connection preferably also prevents formation of any gas pockets between the two converter plates **20**, **21**.

There are various alternatives and variants that can be used in order to achieve an airtight or gastight but still electrically conducting connection between the converter plates **20**, **21**. Non-limiting but preferred examples include using a conductive glue, welding and diffusion bonding. It is also possible to use external mechanical fixtures that tightly interconnect the converter plates **20**, **21** and keep them connected in an airtight and electrically conductive manner.

The two converter plates **20**, **21** can be made of a same metal material or different metal materials. The converter plate **20** with the through holes **26** is preferably made of a metal material as previously discussed for the converter plate **10** of FIG. **1**, i.e. tungsten, tungsten alloys, copper, copper alloys, rhenium, rhenium alloys, molybdenum, molybdenum alloys, tantalum, tantalum alloy, chromium, chromium alloys, iron and iron alloys. Particularly, suitable materials are tungsten and tungsten alloys. The solid converter plate **21** could also be made of a metal material selected from this group of metals and metal alloys. However, it is alternatively possible to manufacture the solid converter plate **21** from a material selected among aluminum, an aluminum alloy and stainless steel.

The converter plate **10** with blind holes **16** in FIG. **1** and the converter plate **20** with through holes **26** in FIG. **2** can be manufactured with conventional machining, for instance, using drills and mills. This production method is particularly suitable for standard metals, e.g. copper, aluminum and stainless steel. High aspect ratio holes **16**, **26** can be achieved as well as blind holes **16** and through holes **26**. Ultrasonic activation of the tools can increase the processing speed and extend the tool life.

Electro Discharge Machining (EDM) can be used as an alternative to conventional machining. EDM generally have similar advantages and constrains but typically somewhat lower processing speed.

Particle beam drilling, e.g. using electrons, is also an option for the metal materials.

Additive layer manufacturing, using metal powder and a laser or an electron beam to form the convert plate structure by precisely, layer by layer, melting the metal powder according to the desired geometry is also possible.

Laser drilling is also feasible for some of the preferred metal materials. A preferred metal material, i.e. tungsten, is typically difficult to laser drill and sufficient hole depth may be hard to achieve using a single converter plate **10**, **20**. One solution is to drill thinner sheets or plates of tungsten and then align and bond the plates together, such as using a diffusion bonding process. Such an approach will be further discussed below in connection with FIG. **5**.

Another manufacture technique that can be applied if using multiple thinner sheets or plates is chemical etching. In order to improve the aspect ratio of the blind or through holes **16**, **26** anisotropic etching, e.g. spray etching, could be utilized.

In the embodiment shown in FIG. **5** the converter unit **2** comprises multiple, i.e. at least two, converter plates **20A**, **20B**, each of which has multiple through holes **26** extending through the whole thickness of respective converter plate **20A**, **20B**. These multiple converter plates **20A**, **20B** are attached together to form a layered structure as shown in the figure. The multiple converter plates **20A**, **20B** are preferably arranged in the resulting layered structure so that the multiple through holes **26** of the converter plates **20A**, **20B** are aligned.

This means that the final blind holes of the converter unit **2** are formed by aligned and corresponding through holes **26** in each converter plate **20A**, **20B** once these are attached to each other in the layered structure as shown in FIG. 5 and the layered structure is attached to the solid converter plate 21.

As is shown in FIG. 5, the second main side 25 of the solid converter plate 21 faces a first main side 22 of a first converter plate 20A with through holes 26. A second, opposite main side 24 of the first converter plate 20B in turn faces a first main side of second converter plate 20B with through holes 26 and so on until reaching the final converter plate with through holes 26 in the stacked or layered structure.

The different converter plates 20A, 20B with through holes 26 can be attached to each other using similar techniques that have been discussed in the foregoing in connection with FIG. 4 and attaching the converter plate 20 with through holes 26 to the solid converter plate 20. This means that the connections between the multiple converter plates 20A, 20B with through holes 26 and between the first converter plate 20A with through holes 26 and the solid converter plate 21 are preferably airtight and electrically conducting connections or bonds. Preferred examples, thus, include using a conductive glue, welding and diffusion bonding. It is also possible to use external mechanical fixtures.

The multiple converter plates 20A, 20B with through holes 26 could all be made of a same metal material. However, it is in fact possible to use different metal materials for different converter plates 20A, 20B with through holes 26. The metal material(s) for the converter plates 20A, 20B with through holes 26 is(are) preferably selected from the group previously discussed herein in connection with FIG. 4.

The embodiments of the converter unit 1, 2 shown in FIGS. 1, 4 and 5 have various degrees of freedom with regard to affecting the formation of electrons and reducing the risk of electron and photon scattering. For instance, the converter unit 1 of FIG. 1 can be designed to be adapted to various applications, such as ranging from MeV to keV applications, by the selection of, for instance, the metal material of the converter plate 10; the geometry of the blind holes 16, such as shape, cross-sectional area, length L and overall pattern, including hole pitch (compare FIGS. 2 and 3); and the thickness W of the solid portion of the converter plate 10.

The converter unit 2 of FIG. 4 has one additional degree of freedom in affecting the operation characteristics of the converter unit 2 since it can use different metal materials for the solid converter plate 21 and the converter plate 20 with through holes 26. The converter unit 2 of FIG. 5 provides further degrees of freedom since it is possible to use different metal materials for different converter plates 20A, 20B with through holes 26.

Thus, the converter unit 1, 2 of the embodiments can easily be designed to be adapted to the particular characteristics that are wanted for a particular application or use of the converter unit 1, 2.

FIG. 6 illustrates yet another embodiment of a converter unit 3 according to the embodiments. This embodiment is similar to FIG. 4 but with the difference that the solid converter plate of FIG. 4 is replaced by an anti-scatter grid 31. Hence, the converter unit 3 comprises a converter plate 30 with multiple through holes 36 and an anti-scatter grid 31 attached to the converter plate 30 as a lid for the through holes 36 to thereby form multiple blind holes of the converter unit 3.

An anti-scatter grid 31 is a device adapted to limit the amount of radiation scatter. It is generally constructed of a series of alternating parallel strips of lead, or another attenuating metal material, and a radiolucent substance, such as a plastic. A primary X-ray beam of photons 100 passes through the radiolucent strips as it travels roughly parallel to them. Scattered radiation, which has deviated from the primary X-ray beam, cannot easily pass through the anti-scatter grid 31 as it encounters the lead strips at an angle and is attenuated or lost from the primary X-ray beam.

The anti-scatter grid 31 has a first main side 33 adapted to face the incident photons 100 and a second main side 35 opposite to the first main side 33 and attached to a first main side 32 of the converter plate 30. A second main side 34 of the converter plate opposite to the first main side 32 is facing the direction in which electrons 110 exit the converter unit 3.

The anti-scatter grid 31 is preferably attached to the converter plate 30 with an airtight and electrically conducting connection. This connection can be in the form of any the embodiments discussed in the foregoing with regard to the connection between the solid converter plate and a converter plate with through holes.

A variant of the converter unit 3 of FIG. 6 is to have the anti-scatter grid 31 and a layered structure of multiple converter plates 30 with through holes 36 as shown in FIG. 5.

In an embodiment, at least a portion of the walls of the blind holes 16 in the converter unit 1, 2, 3 of the embodiments can be coated with a photoelectric converting layer. In addition, or alternatively, at least a portion of the first main side 23 or the second main side 25 of the solid converter plate 21 in FIG. 4 or 5 could be coated with a photoelectric converting layer. In this latter case, it is generally preferred to provide the photoelectric converting layer on at least a portion of the second main side 25 and in particular to at least the portion of the second main side 25 aligned with the through holes 26. This means that the photoelectric converting layer is preferably provided at the bottom of the blind holes. This approach is also possible with the converter unit 1 as shown in FIG. 1 where the photoelectric converting layer can be applied to the bottom of the blind holes 16 in addition to, or alternatively to, on the walls of the blind holes 16.

The photoelectric converting layer(s) can be included in the converter unit 1, 2, 3 in order to customize the conversion efficiency for selected photon energies.

The photoelectric converting layer(s) is(are) typically made of a metal selected among alkali, bi-alkali and multialkali metals. Non-limiting, but preferred examples, include Cs—I, Cs—Te, Na—K—Sb—Cs, Sb—K—Cs, Sb—Rb—Cs and Sb—Cs.

The converter unit of the embodiments is preferably included as a part of a detector. Various detector embodiments incorporating a converter unit will now be further described herein.

An aspect of the embodiments relates to a detector comprising a converter unit of the embodiments, such as any of the converter units 1, 2, 3 discussed in the foregoing in connection with FIGS. 1-6. In this aspect, the detector also comprises an electron amplification device configured to produce further electrons from the electrons exiting the converter unit. The electron amplification device is attached to the converter unit with an electrically isolating connection.

FIG. 7 is a cross-sectional view of a detector 4 according to an embodiment. In the figure, the converter unit 1 has been exemplified by the embodiment as shown in FIG. 1. This should, however, merely be seen as an illustrative but non-limiting example. Any of the other converter unit embodiments, such as shown in FIGS. **4-6** could instead be arranged in the detector **4**.

As is shown in the figure the electron amplification device **40** is preferably arranged attached to the main side **14** of the converter unit **1** comprising the entrances of the blind holes **16**. Thus, the second main side **14** of the converter unit **1**, being opposite to the first main side **12** facing the incident photons **100**, is attached to a first main side **42** of the electron amplification device **40**. Electrons **120**, sometimes denoted secondary electrons in the art, formed in the electron amplification device **40** exit a second, opposite main side **44** of the electron amplification device **40**.

As stated in the foregoing, the converter unit **1** and the electron amplification device **40** are electrically isolated from each other by an electrically isolating connection, bond or layer **50** between these two units. The electrically isolating connection **50** could, for instance, be in the form of an electrically isolating glue or a photo patternable dry film. Further variants include using polyimides, such as Kapton (4,4'-oxydiphenylamine), or FR-4, which is a composite material composed of woven fiberglass cloth with an epoxy resin binder.

The electrical isolation **50** between the converter unit **1** and the electron amplification device **40** implies that a voltage source **52** can be connected to the converter unit **1** and the electron amplification device **40**. The voltage source **52** is thereby adapted to apply a voltage and electric field across the electrical isolation layer **50** that forces electrons present in the blind holes **16** towards the electron amplification device **40**.

Thus, the voltage source **52** provides the driving force (electric field) that directs electrons converted in the converter unit **1** from the incident photons **100** towards the electron amplification device **40**.

The purpose of the electron amplification device **40** is, as its name indicates, to amplify the electron signal exiting the converter unit **1**. Thus, the electron amplification device **40** produces a multiplicity of electrons **120** from the electrons emitted from the converter unit **1**. This multiplicity of electrons **120** then represents a signal proportional to the incident fluence of photons **100**.

A suitable voltage applied by the voltage source **52** could be about 50 V between the converting unit **1** and the electron amplification device **40**. However, the actual voltage value depends on various design aspects, such as the depth of the blind holes **16** in the converter unit **1**.

There are various implementation examples of electron amplification devices **40** that can be used in a detector **4** in order to amplify an input electron signal and output an amplified electron signal. A preferred example is a Gas Electron Multiplier (GEM).

A GEM **40** is, in its most basic design, a thin structure of two metal electrodes with an insulating foil inserted between. The structure is perforated with through holes **46** where the electron multiplication can occur. In a preferred embodiment, a voltage source **54** is connected to the two metal electrodes of the GEM **40** and is adapted to apply a voltage across the metal electrodes. This applied voltage will create large electric fields in the through holes **46**.

In typical implementations, the voltage source **54** could provide a voltage within the range of 150-400 V across the two metal electrodes. This should, however, merely be seen as an illustrative but non-limiting example.

In FIG. **7** the detector **4** has been illustrated with two voltage sources **52**, **54**, one for providing a voltage across the electrically isolating connection **50**, preferably between the converter unit **1** and the metal electrode facing the converter unit **1** and the electrically isolating connection **50**, and one for providing a voltage across the metal electrodes of the GEM **40**. In an alternative embodiment, a single voltage source is used to provide both these voltages, possible in connection with one or more resistors to get the correct voltage values.

In an embodiment, the multiple through holes **46** of the GEM **40** are aligned with the multiple blind holes **16** of the converter unit **1** as schematically indicated in FIG. **8**. In such an embodiment, the diameter or the cross-sectional area of the through holes **46** in the GEM **40** is typically smaller than the corresponding diameter or cross-sectional area of the blind holes **16** in the converter unit **1**.

It is, however, generally not necessary to align the through holes **46** with the blind holes **16**. For instance, by having a GEM **40** with a smaller pitch for the pattern of through holes **46** in the GEM **40** as compared to the converter unit **1** then a certain number of through holes **46** will always match a blind hole **16** in the converter unit **1**. This approach thereby reduces the need for any alignment.

GEMs **40** are well known in the art and there are various documents disclosing GEM examples [1-4].

In some prior art detectors, a stack of multiple GEMs **40** could be used to even further amplify the electron signal. Such an approach is also possible for detector **4** of the embodiments. In such a case, the multiple GEMs **40** could be separated from each other by a respective electrically insulating layer, similar to the electrically insulating layer **50** between the converter unit and the GEM **40** in FIG. **7**. Alternatively, a small gas gap could be present between adjacent GEMs **40**.

Other non-limiting examples of electron amplification devices **40** that can be used in the detector **4** include Micro Channel Plate (MCP), Capillary Plate (CP) and Micro-Mesh Gaseous Structure (MicroMegas).

Generally, a MCP is a slab made from highly resistive material with a regular array of tubes or slots (microchannels) leading from one face to the opposite. These tubes or slots are typically densely distributed over the whole structure. In operation, each microchannel is a continuous-dynode electron multiplier, in which multiplication of electrons takes place under the presence of a strong electric field. An electron or photon entering a microchannel through a small orifice is guaranteed to hit the channel wall since the microchannels are angled to the plate and, thus, angled relative to the angle of impact. The impact between the electron or photon and the channel wall starts a cascade of electrons that propagate through the microchannel. Accordingly, an amplification of the original signal by several orders of magnitude is possible depending on the electric field strength and the geometry of the MCP.

There are variants of MCP in the art that can also be used according to the embodiments, such as chevron MCP and Z stack MCP.

An example of a MCP design is disclosed in a document [5].

A CP is basically a thin plate-like member, in which a plurality of lead glass capillaries constituting a hollow-like shape is integrated. Thin film electrodes are formed on opposite surfaces of the CP. More information of CP design can be found in a document [7].

In a MicroMegas a gas volume is divided in two by a metallic micro-mesh. An electron or photon passing through the MicroMegas will ionize gas atoms by puling up an electron creating an electron-ion pair. By applying an electric field the electron will drift toward the micro-mesh operating as amplification electrode. When the electron enters close to the micro-mesh it enters an intense electric field. Accelerated by this high electric field, the electron reaches enough energy produce electron-ion pairs that will also ionize the gas causing an avalanche effect.

In operation, electrons formed in the converter unit **1** and having sufficient low energy will directly be captured by the electric field and transported towards the electron amplification device **40**. An optional photoelectric converting layer on the surfaces defining the blind holes **16** increases the amount of such low energy electrons since the preferred alkali, bi-alkali and multialkali metals of the photoconverting layer are ionized at lower energies as compared to the preferred materials of the converter plate(s).

Electrons with higher energy and photons will typically not follow the electric field but will instead form ion tracks in the gas present in the blind holes forming electron-ion pairs. The free electrons of the electron-ion pairs generally have low energy and will therefore be transported by the electric field towards the electron amplification device **40**. In this case, the blind holes **16** will operate as ionization chambers and the amount of formed electrons will be substantially proportional to the total gas volume in the blind holes.

The sum of the low energy electrons generated as described above will be amplified by the electron amplification device **40**.

In an embodiment, the detector **5** also comprises a readout device **60** adapted to generate a signal representative of the incident photons **100** in addition to the previously described converter unit **1** having multiple blind holes **16** and the electron amplification device **40** as shown in FIG. **9**.

The readout device **60** is preferably arranged with a small gas gap **58** between the electron amplification device **40** and the readout device **40**. It is, however, also possible to attach the readout device **60** to the main side of the electron amplification device **40** facing away from the converter unit **1**. In such a case, an electrically isolating connection is employed, similar to the electrically isolating connection **50** between the converter unit **1** and the electron amplification device **40**.

The small gas gap **58** could be in the range of about one or a few millimeters for most practical implementations.

In a preferred embodiment, a voltage source **56** is connected to the electron amplification device **40** and the readout device **60**. This voltage source **56** is adapted to apply a voltage and thereby generate an electric field across the gas gap **58** to force electrons **120** exiting the electron amplification towards the readout device **60** for detection therein.

If the electron amplification device **40** is implemented by a GEM **40**, the voltage source **56** is preferably connected between the metal layer of the GEM **40** facing the readout device **60** and the readout device **60**.

In FIG. **9** three separate voltage sources **52, 54, 56** have been illustrated. In alternative embodiments, it could be sufficient to only use one or two voltage sources, possible together with one or more resistors, to provide the correct voltages and electric fields across the electrically isolating layer **50**, across the electron amplification device **40** and across the gas gap **58**.

In an embodiment, the readout device **60** is configured to generate a signal representative of an X-ray transmission image of an object based on detection of electrons **120**. In this embodiment, the detector **5** is preferably in the form an X-ray detector **5** that can be used to generate an image of an object, such as a patient or a portion of a patient's body. The input photons **100** could then be from a diagnostic X-ray source or indeed from a therapeutic radiation source to be used to irradiate the patient, e.g. irradiate a tumor in the patient's body. This latter case is generally referred to as portal imaging in the art.

An example of a readout device **60** that can be used according to the embodiments is a two-dimensional (2D) charge sensitive device. There are various such 2D charge sensitive devices available in the art including, for instance, a thin-film transistor (TFT) panel.

Other possible readout devices **60** that can be used in the detector **5** include direct readout, for instance, through metallized pixels and stacked printed circuit boards (PCBs) with edge patterned pixels [6]. Further examples are also discussed in document [4], see for instance section 2.1.4 Electronic readout system.

In an embodiment, the pattern formed by the blind holes **16** in the converter unit **1**, see FIGS. **2** and **3**, preferably has at least substantially a same resolution as the readout device **60**.

In the above described embodiment, the detector **5** is preferably in the form of an X-ray detector configured to generate a signal representative of an X-ray transmission image based on the incident X-ray beam(s) of photons **100**. The embodiments are, however, not limited thereto but can alternatively be used for other detection purposes and detector implementations. For instance, in an embodiment the readout device **60** of the detector **5** is configured to generate a signal representative of an absolute radiation dose of the incident photons **100** by detection of electrons **120** exiting the converter unit **1** and the electron amplification device **40**. Hence, in this embodiment the detector **5** is employed for measuring radiation doses. The detector **5** could then, for instance, be employed for radiation machine quality assurance as well as verification of treatment plans.

The detector **6** preferably comprises a detector housing **70** as shown in FIG. **10**. In such a case, the detector housing **70** comprises the converter unit **1**, the electron amplification device **40** and preferably also the readout device **60**. These units **1, 40, 60** could be fully encompassed within the detector housing **70** as shown in FIG. **10**. In an alternative approach as shown in FIG. **11**, the detector housing **80** of the detector **7** at least partly encloses the converter unit **1**, the electron amplification device **40** and preferably the readout device **60**. For instance, the first main side of the converter unit **1** facing the incident photons could extend outside of the detector housing **80**, which is then typically connected to the end side(s) of the converter unit **1**. Correspondingly or alternatively, the main side of the readout device **60** facing away from the incident photons and electrons could be present outside of the detector housing **80**.

It is, however, generally preferred if the detector housing **70, 80** at least encloses portions of the converter unit **1** and the readout device **60** so that the blind holes, the electron amplification device **40** and the gap between the electron amplification device **40** and the readout device **60** will be present within the detector housing **70, 80**.

The detector housing **70, 80** is preferably filled with a gas. This means that this gas will be present in the blind holes of the converter unit **1** and preferably also within the through holes of the electron amplification device **40** and in the gap between the electron amplification device **40** and the readout device **60**.

Various gases, including gas mixtures, are possible and can be used according to the embodiments. Non-limiting examples include argon, xenon, carbon dioxide, dimethyl ether (DME) and mixtures thereof. However, other quenching gases or penning mixtures are possible.

In FIGS. 7, 9-10 the detector 4-7 has been illustrated as comprising the converter unit 1 and an electron amplification device 40 in addition to a preferred readout device 60. In another approach, the electron amplification device 40 could be emitted. Hence, another aspect of the embodiments relates to a detector comprising a converter unit according to the embodiments and a readout device configured to generate a signal representative of the incident photons. In such an embodiment, the converter unit and the readout device are preferably arranged in a detector, such as at least partly within a detector housing, with a small gas gap between the converter unit and the readout device. A voltage source is preferably connected to the converter unit and the readout device across the gas gap in order to force electrons formed in the converter unit towards the readout device for detection therein.

Though, this aspect of the detector works it is generally preferred to include an electron amplification device as discussed in the foregoing in order to achieve an amplification of the electrons prior to detection thereof by the readout device.

The drawings of the converter unit and detector of the embodiments should be regarded as schematic representations of various implementation embodiments. Hence, the drawings are not intended to show the including units and devices in any particular scales or relative sizes.

The embodiments described above are to be understood as a few illustrative examples of the present invention. It will be understood by those skilled in the art that various modifications, combinations and changes may be made to the embodiments without departing from the scope of the present invention. In particular, different part solutions in the different embodiments can be combined in other configurations, where technically possible. The scope of the present invention is, however, defined by the appended claims.

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[3] International application no. WO 2007/061235
[4] Janina Östling, New Efficient Detector for Radiation Therapy Imaging using Gas Electron Multipliers, Doctorial Thesis, Stockholm, 2006
[5] U.S. Pat. No. 8,134,129
[6] U.S. Pat. No. 6,841,784
[7] Iacobaeous et al., Study of capillary-based gaseous detectors, *IEEE T. Nucl. Sci.* 51(3): Part 1, June 2004

The invention claimed is:

1. A detector comprising:

a metal converter unit adapted to convert incident photons into electrons and comprising multiple blind holes forming respective ionization chambers,

wherein said multiple blind holes extend from a surface of the converter unit through a portion of a thickness of said converter unit but do not extend through a whole thickness of said converter unit,

wherein said multiple blind holes have a cross-sectional configuration selected from a group consisting of circular, quadratic, pentagon, hexagon, octagon and elliptic cross-sectional configurations, and

wherein said multiple blind holes are filled with gas; and

an electron amplification device adapted to produce further electrons from said electrons and comprising multiple through holes,

wherein at least a portion of said multiple through holes are aligned with said multiple blind holes, and

wherein said electron amplification device is attached to said converter unit with an electrically isolating connection.

2. The detector according to claim 1, wherein said multiple blind holes are arranged in said converter unit to have a respective longitudinal axis substantially parallel to a normal of a main side of said converter unit.

3. The detector according to claim 1, wherein at least a portion of walls of said multiple blind holes is coated with a photoelectric converting layer.

4. The detector according to claim 3, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of an alkali metal, a bi-alkali metal and a multialkali metal.

5. The detector according to claim 3, wherein said photoelectric converting layer is made of a metal selected from a group consisting of Cs—I, Cs—Te, Na—K—Sb—Cs, Sb—K—Cs, Sb—Rb—Cs and Sb—Cs.

6. The detector according to claim 1, wherein said converter unit is in a form of a single, unitary converter plate comprising said multiple blind holes extending through a portion of a thickness of said converter plate but not extending through a whole thickness of said converter plate.

7. The detector according to claim 6, wherein said converter plate comprises:

a first main side adapted to face said incident photons; and

a second main side opposite to said first main side and comprising entrances of said multiple blind holes.

8. The detector according to claim 6, wherein said converter plate is made of a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys.

9. The detector according to claim 1, wherein the converter unit comprises:

a converter plate with multiple through holes; and

a solid converter plate, wherein said solid converter plate is attached to said converter plate with said multiple through holes as a lid for said multiple through holes to form said multiple blind holes.

10. The detector according to claim 9, wherein said solid converter plate comprises:

a first main side adapted to face said incident photons; and

a second main side opposite to said first main side and attached to said converter plate with multiple through holes.

11. The detector according to claim 10, wherein at least a portion of at least one of said first main side and said second main side is coated with a photoelectric converting layer.

12. The detector according to claim 11, wherein at least a portion of said second main side aligned with said through holes is coated with said photoelectric converting layer.

13. The detector according to claim 11, wherein said photoelectric converting layer is a made of a metal selected from a group consisting of an alkali metal, a bi-alkali metal and a multialkali metal.

14. The detector according to claim 13, wherein said photoelectric converting layer is made of a metal selected from a group consisting of Cs—I, Cs—Te, Na—K—Sb—Cs, Sb—K—Cs, Sb—Rb—Cs and Sb—Cs.

15. The detector according to claim 9, wherein said solid converter plate is attached with an airtight and electrically conducting connection to said converter plate with multiple through holes.

16. The detector according to claim 15, wherein said solid converter plate is attached to said converter plate with

multiple through holes by means of at least one of a group consisting of a conductive glue, welding and a diffusion bonding.

17. The detector according to claim 9, wherein

said converter plate with multiple through holes is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys; and

said solid converter plate is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron, iron alloys, aluminium, an aluminium alloy and stainless steel.

18. The detector according to claim 9, wherein the converter unit comprises multiple converter plates, wherein each converter plate of said multiple converter plates has multiple through holes, wherein

said multiple converter plates are attached together to form a layered structure in which said multiple through holes of said multiple converter plates are aligned, and

said solid converter plate is attached to said layered structure as a lid for said multiple through holes to form said multiple blind holes.

19. The detector according to claim 1, wherein the converter unit comprises:

a converter plate with multiple through holes; and

an anti-scatter grid, wherein said anti-scatter grid is attached to said converter plate as a lid for said multiple through holes to form said multiple blind holes.

20. The detector according to claim 19, wherein said anti-scatter grid comprises:

a first main side adapted to face said incident photons; and

a second main side opposite to said first main side and attached to said converter plate.

21. The detector according to claim 19, wherein said anti-scatter grid is attached with an airtight and electrically conducting connection to said converter plate.

22. The detector according to claim 21, wherein said anti-scatter grid is attached to said converter plate by means of at least one of a group consisting of a conductive glue and a diffusion bond.

23. The detector according to claim 19, wherein said converter plate is made from a metal material selected from a group consisting of tungsten, a tungsten alloy, copper, a copper alloy, rhenium, a rhenium alloy, molybdenum, a molybdenum alloy, tantalum, a tantalum alloy, chromium, chromium alloys, iron and iron alloys.

24. The detector according to claim 1, wherein said converter unit comprises:

a first main side adapted to face said incident photons; and

a second main side opposite to said first main side and comprising entrances of said multiple blind holes, wherein said electron amplification device is attached to said second main side.

25. The detector according to claim 1, further comprising a voltage source connected to said converter unit and said electron amplification device and adapted to force electrons present in said multiple blind holes towards said electron amplification device.

26. The detector according to claim 1, wherein said electrically isolating connection is selected from a group consisting of an electrically isolating glue, a photo patternable dry film and a polyimide.

27. The detector according to claim 1, wherein said electron amplification device is selected from a group consisting of a Gas Electron Multiplier, GEM; a Micro Channel Plate, MCP; a Capillary Plate, CP; and a Micro-Mesh Gaseous Structure, MicroMegas.

28. The detector according to claim 27, wherein said electron amplification device is a GEM.

29. The detector according to claim 1, further comprising a readout device adapted to generate a signal representative of said incident photons.

30. The detector according to claim 29, further comprising a voltage source connected to said electron amplification device and said readout device and adapted to force electrons exiting said electron amplification device towards said readout device.

31. The detector according to claim 29, wherein said readout device is arranged with a gas gap between said electron amplification device and said readout device.

32. The detector according to claim 29, wherein said readout device is adapted to generate a signal representative of an X-ray transmission image of an object based on detection of electrons.

33. The detector according to claim 32, wherein said readout device is a two-dimensional charge sensitive device.

34. The detector according to claim 33, wherein said two-dimensional charge sensitive device is a thin-film transistor, TFT, panel.

35. The detector according to claim 29, wherein said readout device is adapted to generate a signal representative of an absolute radiation dose of said photons based on detection of electrons.

36. The detector according to claim 29, wherein a pattern formed by said blind holes in said converter unit has at least substantially a same resolution as said readout device.

37. The detector according to claim 1, further comprising a detector housing comprising said electron amplification device and at least a portion of said converter unit, wherein said detector housing is filled with a gas and said gas is present in said blind holes.

38. The detector according to claim 37, wherein said gas is selected from a group consisting of argon, xenon, carbon dioxide, dimethyl ether or mixtures thereof.

39. The detector according to claim 1, wherein said multiple blind holes have a circular cross-sectional configuration.

40. The detector according to claim 1, wherein said multiple blind holes have a hexagonal cross-sectional configuration.

41. The detector according to claim 1, wherein each of said multiple blind holes has a length through the portion of the thickness of said converter unit which is greater than any width dimension of the blind hole.

42. A detector comprising:

a metal converter unit adapted to convert incident photons into electrons, the metal converter unit comprising a first metal converter plate with multiple through holes and a second metal converter plate closing the multiple through holes at a photon-receiving end of the converter unit to form multiple blind holes serving as respective ionization chambers,

wherein said multiple blind holes extend from a surface of the converter unit through a portion of a thickness of said converter unit but do not extend through a whole thickness of said converter unit,

wherein said multiple blind holes have a cross-sectional configuration selected from a group consisting of circular, quadratic, pentagon, hexagon, octagon and elliptic cross-sectional configurations, and

wherein said multiple blind holes are filled with gas; and

an electron amplification device adapted to produce further electrons from said electrons and comprising multiple through holes,

wherein at least a portion of said multiple through holes of the electron amplification device are aligned with said multiple blind holes, and

wherein said electron amplification device is attached to said converter unit with an electrically isolating connection.

43. The detector according to claim **42**, wherein the first metal converter plate and the second metal converter plate are formed as a single unitary piece.

44. The detector according to claim **42**, wherein the first metal converter plate and the second metal converter plate are formed as separate pieces and are attached with an airtight and electrically conducting connection.

45. The detector according to claim **42**, wherein the electrically isolating connection comprises an electrically isolating layer arranged between the second plate of the converter unit and a surface of the electron amplification device.

46. The detector according to claim **7**, wherein the electrically isolating connection comprises an electrically isolating layer arranged between the second main side of the converter unit and a surface of the electron amplification device.

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(54) IONIZING RADIATION DETECTING DEVICE

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(57) ABSTRACT

The inventionrelates to a detecting unit for detecting ionizing radiation. The device comprises a converter unit for the amplification of ionizing radiation and a read-out unit, wherein the converter unit comprises a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface anda stack of accelerator plates in contact with the electron-emitting major side, wherein said stack comprises a plurality of perforated accelerator plates wherein the perforations of the perforated accelerator plates are aligned to forma matrix of blind holes.

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Fig. 1d)

25
7
1
9

23
27
Fig. lc)

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' 3k:fO:ete; Kb i•J4j. 57

CC2

1: ·

Fig. 2a)

-- :::1 4 Tmin

43 39

.4..0. :

Ot:0:40:

Jb.4.<94.444

49

63

41 51

Fig. 2b)

43

Å

-800 V

55

55 55n-1 55n

1147.53

-600V

s-s1,s,esse,sLIssILsles.+IsnilLsoississILs-1.s-LissILsisnIss

-300V

65

45

OV

61

47

D 65 73

551

52

Fig. 2d)

67

fy, i

69

87

67

roa IM

79

111513111916Y

55n-1

MIM .1119 eiii th:NN

fr msFJP AMM FIK WE r."151

55n

le> /lekleMitSkV'

NEM \

87

4

5

83

Fig. 2c)

81

8

5

7

1

7

8

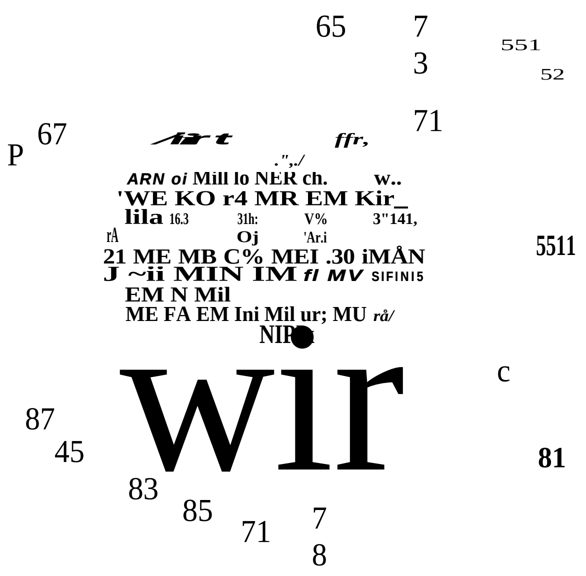

Fig. 3

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IONIZING RADIATION DETECTING DEVICE

TECHNICAL FIELD

[0001] The present invention relates to a detecting device for ionizing radiation, converter units for such devices, as weil as converters and gas electron multipliers for such converter units.

BACKGROUND OF THE INVENTION

[0002] In the medical field ionizing radiation has many diagnostic and therapeutic uses . It can be used for imaging the body of a patient for example to detect tumors and it can also be used for the treatment of a patient for example to irradiate detected tumors. In order to obtain good resolution images and accurately placed treatment it is necessary to detect the ionizing radiation after it has passed through the body being examined or treated and then process the signals obtained for the detecting means. The signals can be proces sed to obtain an image which represents the body through which it has passed and/or which represents the distribution of the ionizing radiation. In general the term "imaging" means forming an image of the measured data, and the term "dosimetry" measurement of the absorbed dose due to incident ionizing radiation.

[0003] In order to detect in real time the intensity and spatial distribution of incoming ionizing radiation such as high energy photons generated in X-ray imaging or treatment devices, digital detecting units have been developed which convert the incoming radiation, for example photons, into electrons. This can be achieved by electromagnetic interaction with the photons and maner which can cause some of the energy of the photon to be transferred to the maner anda free electron to be excited. Devices within a detecting unit which achieve this effect are called converters. Solid converters rely on the interaction of the incident photons with a solid sheet of material to generate electrons by the Compton Effect or pair production. Gas converters rely on the interaction of incident photons with a gas in a chamber to generate electrons. An example of a prior art unit is known from PCT patent application W02007/061235. A simplified example of a digital detecting unit (1) is shown in FIGS. la) to 1d). This device comprises a housing **(3)** (shown in dashed lines) filled with a gas **(16).** The housing contains a converter **(5),** a GEM **(7)** separated from the converter by a gas filled gap of depth G, and a read-out unit **(9).** The converter is formed from a substrate of metal **(11).** The substrate has a first major face (13) which faces incident ionizing radiation I. This incident radiation causes the formation of electrons in the substrate and these electrons travel through the substrate towards the second major face (15) of the substrate. Electrons which pass through the substrate and impact with the gas molecules in the gas-filled gap cause ionization of the gas molecules and the production of secondary electrons. These electrons need to be multiplied in order to achieve a detectable signal. One way of performing electron multiplication is by providing a micropattem gas amplification device (MPGAD) such a gas-electron multiplier (GEM) **(7)** of the type developed by CERN, separated from the second major face of the converter by the gas-filled gap of depth G. The GEM compri ses a thin, insulating, perforated gas electron multiplication foil **(17).** Typically the foil is made of an insulating substrate **(19)** of polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kapton®", that is coated on both major sides (21,23) with a coating (25,27) made of a conducting material such as copper. The perforations in the foil form a regular matrix **(29)** of GEM through holes (31) which extend between the major sides (21, 23) and which form a grid of equidistantly-spaced GEM through holes over substantially the whole of the major surfaces. A potential difference can be placed across the coatings (25, 27) thereby generating an electric field in the GEM through holes which electrical field guides electrons from the converter into the GEM through holes **(19).** The electrical field generated in the gas in the through holes initiates electron avalanches which increase the munber of electrons leaving each through hole. The number of electrons generated in the avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by processing signals generated in the read-out unit which could be, for example a thin film transistor. The electrical fields necessary to ensure the electrons are guided to the read-out unit can be achieved by connecting the converter to a high negative potential, for example —700 V, the upper surface of the GEM to a medium negative potential, for example —600 V, the lower surface of the GEM to a lower negative potential e.g. —300V and the read-out unit to ground. In order to achieve a large amplification of the electrons leaving the converter it is necessary to have a large potential difference between the converter and the GEM. However if the potential difference is too high then there is a risk of electrical discharges in the form of sparking between the converter and the GEM.

[0004] A problem with the prior art devices is that high energy electrons which leave the electron-emitting face of the converter with a large lateral vector will collide with many gas molecules as they travel laterally in the gas gap between the converter and the GEM. These gas molecules will generate electrons, some of which will travel to the GEM and be multiplied by the GEM in a through hole which is not directly under the arrive point of the incident ionizing radiation on the first major face of the substrate which gave rise to the high energy electron and thus will an erroneous position of the incident ionizing radiation when they are detected by the read-out unit. These give rise to errors in the signals produced by the rad-out unit and lead to decreased accuracy and resolution in images of the incident radiation

[0005] Another problem which can occur is that a large GEM acts as a capacitor which leads to unwanted electrical fields and the possibility of dangerous charges becoming stored in the device.

BRIEF DESCRIPTION OF THE INVENTION

[0006] The present invention relates to detecting devices which comprise a converter unit which overcomes one or more of the problems in the prior art by providing a new type of converter and a GEM matched to the converter. in one embodiment of the invention this is achieved by matching the position of the through holes in the GEM with the positions of the blind holes in the converter to reduce the risk of electrical discharges between these two components. In a further embodiment of the invention a reduction in the risk of discharges between the two components is achieved by dividing the copper coatings on the GEM into segments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG, la) shows schematically a view from above of a detecting unit according to the prior art.

[0008] FIG. 1b) shows schematically a section through line A-A of the unit of FIG. la).

[0009] FIG, le) shows schematically an enlargement of part of the section of FIG. ib).

[0010] FIG. 1d) shows schematically the view from line B-B of FIG. 1c).

[0011] FIG. 2a) shows schematically a view from above of an embodiment of an detecting unit according to the present invention.

[0012] FIG. 2b) shows schematically a section through line C-C of the unit of FIG. 2a).

[0013] FIG. 2c) shows schematically an enlargement of part of the section of FIG. 2b).

[0014] FIG. 2d) shows schematically the view from line D-D of FIG. le).

[0015] FIG. 3 shows schematically a view corresponding to that of FIG. 2c) for another embodiment of a digital detecting unit in accordance with the present invention.

[0016] FIG. 4 shows a view from below of a further embodiment of a GEM according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] An example of a detecting unit (39) in accordance with an embodiment of the present invention is shown in FIGS. 2a) to 2d). This detecting unit (39) comprises a housing (41), shown by dashed lines, containing a converter unit (comprising a converter (43), a gas-electron multiplier (GEM) (45)), anda read-out unit (47) which generates signals relating to the position and intensity of electrons which interact with it. Signals generated in the read-out unit can be collected by a signal processing system (not shown) which may convert the signals into images. The housing is filled by a gas (49). Preferably the gas is a mixture of gases, preferably a Penning gas mixture, for example a mixture of argon-xenon or neon-argon.

[0018] The converter (43) is formed of a solid substrate (51) anda stack (53) formed of a plurality of perforated accelerator plates (55'-55"), which have their perforations (57) aligned to forma regular matrix (59) of gas-filled blind holes (61). The solid substrate is made of a suitable metal, for example tungsten, chromium, copper, rhenium, molybdenum, tantalum, iron, steel, or made of an alloy of such metals. It has a height h, width w and length 1, and has an ionizing radiation-receiving major surface (63) upon which ionizing radiation I may be incident, and an electron-emitting major surface (65) from which electrons may be emitted.

[0019] In the embodiment of a converter shown in FIGS. 2a) to 2d) the electron-emitting major surface (65) of the converter is in electrically-insulated contact with the stack (53) of perforated accelerator plates (55'-55'). FIG. 3 shows an alternative arrangement of a converter according to the present invention in which a non-perforated plate (55), preferably made of the same material as the accelerator plates or a material with a similar coefficient of expansion as the accelerator plates, is provided between the electron-emitting major surface (65) of the substrate and the stack of accelerator plates. This non-perforated plate is in electrical contact with the substrate and is electrically insulated from the stack and serves to reduce mechanical stress at the interface between the bulk of the converter and the stack when the device heats up during use. In all other respects the converter shown in FIG. 3 is identical to that of FIG. 2 and the same references number are used to represent identical features in both embodiments.

[0020] Preferably in all embodiments of a converter according to the present invention the number n of accelerator plates is greater than or equal to 2 and less than or equal to 100. More preferably the number n of accelerator plates is greater or equal to 10 and less than or equal to 50. Most preferably the number n of accelerator plates is greater or equal to 15 and less than or equal to 30. The accelerator plates are made of conducting material, preferably a metat such as stainless steel, which is sufficiently dense and thick enough to attenuate and/or absorb scattered electrons which have a significant lateral vector. The individual accelerator plates that form the stack may be joined together by electrostatic forces of attraction and/or by an adhesive which may be provided completely or partly over the contact area between adjacent plates. The stack may be connected to the electron-emitting major surface of the substrate by any of the methods used to join the accelerator plates together. Mechanical fasteners or clamps may also be used to hold the accelerator plates together and/or the accelerator plates to the substrate.

[0021] The arrangement of the blind holes in the matrix may be quadratic (as shown in the figures)—where each hole (except of course the holes nearest the edges of the plates) is surrounded by four equally spaced holes, or staggered—where each blind hole is surrounded by six equally spaced blind holes. Preferably the blind holes have a diameter Dl which is equal to or greater than 0.3 mm and less than or equal to 0.5 mm. The distance between centers CC1 of the blind holes is preferably equal to or greater than 0.45 mm and equal to or less than 0.65 mm, while at the same time the minimum wall thickness Tmin between the blind holes should be equal to or greater than 0.1 mm to ensure attenuation of laterally moving high energy electrons. Thickness Tmin should be less lan or equal to 0.5 mm to ensure that the resolution of the device is adequate. Preferably Tmin is equal to or greater than 0.15 and equal to or less than 0.25 mm.

[0022] Insulation (67) in the form of a conformal insulating coating, e.g. vapor deposited poly(p-xylylene) polymer such as "Parylene"0, or an insulating film or insulating layer is provided on the accelerator plates to insulate them from one another. Insulation further covers the longitudinally-extending cylindrical surfaces (69) of the blind holes and reflects low energy electrons which contact the cylindrical surfaces back into the through holes. The exposed portion (71) of the electron-emitting major surface which forms the closed end (73) of each blind hole is not electrically insulated and, when connected to a negative potential, serves to attract and neutralize the positive ions formed in the through holes thus preventing these ions from reacting with and neutralizing the electrons leaving the substrate. Other arrangement to attract and neutralize positive ions are also possible, for example a portion of the longitudinally extending wall of each blind hole may be uninsulated, thereby providing a portion of the surface which can attract and neutralize positive ions.

[0023] Preferably each accelerator plate has a thickness p which is equal to or greater than 0.05 mm and equal to or less than 0.2 mm. More preferably each plate has a thickness of 0.1 mm+/-0.01 mm. The substrate and each acceleration plate are provided with a respective electrical contact (not shown). These are connectable to an electrical supply (not shown) which is arranged to form an electrical field which increases from negative to positive in the direction from the substrate to the distal accelerator plate (55") in order to accelerate electrons toward the open ends of the blind holes. Preferably the electrical field strength along the blind holes is equal to or greater than 0.5 kV/cm and is less than or equal to 2 kV/cm. More preferably the field strength is 1 kV/cm+/-0.1 kV/cm. For example, if the stack of thickness 2 min is made of 20 accelerator plates and 20 layers of insulation, then the average thickness per layer of the stack is 0.1 mm and the potential difference between each adjacent accelerator plate of the stack should be in the order of 10 V. For example if the converter is held at a voltage of —800 y then the first accelerator plate (551) would be at a voltage of —790 V and the last accelerator plate at a voltage of —600V. The use of a plurality of accelerator plates permits the establishment of a powerful electrical field though substantially the whole length of each blind hole.

[0024] The electrical field in the blind holes can be shaped by adjusting the potential difference between each pair of accelerator plates. In one example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the same, i.e. the potential difference drops linearly along the length of a blind hole from the do sed end to the open end.

[0025] In another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is not the same. e.g. the potential difference drops non-linearly along the length of a blind hole from the closed end to the open end. This non-linearity could be in the form of a small voltage drop between arranged between the first accelerator plate (551) and the second accelerator plate (552), a larger voltage drop between the second accelerator plate (552) and the third accelerator plate (553), and so on, wherein the voltage drop between each pair of accelerator plates reaches a maximum between the penultimate accelerator plate (55"-1) and the last accelerator plate (55").

[0026] In yet another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the opposite, i.e. the voltage drop is arranged to be largest between the first accelerator plate (551) and the second accelerator plate (552), and smallest between the penultimate accelerator plate (55"-') and the last accelerator plate (55").

[0027] In a further example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is arranged to be how between the first accelerator plate (551) and the second accelerator plate (552), raising to a peak between two intermediate accelerator plates and then falling to a lower potential difference between the penultimate accelerator plate (55"1) and the last accelerator plate (55").

[0028] Incident ionizing radiation, for example photons, is directed to the radiation-receiving major surface of the substrate and generates electrons which enter the closed ends **(73)** of the blind holes. Electrons which are travelling substantially parallel to the axis of the holes pass though the blind holes and cause ionization of the gas molecules thereby producing secondary electrons. High energy electrons which have significant lateral vectors will pass through the insulation of the cylindrical surfaces of the blind holes and will be absorbed or attenuated by the material of the accelerator plates thus reducing the erroneous effects of these electrons. The electrons leaving the gas-filled blind holes in the direction towards the GEM need to be multiplied in order to achieve a detectable signal. This is achieved by providing a potential difference across the GEM. Preferably this potential difference is equal to or greater than 40 kV/cm and equal to or less than 80 kV/cm.

[0029] Any prior art GEM of appropriate size and performance may be used with the converter but in the embodiment of a digital detecting unit according to the invention shown in FIGS. 2a) to 2d) a new type of GEM may be used. An example of such a new GEM (45) comprises a thin, insulating, perforated gas electron multiplication foil **(77).** The foil is made of an insulating core substrate **(78)** of, for example, polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kaptong", and is coated on both major sides **(79, 81)** with a coating (83, 85) made of a conducting material such as copper. The perforations in the foil form GEM through holes **(87)** which extend between the major sides **(79, 81).** Preferably the GEM substrate has a thickness k equal to or greater than 40 gm and equal to or less than 60 gm and preferably is 50 gm+/-2 gm. Preferably the conducting material has a thickness c equal to or greater than 3 gm and equal to or less than 7 gm and preferably is 5 gm+/-1 gm. The GEM through holes **(87)** extend between the major sides of the GEM and have their longitudinal axis parallel with the longitudinal axis of the blind holes in the accelerator plates.

[0030] Contrary to the prior art wherein the GEM through holes are evenly distributed, the GEM through holes are arranged as regularly spaced-apart groups **(89)** of GEM through holes wherein each group compri ses a number M, for example, M=3 as shown in FIGS. 2a)-2d), of GEM through holes, wherein M preferably is greater or equal to 1 and less than or equal to 20. Preferably the groups of GEM through holes are arranged in a matrix at a centre-to-centre distance CC2 which corresponds to the centre-to-centre distance CC1 between the blind holes and each group of GEM through holes is arranged aligned with a respective blind hole. Such groups of GEM through holes, called "active GEM through holes" in the following, act to multiply incoming electrons. It is possible that for production reasons additional groups of GEM through holes may be provided which are not aligned with the blind holes. Such GEM through holes are not intended to multiply incoming electrons and are called "surplus GEM through holes" in the following. Preferably the GEM through holes have a nominal diameter Di greater or equal to 10 gm and less than or equal to 100 gm. More preferably the GEM through holes have a nominal diameter greater than or equal to 30 gm and less than or equal to 90 pm. Even more preferably the GEM through holes have a nominal diameter greater than or equal to 50 gm and less than or equal to 70 gm. Preferably the GEM through holes comprises in a group of GEM through holes have a centre-to-centre spacing CC3 equal to or greater than 20 pm and less than or equal to 200 gm. More preferably the GEM through holes in a group have a centre-to-centre spacing equal to or greater than 50 gm and less than or equal to 180 gm. Most preferably the GEM throughholes in a group haven centre-to-centre spacing CC3 which is equal to or greater than 100 gm and less than or equal to 160 gm. Even more preferably the centre-to-centre spacing CC3 is 140 gm+/-2 pm. Preferably every blind hole in the converter leads to a respective group of active GEM through holes.

[0031] When a potential difference is provided between the coatings (83, 85) of the GEM by means of the power supply an electric field is generated in the GEM through holes. In order to prevent unwanted di scharges between the edge of any GEM through hole and the edge of the open end of a blind hole in an accelerator plate of the converter, the groups of GEM through holes are arranged so that the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate (55") and the closest point of the circumference of a GEM through hole is preferably equal to or greater than 20 gm. More preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (55') and the closest point of the circumference of a GEM through hole is equal to or greater than 40 gm. Even more preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (55") and the closest point of the circumference of a GEM throughhole is equal to or greater than 50 gm. The use of a annular region of radial width R in which no GEM through holes are permitted means that in comparison to a prior art GEM with equally distributed GEM blind holes the voltage difference between the converter and the GEM can be increased compared to that used in the prior art. This increase in potential difference may allow a greater electrical field strength and better multiplication of the electrons entering the electrical field.

[0032] As an illustrative example of an embodiment of the invention, blind holes of diameter 0.4 min in a converter are arranged at a centre to centre distance CC1 of 0.5 mm, i.e. the minimum wall thickness between the blind holes would be 0.1 mm. Each group of GEM through holes contains a plurality of GEM through holes of diameter 50 gm. The centre to centre distance of the groups of GEM through holes would be the same as CC1 i.e. it would be 0.5 mm. If the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate and the closest point of the circumference of a GEM through hole is made equal to 50 gm then the centers of the GEM through holes may not be doser than 75 gm to the circumference of the nearest blind hole in the distal accelerator plate. This means that the diameter of the group of GEM through holes, i.e. the diameter of a circle enclosing the group of GEM through holes, would be equal to 0.4 mm—(2x50 gm)=0.3 mm. In the case of a matrix in which the groups of through holes are aligned in a quadratic formation this would mean that each group of GEM through holes would be separated from the nearest neighboring group of GEM through holes by a region devoid of through holes which isa minimum of 0.2 mm wide. Preferably the diameter of a group of GEN through holes is less than or equal to 0.6 mm and greater than or equal to 0.2 mm. More preferably the diameter of a group of GEN through holes is less than or equal to 0.4 mm and greater than or equal to 0.25 mm.

[0033] The electrical field generated in the gas in the GEM through holes initiates electron avalanches which increases the number of electrons leaving each hole. The number of electrons generated in an electron avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by the read-out unit (47) which is of conventional design and not described further. Signals regarding the position and intensity of the incident radiation generated in the read-out unit can be collected by a signal processing system (not shown) which converts the signals into images.

[0034] FIG. 4 shows a view from below of further GEM (359) in accordance with the invention. The conducting coating (373) of this visible lower major surface of the GEM is divided into a number Q of electrically-unconnected regions (3751-375e) by a plurality of grooves (377'-377(')) each of which extend from edge to edge across the surface and which extend through the surface to the underlying electrically insulating substrate. The grooves may be formed by removing conducting coating from the respective surface or, when applying the coating, by preventing coating from being appliecl where the grooves are to be positioned. These electrically-unconnected regions may each form a capacitor but the total capacitance of the GEM is less than that which would be formed if the conducting coating covered the maj or surface as a continuous coating.

[0035] In a further embodiment of a GEM in accordance with the invention the conducting coating of the upper major surface of the GEM is divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.

[0036] In a another further embodiment of a GEM in accordance with the invention both the conducting coating of the upper major surface and the lower major surface of the GEM are divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.

[0037] The invention is not to be seen as limited by the preferred embodiments described above, but may be varied within the scope of the appended claims as is readily apparent to the person skilled in the art. The various embodiments can be combined with each other in any suitable manner.

What is claimed is:

1. Detecting device for detecting ionizing radiation compri sing a converter unit for amplifying ionizing radiation and a read-out unit, wherein the converter unit comprises a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates wherein perforations of the perforated accelerator plates are aligned with each other and are distributed to forma matrix of blind holes.

2. Detecting device according to claim 1 wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein said groups are aligned with a respective blind hole.

3. Detecting device according to claim 1 wherein the gas-electron multiplier comprises a first major surface and a seeond major surface made of a conducting material and wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

4. Detecting device according to claim 1 wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein both of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

5. Detecting device according to claim 1 wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole anda closest point of the circumference of a GEM through hole is equal to or greater than 40 gm.

6. Detecting device according to claim 1 wherein the diameter of each blind hole is equal to or greater than 0.3 mm and less than or equal to 0.5 mm.

6-17. (canceled)

18. Detecting device according to claim 2 wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and

wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

19. Detecting device according to claim **2** wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein both of said first and second maj or surfaces is formed as a plurality of electrically unconnected regions.

20. Detecting device according to claim **2** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole and a closest point of the circumference of a GEM through hole is equal to or greater than **40** gm.

21. Detecting device according to claim **2** wherein the diameter of each blind hole is equal to or greater than 0.3 mm and less than or equal to 0.5 mm.

22. Converter unit comprising a converter anda gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates, wherein perforations of the perforated accelerator plates are aligned to form a matrix of blind holes.

23. Converter unit according to claim **22** wherein a surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions.

24. Converter unit according to claim **22** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of a GEM through hole is equal to or greater than 20 gm.

25. Converter unit according to claim **22** wherein said gas -electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of a GEM through hole is equal to or greater than 40 gm.

26. Converter unit according to claim **22** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole anda closest point of a circumference of a GEM through hole is equal to or greater than 50 gm.

27. Converter for converting ionizing radiation wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates wherein perforations of the perforated accelerator plates are aligned to forma matrix of blind holes.

28. Converter according to claim **27** wherein a surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions.

29. Converter unit according to claim **23** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole anda closest point of a circumference of a GEM through hole is equal to or greater than 20 gm.

30. Converter unit according to claim **23** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole anda closest point of a circumference of a GEM through hole is equal to or greater than 40 gm.

31. Converter unit according to claim **23** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole anda closest point of a circumference of a GEM through hole is equal to or greater than 50 gm.

32. Detecting device according to claim **1** wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein each of said groups of GEM through holes are aligned with a respective blind hole; wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material; wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions compri sing pairs of adjacent electrically unconnected regions with a groove between each pair of adjacent electrically unconnected regions; and wherein said grooves are not in contact with any GEM through holes.

33. Converter unit according to claim **22** wherein said gas-electron multiplier comprises a matrix formed of a plurality of group s of GEM through holes wherein each of said groups of GEM through holes are aligned with a respective blind hole; wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material; wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions compri sing pairs of adjacent electrically unconnected regions with a groove between each pair of adjacent electrically unconnected regions; and wherein said grooves are not in contact with any GEM through holes.

* * * * *

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Maad et al.

(10) **Patent No.: US 9,880,291 B2**
(45) **Date of Patent: Jan. 30, 2018**

(54) **IONIZING RADIATION DETECTING DEVICE**

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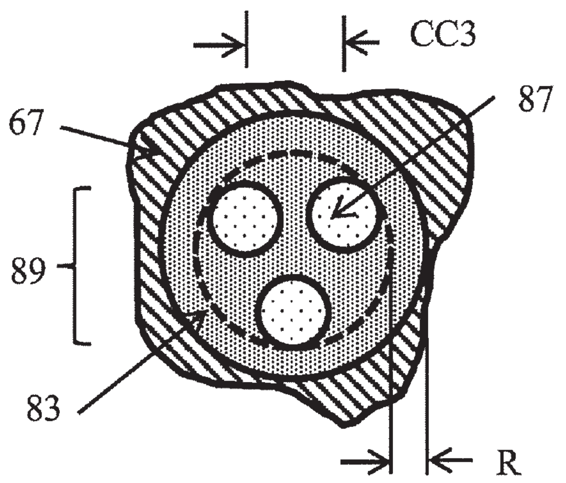
(57) **ABSTRACT**

The invention relates to a detecting unit for detecting ionizing radiation. The device comprises a converter unit for the amplification of ionizing radiation and a read-out unit, wherein the converter unit comprises a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major side, wherein said stack comprises a plurality of perforated accelerator plates wherein the perforations of the perforated accelerator plates are aligned to form a matrix of blind holes.

27 Claims, 4 Drawing Sheets



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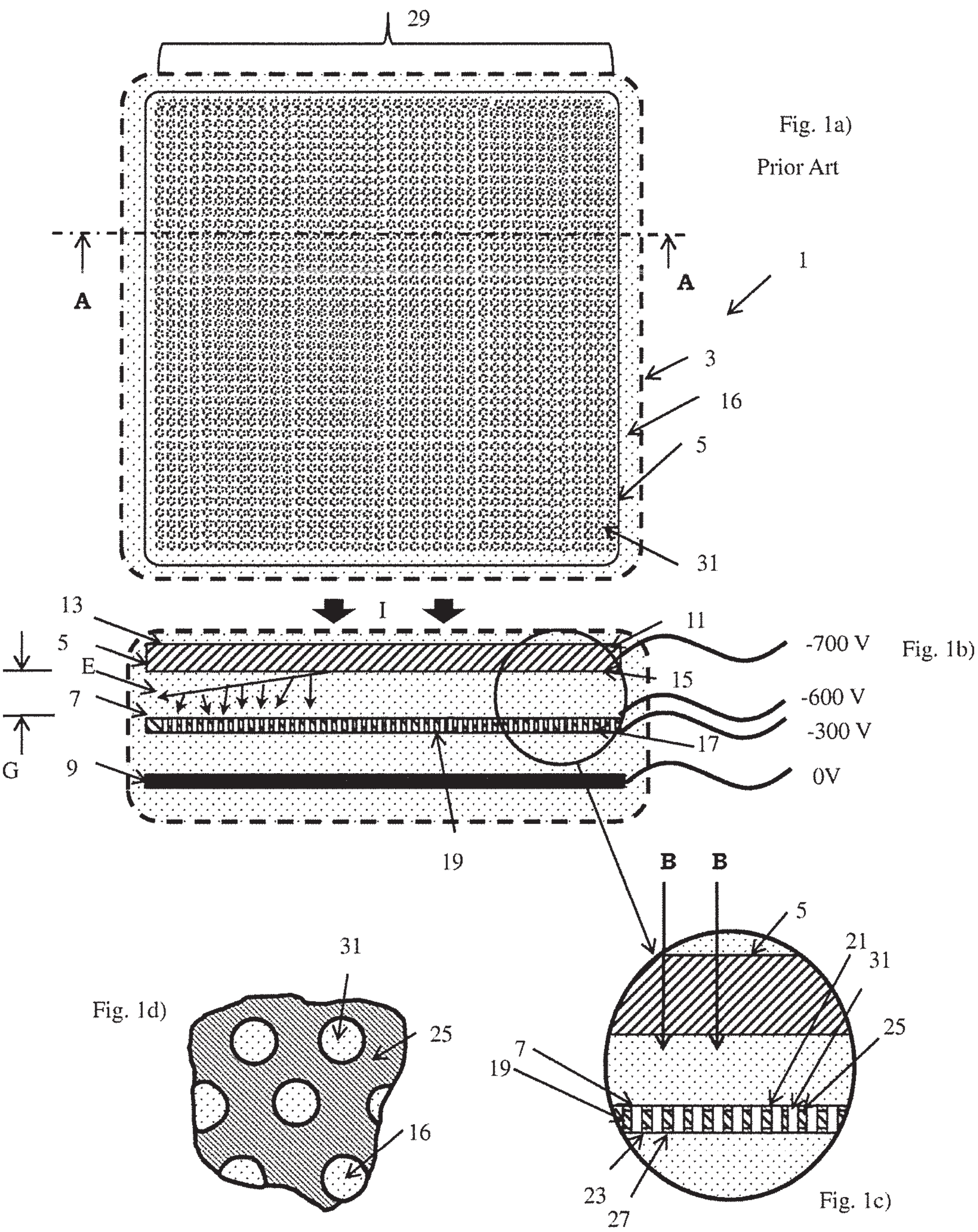


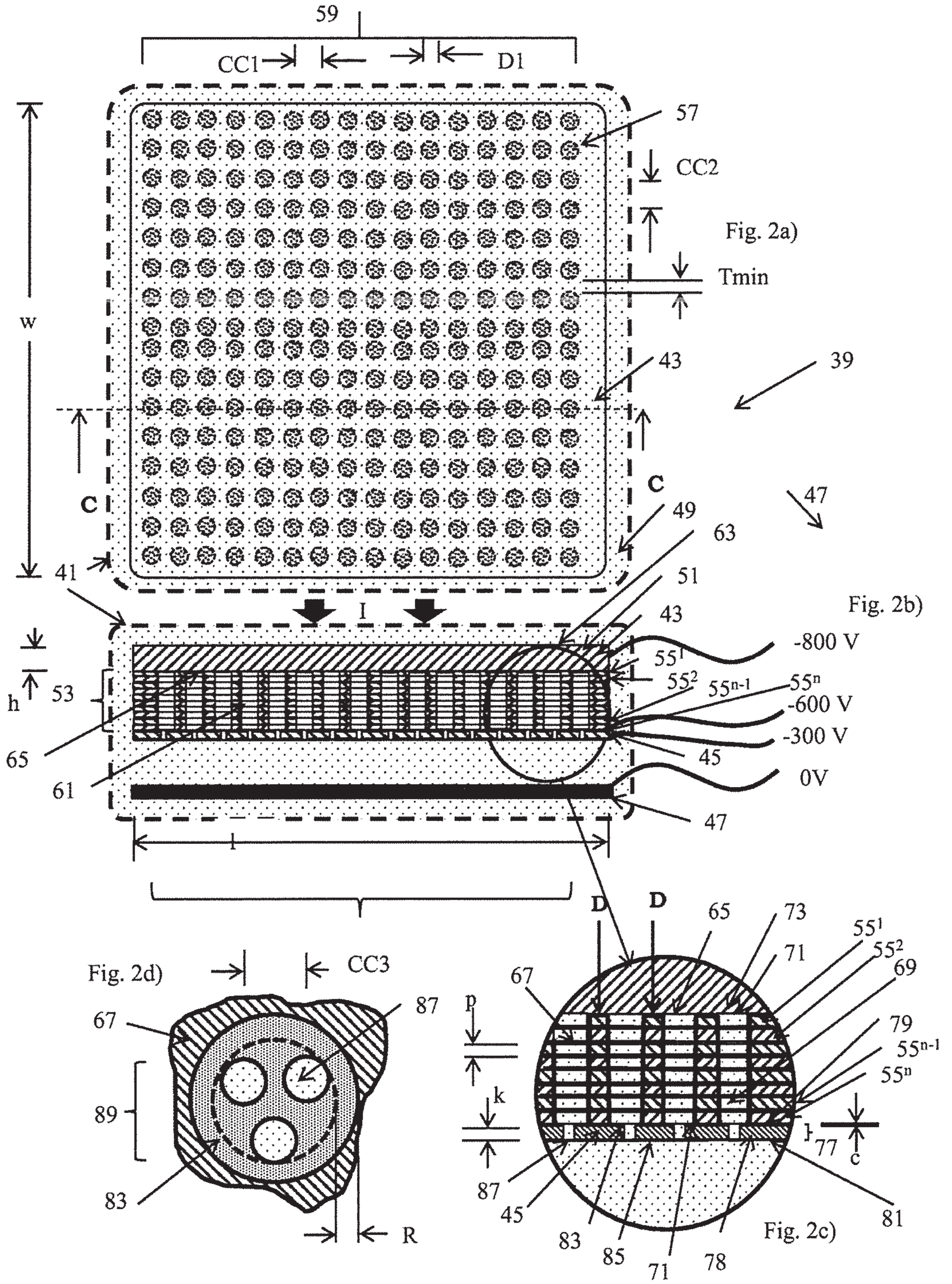
Fig. 1a)

Prior Art

Fig. 1b)

Fig. 1c)

Fig. 1d)


59
CC1
D1
57
CC2
Fig. 2a)
Tmin
w
43
39
C
C
47
49
63
41
51
I
43
Fig. 2b)
-800 V
55¹
55²
55ⁿ⁻¹
55ⁿ
-600 V
-300 V
h
53
65
45
61
0V
47
l
Fig. 2d)
CC3
87
67
89
83
R
D
D
65
73
55¹
55²
71
69
67
p
79
55ⁿ⁻¹
55ⁿ
k
77
c
87
45
83
85
71
78
81
Fig. 2c)

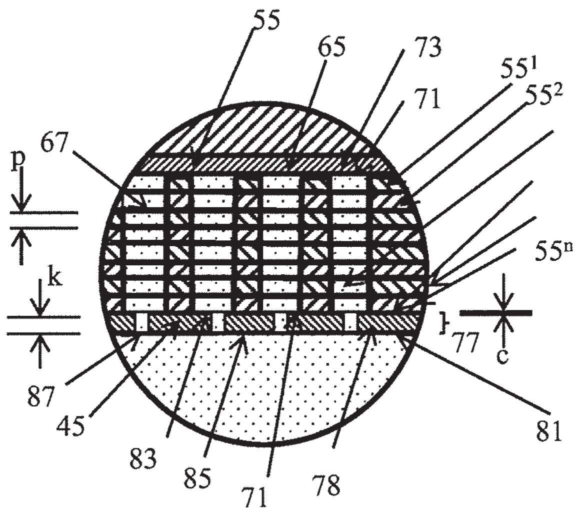


Fig. 3

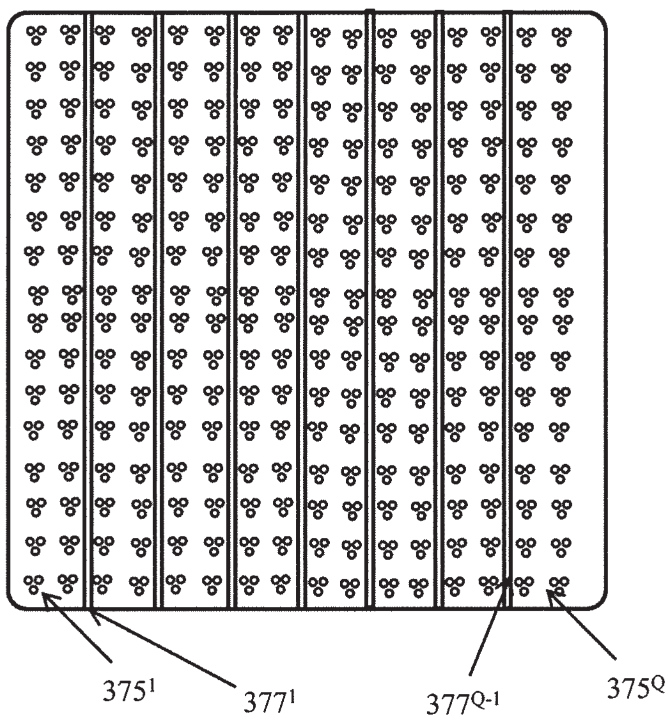


Fig. 4

IONIZING RADIATION DETECTING DEVICE

TECHNICAL FIELD

The present invention relates to a detecting device for ionizing radiation, converter units for such devices, as well as converters and gas electron multipliers for such converter units.

BACKGROUND OF THE INVENTION

In the medical field ionizing radiation has many diagnostic and therapeutic uses. It can be used for imaging the body of a patient for example to detect tumors and it can also be used for the treatment of a patient for example to irradiate detected tumors. In order to obtain good resolution images and accurately placed treatment it is necessary to detect the ionizing radiation after it has passed through the body being examined or treated and then process the signals obtained for the detecting means. The signals can be processed to obtain an image which represents the body through which it has passed and/or which represents the distribution of the ionizing radiation. In general the term "imaging" means forming an image of the measured data, and the term "dosimetry" measurement of the absorbed dose due to incident ionizing radiation.

In order to detect in real time the intensity and spatial distribution of incoming ionizing radiation such as high energy photons generated in X-ray imaging or treatment devices, digital detecting units have been developed which convert the incoming radiation, for example photons, into electrons. This can be achieved by electromagnetic interaction with the photons and matter which can cause some of the energy of the photon to be transferred to the matter and a free electron to be excited. Devices within a detecting unit which achieve this effect are called converters. Solid converters rely on the interaction of the incident photons with a solid sheet of material to generate electrons by the Compton Effect or pair production. Gas converters rely on the interaction of incident photons with a gas in a chamber to generate electrons. An example of a prior art unit is known from PCT patent application WO2007/061235. A simplified example of a digital detecting unit (**1**) is shown in FIGS. **1***a*) to **1***d*). This device comprises a housing (**3**) (shown in dashed lines) filled with a gas (**16**). The housing contains a converter (**5**), a GEM (**7**) separated from the converter by a gas filled gap of depth G, and a read-out unit (**9**). The converter is formed from a substrate of metal (**11**). The substrate has a first major face (**13**) which faces incident ionizing radiation I. This incident radiation causes the formation of electrons in the substrate and these electrons travel through the substrate towards the second major face (**15**) of the substrate. Electrons which pass through the substrate and impact with the gas molecules in the gas-filled gap cause ionization of the gas molecules and the production of secondary electrons. These electrons need to be multiplied in order to achieve a detectable signal. One way of performing electron multiplication is by providing a micropattern gas amplification device (MPGAD) such as a gas-electron multiplier (GEM) (**7**) of the type developed by CERN, separated from the second major face of the converter by the gas-filled gap of depth G. The GEM comprises a thin, insulating, perforated gas electron multiplication foil (**17**). Typically the foil is made of an insulating substrate (**19**) of polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kapton®", that is coated on both major sides (**21**, **23**) with a coating (**25**, **27**) made of a conducting material such as copper. The perforations in the foil form a regular matrix (**29**) of GEM through holes (**31**) which extend between the major sides (**21**, **23**) and which form a grid of equidistantly-spaced GEM through holes over substantially the whole of the major surfaces. A potential difference can be placed across the coatings (**25**, **27**) thereby generating an electric field in the GEM through holes which electrical field guides electrons from the converter into the GEM through holes (**19**). The electrical field generated m the gas in the through holes initiates electron avalanches which increase the number of electrons leaving each through hole. The number of electrons generated in the avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by processing signals generated in the read-out unit which could be, for example a thin film transistor. The electrical fields necessary to ensure the electrons are guided to the read-out unit can be achieved by connecting the converter to a high negative potential, for example −700 V, the upper surface of the GEM to a medium negative potential, for example −600 V, the lower surface of the GEM to a lower negative potential e.g. −300 V and the read-out unit to ground. In order to achieve a large amplification of the electrons leaving the converter it is necessary to have a large potential difference between the converter and the GEM. However, if the potential difference is too high then there is a risk of electrical discharges in the form of sparking between the converter and the GEM.

A problem with the prior art devices is that high energy electrons which leave the electron-emitting face of the converter with a large lateral vector will collide with many gas molecules as they travel laterally in the gas gap between the converter and the GEM. These gas molecules will generate electrons, some of which will travel to the GEM and be multiplied by the GEM in a through hole which is not directly under the arrive point of the incident ionizing radiation on the first major face of the substrate which gave rise to the high energy electron and thus will an erroneous position of the incident ionizing radiation when they are detected by the read-out unit. These give rise to errors in the signals produced by the rad-out unit and lead to decreased accuracy and resolution in images of the incident radiation

Another problem which can occur is that a large GEM acts as a capacitor which leads to unwanted electrical fields and the possibility of dangerous charges becoming stored in the device.

BRIEF DESCRIPTION OF THE INVENTION

The present invention relates to detecting devices which comprise a converter unit which overcomes one or more of the problems in the prior art by providing a new type of converter and a GEM matched to the converter. In one embodiment of the invention this is achieved by matching the position of the through holes in the GEM with the positions of the blind holes in the converter to reduce the risk of electrical discharges between these two components. In a further embodiment of the invention a reduction in the risk of discharges between the two components is achieved by dividing the copper coatings on the GEM into segments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1***a*) shows schematically a view from above of a detecting unit according to the prior art.

FIG. 1*b*) shows schematically a section through line A-A of the unit of FIG. 1*a*).

FIG. 1*c*) shows schematically an enlargement of part of the section of FIG. 1*b*).

FIG. 1*d*) shows schematically the view from line B-B of FIG. 1*c*).

FIG. 2*a*) shows schematically a view from above of an embodiment of an detecting unit according to the present invention.

FIG. 2*b*) shows schematically a section through line C-C of the unit of FIG. 2*a*).

FIG. 2*c*) shows schematically an enlargement of part of the section of FIG. 2*b*).

FIG. 2*d*) shows schematically the view from line D-D of FIG. 1*c*).

FIG. 3 shows schematically a view corresponding to that of FIG. 2*c*) for another embodiment of a digital detecting unit in accordance with the present invention.

FIG. 4 shows a view from below of a further embodiment of a GEM according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

An example of a detecting unit (**39**) in accordance with an embodiment of the present invention is shown in FIGS. 2*a*) to 2*d*). This detecting unit (**39**) comprises a housing (**41**), shown by dashed lines, containing a converter unit (comprising a converter (**43**), a gas-electron multiplier (GEM) (**45**)), and a read-out unit (**47**) which generates signals relating to the position and intensity of electrons which interact with it. Signals generated in the read-out unit can be collected by a signal processing system (not shown) which may convert the signals into images. The housing is filled by a gas (**49**). Preferably the gas is a mixture of gases, preferably a Penning gas mixture, for example a mixture of argon-xenon or neon-argon.

The converter (**43**) is formed of a solid substrate (**51**) and a stack (**53**) formed of a plurality of perforated accelerator plates (55^1-55^n), which have their perforations (**57**) aligned to form a regular matrix (**59**) of gas-filled blind holes (**61**). The solid substrate is made of a suitable metal, for example tungsten, chromium, copper, rhenium, molybdenum, tantalum, iron, steel, or made of an alloy of such metals. It has a height h, width w and length l, and has an ionizing radiation-receiving major surface (**63**) upon which ionizing radiation I may be incident, and an electron-emitting major surface (**65**) from which electrons may be emitted.

In the embodiment of a converter shown in FIGS. 2*a*) to 2*d*) the electron-emitting major surface (**65**) of the converter is in electrically-insulated contact with the stack (**53**) of perforated accelerator plates (55^1-55^n). FIG. 3 shows an alternative arrangement of a converter according to the present invention in which a non-perforated plate (**55**), preferably made of the same material as the accelerator plates or a material with a similar coefficient of expansion as the accelerator plates, is provided between the electron-emitting major surface (**65**) of the substrate and the stack of accelerator plates. This non-perforated plate is in electrical contact with the substrate and is electrically insulated from the stack and serves to reduce mechanical stress at the interface between the bulk of the converter and the stack when the device heats up during use. In all other respects the converter shown in FIG. 3 is identical to that of FIG. 2 and the same references number are used to represent identical features in both embodiments.

Preferably in all embodiments of a converter according to the present invention the number n of accelerator plates is greater than or equal to 2 and less than or equal to 100. More preferably the number n of accelerator plates is greater or equal to 10 and less than or equal to 50. Most preferably the number n of accelerator plates is greater or equal to 15 and less than or equal to 30. The accelerator plates are made of conducting material, preferably a metal such as stainless steel, which is sufficiently dense and thick enough to attenuate and/or absorb scattered electrons which have a significant lateral vector. The individual accelerator plates that form the stack may be joined together by electrostatic forces of attraction and/or by an adhesive which may be provided completely or partly over the contact area between adjacent plates. The stack may be connected to the electron-emitting major surface of the substrate by any of the methods used to join the accelerator plates together. Mechanical fasteners or clamps may also be used to hold the accelerator plates together and/or the accelerator plates to the substrate.

The arrangement of the blind holes in the matrix may be quadratic (as shown in the figures)—where each hole (except of course the holes nearest the edges of the plates) is surrounded by four equally spaced holes, or staggered—where each blind hole is surrounded by six equally spaced blind holes. Preferably the blind holes have a diameter D1 which is equal to or greater than 0.3 mm and less than or equal to 0.5 mm. The distance between centers CC1 of the blind holes is preferably equal to or greater than 0.45 mm and equal to or less than 0.65 mm, while at the same time the minimum wall thickness Tmin between the blind holes should be equal to or greater than 0.1 mm to ensure attenuation of laterally moving high energy electrons. Thickness Tmin should be less than or equal to 0.5 mm to ensure that the resolution of the device is adequate. Preferably Tmin is equal to or greater than 0.15 and equal to or less than 0.25 mm.

Insulation (**67**) in the form of a conformal insulating coating, e.g. vapor deposited poly(p-xylylene) polymer such as "Parylene"®, or an insulating film or insulating layer is provided on the accelerator plates to insulate them from one another. Insulation further covers the longitudinally-extending cylindrical surfaces (**69**) of the blind holes and reflects low energy electrons which contact the cylindrical surfaces back into the through holes. The exposed portion (**71**) of the electron-emitting major surface which forms the closed end (**73**) of each blind hole is not electrically insulated and, when connected to a negative potential, serves to attract and neutralize the positive ions formed in the through holes thus preventing these ions from reacting with and neutralizing the electrons leaving the substrate. Other arrangement to attract and neutralize positive ions are also possible, for example a portion of the longitudinally extending wall of each blind hole may be uninsulated, thereby providing a portion of the surface which can attract and neutralize positive ions.

Preferably each accelerator plate has a thickness p which is equal to or greater than 0.05 mm and equal to or less than 0.2 mm. More preferably each plate has a thickness of 0.1 mm+/−0.01 mm. The substrate and each acceleration plate are provided with a respective electrical contact (not shown). These are connectable to an electrical supply (not shown) which is arranged to form an electrical field which increases from negative to positive in the direction from the substrate to the distal accelerator plate (**55**^{n}) in order to accelerate electrons toward the open ends of the blind holes. Preferably the electrical field strength along the blind holes is equal to or greater than 0.5 kV/cm and is less than or equal to 2 kV/cm. More preferably the field strength is 1 kV/cm+/−0.1

kV/cm. For example, if the stack of thickness 2 mm is made of 20 accelerator plates and 20 layers of insulation, then the average thickness per layer of the stack is 0.1 mm and the potential difference between each adjacent accelerator plate of the stack should be in the order of 10 V. For example if the converter is held at a voltage of −800 V, then the first accelerator plate (55^1) would be at a voltage of −790 V and the last accelerator plate at a voltage of −600V. The use of a plurality of accelerator plates permits the establishment of a powerful electrical field though substantially the whole length of each blind hole.

The electrical field in the blind holes can be shaped by adjusting the potential difference between each pair of accelerator plates. In one example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the same, i.e. the potential difference drops linearly along the length of a blind hole from the closed end to the open end.

In another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is not the same, e.g. the potential difference drops non-linearly along the length of a blind hole from the closed end to the open end. This non-linearity could be in the form of a small voltage drop between arranged between the first accelerator plate (55^1) and the second accelerator plate (55^2), a larger voltage drop between the second accelerator plate (55^2) and the third accelerator plate (55^3), and so on, wherein the voltage drop between each pair of accelerator plates reaches a maximum between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

In yet another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the opposite, i.e. the voltage drop is arranged to be largest between the first accelerator plate (55^1) and the second accelerator plate (55^2), and smallest between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

In a further example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is arranged to be low between the first accelerator plate (55^1) and the second accelerator plate (55^2), raising to a peak between two intermediate accelerator plates and then falling to a lower potential difference between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

Incident ionizing radiation, for example photons, is directed to the radiation-receiving major surface of the substrate and generates electrons which enter the closed ends (**73**) of the blind holes. Electrons which are travelling substantially parallel to the axis of the holes pass though the blind holes and cause ionization of the gas molecules thereby producing secondary electrons. High energy electrons which have significant lateral vectors will pass through the insulation of the cylindrical surfaces of the blind holes and will be absorbed or attenuated by the material of the accelerator plates thus reducing the erroneous effects of these electrons. The electrons leaving the gas-filled blind holes in the direction towards the GEM need to be multiplied in order to achieve a detectable signal. This is achieved by providing a potential difference across the GEM. Preferably this potential difference is equal to or greater than 40 kV/cm and equal to or less than 80 kV/cm.

Any prior art GEM of appropriate size and performance may be used with the converter but in the embodiment of a digital detecting unit according to the invention shown in FIGS. **2***a*) to **2***d*) a new type of GEM may be used. An example of such a new GEM (**45**) comprises a thin, insulating, perforated gas electron multiplication foil (**77**). The foil is made of an insulating core substrate (**78**) of, for example, polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kapton®", and is coated on both major sides (**79**, **81**) with a coating (**83**, **85**) made of a conducting material such as copper. The perforations in the foil form GEM through holes (**87**) which extend between the major sides (**79**, **81**). Preferably the GEM substrate has a thickness k equal to or greater than 40 μm and equal to or less than 60 μm and preferably is 50 μm+/−2 μm. Preferably the conducting material has a thickness c equal to or greater than 3 μm and equal to or less than 7 μm and preferably is 5 μm+/−1 μm. The GEM through holes (**87**) extend between the major sides of the GEM and have their longitudinal axis parallel with the longitudinal axis of the blind holes in the accelerator plates.

Contrary to the prior art wherein the GEM through holes are evenly distributed, the GEM through holes are arranged as regularly spaced-apart groups (**89**) of GEM through holes wherein each group comprises a number M, for example, M=3 as shown in FIGS. **2***a*)-**2***d*), of GEM through holes, wherein M preferably is greater or equal to 1 and less than or equal to 20. Preferably the groups of GEM through holes are arranged in a matrix at a centre-to-centre distance CC**2** which corresponds to the centre-to-centre distance CC**1** between the blind holes and each group of GEM through holes is arranged aligned with a respective blind hole. Such groups of GEM through holes, called "active GEM through holes" in the following, act to multiply incoming electrons. It is possible that for production reasons additional groups of GEM through holes may be provided which are not aligned with the blind holes. Such GEM through holes are not intended to multiply incoming electrons and are called "surplus GEM through holes" in the following. Preferably the GEM through holes have a nominal diameter Di greater or equal to 10 μm and less than or equal to 100 μm. More preferably the GEM through holes have a nominal diameter greater than or equal to 30 μm and less than or equal to 90 μm. Even more preferably the GEM through holes have a nominal diameter greater than or equal to 50 μm and less than or equal to 70 μm. Preferably the GEM through holes comprises in a group of GEM through holes have a centre-to-centre spacing CC**3** equal to or greater than 20 μm and less than or equal to 200 μm. More preferably the GEM through holes in a group have a centre-to-centre spacing equal to or greater than 50 μm and less than or equal to 180 μm. Most preferably the GEM through holes in a group have a centre-to-centre spacing CC**3** which is equal to or greater than 100 μm and less than or equal to 160 μm. Even more preferably the centre-to-centre spacing CC**3** is 140 μm+/−2 μm. Preferably every blind hole in the converter leads to a respective group of active GEM through holes.

When a potential difference is provided between the coatings (**83**, **85**) of the GEM by means of the power supply an electric field is generated in the GEM through holes. In order to prevent unwanted discharges between the edge of any GEM through hole and the edge of the open end of a blind hole in an accelerator plate of the converter, the groups of GEM through holes are arranged so that the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate (55^n) and the closest point of the circumference of a GEM through hole is preferably equal to or greater than 20 μm. More preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (55^n) and the closest point of the circumference of a GEM through hole is equal to or greater than 40 μm. Even more preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (**55"**) and the closest point of the circumference of a GEM through hole is equal to or greater than 50 μm. The use of a annular region of radial width R in which no GEM through holes are permitted means that in comparison to a prior art GEM with equally distributed GEM blind holes the voltage difference between the converter and the GEM can be increased compared to that used in the prior art. This increase in potential difference may allow a greater electrical field strength and better multiplication of the electrons entering the electrical field.

As an illustrative example of an embodiment of the invention, blind holes of diameter 0.4 mm in a converter are arranged at a centre to centre distance CC**1** of 0.5 mm, i.e. the minimum wall thickness between the blind holes would be 0.1 mm. Each group of GEM through holes contains a plurality of GEM through holes of diameter 50 μm. The centre to centre distance of the groups of GEM through holes would be the same as CC**1** i.e. it would be 0.5 mm. If the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate and the closest point of the circumference of a GEM through hole is made equal to 50 μm then the centers of the GEM through holes may not be closer than 75 μm to the circumference of the nearest blind hole in the distal accelerator plate. This means that the diameter of the group of GEM through holes, i.e. the diameter of a circle enclosing the group of GEM through holes, would be equal to 0.4 mm−(2×50 μm)=0.3 mm. In the case of a matrix in which the groups of through holes are aligned in a quadratic formation this would mean that each group of GEM through holes would be separated from the nearest neighboring group of GEM through holes by a region devoid of through holes which is a minimum of 0.2 mm wide. Preferably the diameter of a group of GEN through holes is less than or equal to 0.6 mm and greater than or equal to 0.2 mm. More preferably the diameter of a group of GEN through holes is less than or equal to 0.4 mm and greater than or equal to 0.25 mm.

The electrical field generated in the gas in the GEM through holes initiates electron avalanches which increases the number of electrons leaving each hole. The number of electrons generated in an electron avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by the read-out unit (**47**) which is of conventional design and not described further. Signals regarding the position and intensity of the incident radiation generated in the read-out unit can be collected by a signal processing system (not shown) which converts the signals into images.

FIG. **4** shows a view from below of further GEM (**359**) in accordance with the invention. The conducting coating (**373**) of this visible lower major surface of the GEM is divided into a number Q of electrically-unconnected regions (**375^1-375^Q**) by a plurality of grooves (**377^1-$377^{(Q-1)}$**) each of which extend from edge to edge across the surface and which extend through the surface to the underlying electrically insulating substrate. The grooves may be formed by removing conducting coating from the respective surface or, when applying the coating, by preventing coating from being applied where the grooves are to be positioned. These electrically-unconnected regions may each form a capacitor but the total capacitance of the GEM is less than that which would be formed if the conducting coating covered the major surface as a continuous coating.

In a further embodiment of a GEM in accordance with the invention the conducting coating of the upper major surface of the GEM is divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.

In a another further embodiment of a GEM in accordance with the invention both the conducting coating of the upper major surface and the lower major surface of the GEM are divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.

The invention is not to be seen as limited by the preferred embodiments described above, but may be varied within the scope of the appended claims as is readily apparent to the person skilled in the art. The various embodiments can be combined with each other in any suitable manner.

What is claimed is:

1. Detecting device for detecting ionizing radiation comprising a converter unit for amplifying electrons emitted due to the ionizing radiation and a read-out unit, wherein the converter unit comprises a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates, each perforated accelerator plate provided with an insulating layer to insulate each perforated accelerator plate from one another in order to be able to provide separate potential to each perforated accelerator plate, wherein perforations of the perforated accelerator plates are aligned with each other and are distributed to form a matrix of blind holes; and

wherein said gas-electron multiplier comprises a matrix formed of a plurality of regularly spaced apart groups of GEM through holes wherein each group comprises between one and twenty GEM through holes and wherein a longitudinal axis of the center of each of said groups of GEM through holes is aligned with a longitudinal axis of a respective one of said blind holes, and

a surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions.

2. Detecting device according to claim **1** wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

3. Detecting device according to claim **1** wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein both of said first and second major surfaces are formed as a plurality of electrically unconnected regions.

4. Detecting device according to claim **1** wherein a minimum radial distance between a circumference of a blind hole and a closest point of the circumference of the nearest GEM through hole is equal to or greater than 40 μm.

5. Detecting device according to claim **1** wherein the diameter of each blind hole is equal to or greater than 0.3 mm and less than or equal to 0.5 mm.

6. Detecting device according to claim **1**, wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

7. Detecting device according to claim **1**, wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein both of said first and second major surfaces are formed as a plurality of electrically unconnected regions.

8. Detecting device according to claim **1**, wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of GEM through holes wherein a minimum radial distance between a circumference of a blind hole and a closest point of the circumference of the nearest GEM through hole is equal to or greater than 40 μm.

9. Detecting device according to claim **1**, wherein the diameter of each blind hole is equal to or greater than 0.3 mm and less than or equal to 0.5 mm.

10. Detecting device according to claim **1** each of said groups of GEM through holes are aligned with a respective blind hole; wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material;

wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions comprising pairs of adjacent electrically unconnected regions with a groove between each pair of adjacent electrically unconnected regions; and wherein said grooves are not in contact with any GEM through holes.

11. Detecting device according to claim **1**, wherein every blind hole is aligned with a group of GEM through holes.

12. Detecting device according to claim **1**, wherein a diameter of each group of GEM through holes is less than or equal to 0.4 mm and greater than or equal to 0.25 mm.

13. Detecting device according to claim **1**, wherein a diameter of each group of GEM through holes is less than or equal to 0.4 mm and greater than or equal to 0.25 mm and a diameter of each blind hole is equal to or greater than 0.3 mm and equal to or less than 0.5 mm.

14. Detecting device according to claim **13**, wherein a centre-to-centre distance between adjacent groups of GEM through holes is equal to or greater than 0.45 mm and less than or equal to 0.65 mm.

15. Detecting device according to claim **1**, wherein a centre-to-centre distance between adjacent blind holes is the same as the centre-to-centre distance between adjacent groups of GEM through holes.

16. Detecting device according to claim **1**, wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 20 μm.

17. Detecting device according to claim **1**, wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 50 μm.

18. The detecting device of claim **1**, wherein each GEM through hole in each of the plurality of regularly spaced apart groups of GEM through holes is aligned with a respective one of said blind holes.

19. Converter unit comprising a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates, each perforated accelerator plate provided with an insulating layer to insulate each perforated accelerator plate from one another in order to be able to provide separate potential to each perforated accelerator plate, wherein perforations of the perforated accelerator plates are aligned to form a matrix of blind holes, wherein said gas-electron multiplier comprises a matrix formed of a plurality of regularly spaced-apart groups of GEM through holes wherein each group comprises between one and twenty GEM through holes and wherein a longitudinal axis of the center of each of said groups of GEM through holes is aligned with a longitudinal axis of a respective blind hole, wherein a surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions.

20. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 20 μm.

21. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of a GEM through hole is equal to or greater than 40 μm.

22. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 50 μm.

23. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 20 μm.

24. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 40 μm.

25. Converter unit according to claim **19** wherein a minimum radial distance between a circumference of a blind hole and a closest point of a circumference of the nearest GEM through hole is equal to or greater than 50 μm.

26. Converter unit according to claim **19** wherein each of said groups of GEM through holes are aligned with a respective blind hole; wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material;

wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions comprising pairs of adjacent electrically unconnected regions with a groove between each pair of adjacent electrically unconnected regions; and wherein said grooves are not in contact with any GEM through holes.

27. The converter unit of claim **19**, wherein each GEM through hole in each of the plurality of regularly spaced apart groups of GEM through holes is aligned with a respective one of said blind holes.

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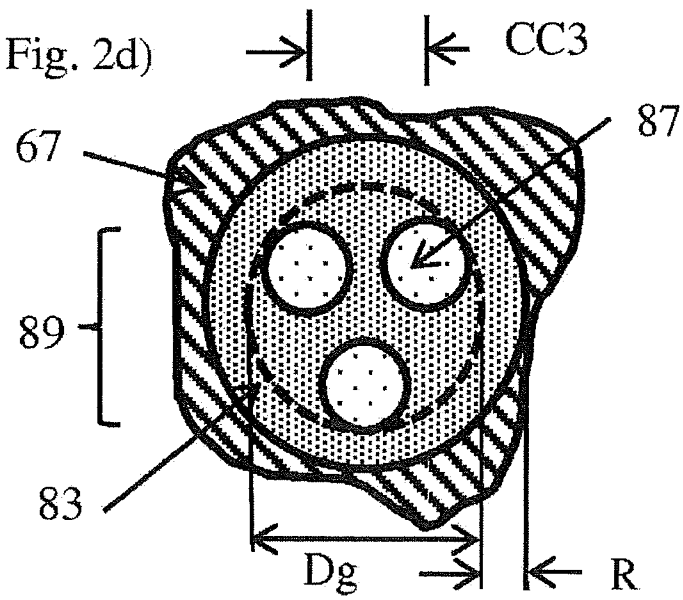

(57) **Abstract**: The invention relates to a detecting unit for detecting ionizing radiation. The device comprises a converter unit for the amplification of ionizing radiation and a read-out unit, wherein the converter unit comprises a converter and a gas-electron multiplier (45), wherein said converter comprises a substrate (51) with an ionizing radiation- receiving major surface (63) and an electron-emitting major surface (65) and a stack (53) of accelerator plates (55) in contact with the electron-emitting major surface (65), wherein said stack comprises a plurality of perforated accelerator plates wherein the perforations (57) of the perforated accelerator plates are aligned to form a matrix of blind holes (61).

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Title of the Invention

Ionizing radiation detecting device

Technical field

The present invention relates to a detecting device for ionizing radiation, converter units for such devices, as well as converters and gas electron multipliers for such converter units.

Background of the Invention

In the medical field ionizing radiation has many diagnostic and therapeutic uses. It can be used for imaging the body of a patient for example to detect tumors and it can also be used for the treatment of a patient for example to irradiate detected tumors. In order to obtain good resolution images and accurately placed treatment it is necessary to detect the ionizing radiation after it has passed through the body being examined or treated and then process the signals obtained for the detecting means. The signals can be processed to obtain an image which represents the body through which it has passed and/or which represents the distribution of the ionizing radiation. In general the term "imaging" means forming an image of the measured data, and the term "dosimetry" measurement of the absorbed dose due to incident ionizing radiation.

In order to detect in real time the intensity and spatial distribution of incoming ionizing radiation such as high energy photons generated in X-ray imaging or treatment devices, digital detecting units have been developed which convert the incoming radiation, for example photons, into electrons. This can be achieved by electromagnetic interaction with the photons and matter which can cause some of the energy of the photon to be transferred to the matter and a free electron to be excited. Devices within a detecting unit which achieve this effect are called converters. Solid converters rely on the interaction of the incident photons with a solid sheet of material to generate electrons by the Compton Effect or pair production. Gas converters rely on the interaction of incident photons with a gas in a chamber to generate electrons. An example of a prior art unit is known from PCT patent application WO2007/061235. A simplified example of a digital detecting unit (1) is shown in figures 1a) to 1d). This device comprises a housing (3) (shown in dashed lines) filled with a gas (16). The housing contains a converter (5), a GEM (7) separated from the converter by a gas filled gap of depth G, and a read-out unit (9). The converter is formed from a substrate of metal (11). The substrate has a first major face (13) which faces incident ionizing radiation I. This incident radiation causes the formation of electrons in the substrate and these electrons travel through the substrate towards the second major face (15) of the substrate. Electrons which pass through the substrate and impact with the gas molecules in the gas-filled gap cause ionization of the gas molecules and the production of secondary electrons. These electrons need to be multiplied in order to achieve a detectable signal. One way of performing electron multiplication is by providing a micro-pattern gas amplification device (MPGAD) such a gas-electron multiplier (GEM) (7) of the type developed by CERN, separated from the second major face of the converter by the gas-filled gap of depth G. The GEM comprises a thin, insulating, perforated gas electron multiplication foil (17). Typically the foil is made of an insulating substrate (19) of polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kapton®", that is coated on both major sides (21, 23) with a coating (25, 27) made of a conducting material such as copper. The perforations in the foil form a regular matrix (29) of GEM through holes (31) which extend between the major sides (21, 23) and which form a grid of equidistantly-spaced GEM through holes over substantially the whole of the major surfaces. A potential difference can be placed across the coatings (27, 29) thereby generating an electric field in the GEM through holes which electrical field guides electrons from the converter into the GEM through holes (19). The electrical field generated in the gas in the through holes initiates electron avalanches which increase the number of electrons leaving each through hole. The number of electrons generated in the avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by processing signals generated in the read-out unit which could be, for example a thin film transistor. The electrical fields necessary to ensure the electrons are guided to the read-out unit can be achieved by connecting the converter to a high negative potential, for example -700 V, the upper surface of the GEM to a medium negative potential, for example - 600 V, the lower surface of the GEM to a lower negative potential e.g. - 300 V and the read-out unit to ground. In order to achieve a large amplification of the electrons leaving the converter it is necessary to have a large potential difference between the converter and the GEM. However if the potential difference is too high then there is a risk of electrical discharges in the form of sparking between the converter and the GEM.

A problem with the prior art devices is that high energy electrons which leave the electron-emitting face of the converter with a large lateral vector will collide with many gas molecules as they travel laterally in the gas gap between the converter and the GEM. These gas molecules will generate electrons, some of which will travel to the GEM and be multiplied by the GEM in a through hole which is not directly under the arrive point of the incident ionizing radiation on the first major face of the substrate which gave rise to the high energy electron and thus will an erroneous position of the incident ionizing radiation when they are detected by the read-out unit. These give rise to errors in the signals produced by the rad-out unit and lead to decreased accuracy and resolution in images of the incident radiation

Another problem which can occur is that a large GEM acts as a capacitor which leads to unwanted electrical fields and the possibility of dangerous charges becoming stored in the device.

Brief Description of the Invention

The present invention relates to detecting devices which comprise a converter unit which overcomes one or more of the problems in the prior art by providing a new type of converter and a GEM matched to the converter. In one embodiment of the invention this is achieved by matching the position of the through holes in the GEM with the positions of the blind holes in the converter to reduce the risk of electrical discharges between these two components. In a further embodiment of the invention a reduction in the risk of discharges between the two components is achieved by dividing the copper coatings on the GEM into segments.

Brief Description of the Drawings

Figure 1a) shows schematically a view from above of a detecting unit according to the prior art.

Figure 1b) shows schematically a section through line A-A of the unit of figure 1a).

Figure 1c) shows schematically an enlargement of part of the section of figure 1b).

Figure 1d) shows schematically the view from line B-B of figure 1c).

Figure 2a) shows schematically a view from above of an embodiment of an detecting unit according to the present invention.

Figure 2b) shows schematically a section through line C-C of the unit of figure 2a).

Figure 2c) shows schematically an enlargement of part of the section of figure 2b).

Figure 2d) shows schematically the view from line D-D of figure 1c).

Figure 3 shows schematically a view corresponding to that of figure 2c) for another embodiment of a digital detecting unit in accordance with the present invention.

Figure 4 shows a view from below of a further embodiment of a GEM according to the present invention.

Detailed Description of the Invention

An example of a detecting unit (39) in accordance with an embodiment of the present invention is shown in figures 2a) to 2d). This detecting unit (39) comprises a housing (41), shown by dashed lines, containing a converter unit (comprising a converter (43), a gas-electron multiplier (GEM) (45)), and a read-out unit (47) which generates signals relating to the position and intensity of electrons which interact with it. Signals generated in the read-out unit can be collected by a signal processing system (not shown) which may convert the signals into images. The housing is filled by a gas (49). Preferably the gas is a mixture of gases, preferably a Penning gas mixture, for example a mixture of argon-xenon or neon-argon.

The converter (43) is formed of a solid substrate (51) and a stack (53) formed of a plurality of perforated accelerator plates (55^1-55^n), which have their perforations (57) aligned to form a regular matrix (59) of gas-filled blind holes (61). The solid substrate is made of a suitable metal, for example tungsten, chromium, copper, rhenium, molybdenum, tantalum, iron, steel, or made of an alloy of such metals. It has a height h, width w and length l, and has an ionizing radiation-receiving major surface (63) upon which ionizing radiation I may be incident, and an electron-emitting major surface (65) from which electrons may be emitted.

In the embodiment of a converter shown in figures 2a) to 2d) the electron-emitting major surface (65) of the converter is in electrically-insulated contact with the stack (53) of perforated accelerator plates (55^1-55^n). Figure 3 shows an alternative arrangement of a converter according to the present invention in which a non-perforated plate (55), preferably made of the same material as the accelerator plates or a material with a similar coefficient of expansion as the accelerator plates, is provided between the electron-emitting major surface (65) of the substrate and the stack of accelerator plates. This non-perforated plate is in electrical contact with the substrate and is electrically insulated from the stack and serves to reduce mechanical stress at the interface between the bulk of the converter and the stack when the device heats up during use. In all other respects the converter shown in figure 3 is identical to that of figure 2 and the same references number are used to represent identical features in both embodiments.

Preferably in all embodiments of a converter according to the present invention the number n of accelerator plates is greater than or equal to 2 and less than or equal to 100. More preferably the number n of accelerator plates is greater or equal to 10 and less than or equal to 50. Most preferably the number n of accelerator plates is greater or equal to 15 and less than or equal to 30. The accelerator plates are made of conducting material, preferably a metal such as stainless steel, which is sufficiently dense and thick enough to attenuate and/or absorb scattered electrons which have a significant lateral vector. The individual accelerator plates that form the stack may be joined together by electrostatic forces of attraction and/or by an adhesive which may be provided completely or partly over the contact area between adjacent plates. The stack may be connected to the electron-emitting major surface of the substrate by any of the methods used to join the accelerator plates together. Mechanical fasteners or clamps may also be used to hold the accelerator plates together and/or the accelerator plates to the substrate.

The arrangement of the blind holes in the matrix may be quadratic (as shown in the figures) - where each hole (except of course the holes nearest the edges of the plates) is surrounded by four equally spaced holes, or staggered - where each blind hole is surrounded by six equally spaced blind holes. Preferably the blind holes have a diameter D1 which is equal to or greater than 0.3 mm and less than or equal to 0.5 mm. The distance between centers CC1 of the blind holes is preferably equal to or greater than 0.45 mm and equal to or less than 0.65 mm, while at the same time the minimum wall thickness Tmin between the blind holes should be equal to or greater than 0.1mm to ensure attenuation of laterally moving high energy electrons. Thickness Tmin should be less than or equal to 0.5 mm to ensure that the resolution of the device is adequate. Preferably Tmin is equal to or greater than 0.15 and equal to or less than 0.25mm.

Insulation (67) in the form of a conformal insulating coating, e.g. vapor deposited poly(p-xylylene) polymer such as "Parylene"®, or an insulating film or insulating layer is provided on the accelerator plates to insulate them from one another. Insulation further covers the longitudinally-extending cylindrical surfaces (69) of the blind holes and reflects low energy electrons which contact the cylindrical surfaces back into the through holes. The exposed portion (71) of the electron-emitting major surface which forms the closed end (73) of each blind hole is not electrically insulated and, when connected to a negative potential, serves to attract and neutralize the positive ions formed in the through holes thus preventing these ions from reacting with and neutralizing the electrons leaving the substrate. Other arrangement to attract and neutralize positive ions are also possible, for example a portion of the longitudinally extending wall of each blind hole may be uninsulated, thereby providing a portion of the surface which can attract and neutralize positive ions.

Preferably each accelerator plate has a thickness p which is equal to or greater than 0.05 mm and equal to or less than 0.2 mm. More preferably each plate has a thickness of 0.1 mm +/- 0.01 mm. The substrate and each acceleration plate are provided with a respective electrical contact (not shown). These are connectable to an electrical supply (not shown) which is arranged to form an electrical field which increases from negative to positive in the direction from the substrate to the distal accelerator plate ($55^{n)}$ in order to accelerate electrons toward the open ends of the blind holes. Preferably the electrical field strength along the blind holes is equal to or greater than 0.5 kV/cm and is less than or equal to 2 kV/cm. More preferably the field strength is 1 kV/cm +/- 0.1 kV/cm. For example, if the stack of thickness 2 mm is made of 20 accelerator plates and 20 layers of insulation, then the average thickness per layer of the stack is 0.1 mm and the potential difference between each adjacent accelerator plate of the stack should be in the order of 10 V. For example if the converter is held at a voltage of -800 V, then the first accelerator plate (55^1) would be at a voltage of -790 V and the last accelerator plate at a voltage of -600V. The use of a plurality of accelerator plates permits the establishment of a powerful electrical field though substantially the whole length of each blind hole.

The electrical field in the blind holes can be shaped by adjusting the potential difference between each pair of accelerator plates. In one example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the same, i.e. the potential difference drops linearly along the length of a blind hole from the closed end to the open end.

In another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is not the same, e.g. the potential difference drops non-linearly along the length of a blind hole from the closed end to the open end. This non-linearity could be in the form of a small voltage drop between arranged between the first accelerator plate (55^1) and the second accelerator plate (55^2), a larger voltage drop between the second accelerator plate (55^2) and the third accelerator plate (55^3), and so on, wherein the voltage drop between each pair of accelerator plates reaches a maximum between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

In yet another example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is the opposite, i.e. the voltage drop is arranged to be largest between the first accelerator plate (55^1) and the second accelerator plate (55^2), and smallest between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

In a further example of adapting the electrical field in converters according to the invention the potential difference between each pair of accelerator plates is arranged to be low between the first accelerator plate (55^1) and the second accelerator plate (55^2), raising to a peak between two intermediate accelerator plates and then falling to a lower potential difference between the penultimate accelerator plate (55^{n-1}) and the last accelerator plate (55^n).

Incident ionizing radiation, for example photons, is directed to the radiation-receiving major surface of the substrate and generates electrons which enter the closed ends (73) of the blind holes. Electrons which are travelling substantially parallel to the axis of the holes pass though the blind holes and cause ionization of the gas molecules thereby producing secondary electrons. High energy electrons which have significant lateral vectors will pass through the insulation of the cylindrical surfaces of the blind holes and will be absorbed or attenuated by the material of the accelerator plates thus reducing the erroneous effects of these electrons. The electrons leaving the gas-filled blind holes in the direction towards the GEM need to be multiplied in order to achieve a detectable signal. This is achieved by providing a potential difference across the GEM. Preferably this potential difference is equal to or greater than 40 kV/cm and equal to or less than 80 kV/cm.

Any prior art GEM of appropriate size and performance may be used with the converter but in the embodiment of a digital detecting unit according to the invention shown in figure 2a) to 2d) a new type of GEM may be used. An example of such a new GEM (45) comprises a thin, insulating, perforated gas electron multiplication foil (77). The foil is made of an insulating core substrate (78) of, for example, polyimide polymer poly-oxydiphenylene-pyromellitimide, usually called "Kapton®", and is coated on both major sides (79, 81) with a coating (83, 85) made of a conducting material such as copper. The perforations in the foil form GEM through holes (87) which extend between the major sides (79, 81). Preferably the GEM substrate has a thickness k equal to or greater than 40 μm and equal to or less than 60 μm and preferably is 50 μm +/- 2 μm. Preferably the conducting material has a thickness c equal to or greater than 3 μm and equal to or less than 7 μm and preferably is 5 μm +/- 1 μm. The GEM through holes (87) extend between the major sides of the GEM and have their longitudinal axis parallel with the longitudinal axis of the blind holes in the accelerator plates.

Contrary to the prior art wherein the GEM through holes are evenly distributed, the GEM through holes are arranged as regularly spaced-apart groups (89) of GEM through holes. A "group" of GEM through holes comprises a number M, for example, M= 3 as shown in figures 2a)-2d), of GEM through holes, wherein M preferably is greater than or equal to 1 and less than or equal to 20. Preferably the groups of GEM through holes are arranged in a matrix at a centre-to-centre distance CC2 which corresponds to the centre-to-centre distance CC1 between the blind holes and each group of GEM through holes is arranged aligned with a respective blind hole. Preferably the centre of the group of active through holes is aligned with the centre of the respective blind hole. Such groups of GEM through holes, called "active GEM through holes" in the following, act to multiply incoming electrons. It is possible that for production reasons additional individual blind holes or groups of GEM through holes may be provided which are not aligned with the blind holes. Such GEM through holes are not intended to multiply incoming electrons and are called "surplus GEM through holes" in the following. Preferably the GEM through holes have a nominal diameter Di greater or equal to 10 μm and less than or equal to 100 μm. More preferably the GEM through holes have a nominal diameter greater than or equal to 30 μm and less than or equal to 90 μm. Even more preferably the GEM through holes have a nominal diameter greater than or equal to 50 μm and less than or equal to 70 μm. Preferably the GEM through holes comprises in a group of GEM through holes have a centre-to-centre spacing CC3 equal to or greater than 20 μm and less than or equal to 200 μm. More preferably the GEM through holes in a group have a centre-to-centre spacing equal to or greater than 50 μm and less than or equal to 180 μm. Most preferably the GEM through holes in a group have a centre-to-centre spacing CC3 which is equal to or greater than 100 μm and less than or equal to 160 μm. Even more preferably the centre-to-centre spacing CC3 is 140 μm +/- 2 μm. Preferably every blind hole in the converter leads to a respective group of active GEM through holes.

When a potential difference is provided between the coatings (83, 85) of the GEM by means of the power supply an electric field is generated in the GEM through holes. In order to prevent unwanted discharges between the edge of any GEM through hole and the edge of the open end of a blind hole in an accelerator plate of the converter, the groups of GEM through holes are arranged so that the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate (55n) and the closest point of the circumference of a GEM through hole is preferably equal to or greater than 20 μm. More preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (55n) and the closest point of the circumference of a GEM through hole is equal to or greater than 40 μm. Even more preferably the minimum radial distance between the circumference of a blind hole in the distal accelerator plate (55n) and the closest point of the circumference of a GEM through hole is equal to or greater than 50 μm. The use of a annular region of radial width R in which no GEM through holes are permitted means that in comparison to a prior art GEM with equally distributed GEM blind holes the voltage difference between the converter and the GEM can be increased compared to that used in the prior art. This increase in potential difference may allow a greater electrical field strength and better multiplication of the electrons entering the electrical field.

As an illustrative example of an embodiment of the invention, blind holes of diameter 0.4 mm in a converter are arranged at a centre to centre distance CC1 of 0.5 mm, i.e. the minimum wall thickness between the blind holes would be 0.1 mm. Each group of active GEM through holes contains a plurality of GEM through holes of diameter 50 μm. The centre to centre distance between adjacent groups of active GEM through holes would be the same as CC1 i.e. it would be 0.5 mm. If the minimum radial distance R between the circumference of a blind hole in the distal accelerator plate and the closest point of the circumference of a GEM through hole is made equal to 50 μm then the centers of the active GEM through holes with a diameter of 50 μm may not be closer than 75 μm to the circumference of the nearest blind hole in the distal accelerator plate. This means that in this example the diameter Dg of a group of active GEM through holes, which is defined as the diameter of a circle enclosing the group of GEM through holes, would be equal to 0.4 mm – (2 x 50 μm) = 0.3 mm. In the case of a matrix in which the groups of through holes are aligned in a quadratic formation this would mean that each group of active GEM through holes would have a diameter Dg of 0.3 mm and the circumference of a circle with diameter Dg representing the boundary of the group would be separated from the circumference of a circle with diameter Dg representing the boundary of the nearest neighboring group of active GEM through holes by a region S devoid of active through holes which is a minimum of 0.2 mm wide. Preferably the diameter Dg of a group of active GEM through holes is less than or equal to 0.6 mm and greater than or equal to 0.2 mm. More preferably the diameter of a group of active GEM through holes is less than or equal to 0.4 mm and greater than or equal to 0.25 mm. The minimum length L of the region S devoid of active GEM through holes (i.e. the minimum distance between the circumferences of the circles of diameter Dg of adjacent active GEM through holes) is given by the formula L = CC1 – Dg. Preferably the region R is completely devoid of any GEM through holes but it is conceivable that for production reasons one or more surplus GEM through holes may be present in the region.

The electrical field generated in the gas in the active GEM through holes initiates electron avalanches which increases the number of electrons leaving each hole. The number of electrons generated in an electron avalanche can be in the range of 100-1000 per incoming electron. These electrons can be collected and the position and intensity of the incident radiation determined by the read-out unit (47) which is of conventional design and not described further. Signals regarding the position and intensity of the incident radiation generated in the read-out unit can be collected by a signal processing system (not shown) which converts the signals into images.

Figure 4 shows a view from below of further GEM (359) in accordance with the invention which comprises groups of active through holes aligned with the blind holes as described above. The conducting coating (373) of this visible lower major surface of the GEM is divided into a number Q of electrically-unconnected regions (375^1-375^Q) by a plurality of grooves (377^1-$377^{(Q-1)}$) each of which extend from edge to edge across the surface and which extend through the surface to the underlying electrically insulating substrate. The grooves may be formed by removing conducting coating from the respective surface or, when applying the coating, by preventing coating from being applied where the grooves are to be positioned. These electrically-unconnected regions may each form a capacitor but the total capacitance of the GEM is less than that which would be formed if the conducting coating covered the major surface as a continuous coating.

In a further embodiment of a GEM in accordance with the invention which comprises groups of active through holes aligned with the blind holes as described above, the conducting coating of the upper major surface of the GEM is divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance..

In another further embodiment of a GEM in accordance with the invention which comprises groups of active through holes aligned with the blind holes as described above, both the conducting coating of the upper major surface and the lower major surface of the GEM are divided into a number of electrically-unconnected regions in order to achieve the effect of a lower capacitance.

The invention is not to be seen as limited by the preferred embodiments described above, but may be varied within the scope of the appended claims as is readily apparent to the person skilled in the art. The various embodiments can be combined with each other in any suitable manner.

Claims:

1. Detecting device for detecting ionizing radiation comprising a converter unit for the amplifying ionizing radiation and a read-out unit, wherein the converter unit comprises a converter (41) and a gas-electron multiplier (GEM) (45), wherein said converter comprises a substrate (51) with an ionizing radiation-receiving major surface (63) and an electron-emitting major surface (65) and a stack (53) of accelerator plates (55^1-55^n) in contact with the electron-emitting major side, wherein said stack comprises a plurality of perforated accelerator plates wherein the perforations (57) of the perforated accelerator plates are aligned with each other and are distributed to form a matrix of blind holes (61) characterized in that said gas-electron multiplier comprises a matrix formed of a plurality of groups (89) of active GEM through holes (87) wherein each of said groups is aligned with a respective blind hole.

2. Detecting device according to claim 1 wherein the gas-electron multiplier comprises a first major surface (79) and a second major surface (81) made of a conducting material and wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions (375^1-375^Q).

3. Detecting device according to claim 1 wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material and wherein both of said first and second major surfaces is formed as a plurality of electrically unconnected regions.

4. Detecting device according to any of the previous claim wherein wherein the minimum radial distance R between the circumference of a blind hole and the closest point of the circumference of an active GEM through hole is equal to or greater than 40 μm.

5. Detecting device according to any of the previous claims wherein the diameter of each blind hole is equal to or greater than 0.3 mm and less than or equal to 0.5 mm.

6. Converter unit comprising a converter and a gas-electron multiplier, wherein said converter comprises a substrate with an ionizing radiation-receiving major surface and an electron-emitting major surface and a stack of accelerator plates in contact with the electron-emitting major surface, wherein said stack comprises a plurality of perforated accelerator plates, wherein the perforations of the perforated accelerator plates are aligned to form an

matrix of blind holes wherein the blind holes each have a diameter D1 and are arranged with a center-to center spacing CC1.

7. Converter unit according to claim 6 wherein the surface of each blind hole is covered with an insulator except for a portion which is exposed in order to be able to attract and neutralize ions.

8. Converter unit according to claim 6 or claim 7 wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of active GEM through holes wherein the minimum radial distance (R) between the circumference of a blind hole and the closest point of the circumference of a GEM through hole is equal to or greater than 20 μm.

9. Converter unit according to claim 6 or 7 wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of active GEM through holes wherein the minimum radial distance R between the circumference of a blind hole and the closest point of the circumference of a GEM through hole is equal to or greater than 40 μm.

10. Converter unit according to claims 6 or 7 wherein said gas-electron multiplier comprises a matrix formed of a plurality of groups of active GEM through holes wherein the minimum radial distance R between the circumference of a blind hole and the closest point of the circumference of a GEM through hole is equal to or greater than 50 μm.

11. Converter unit according to claims 6 or 7 wherein each of said groups of active GEM through holes is aligned with a respective blind hole, wherein the gas-electron multiplier comprises a first major surface and a second major surface made of a conducting material; wherein at least one of said first and second major surfaces is formed as a plurality of electrically unconnected regions comprising pairs of adjacent electrically unconnected regions with a groove between each pair of adjacent electrically unconnected regions; and wherein said grooves are not in contact with any GEM through holes.

12. Gas-electron multiplier comprising an insulating core substrate and a first major surface and a second major surface covered by a conducting material wherein it comprises a matrix formed of a plurality of groups of active GEM through holes wherein each group is separated

from each adjacent group of active GEM through holes by a region devoid of active GEM through holes.

13. Gas-electron multiplier according to claim 12 wherein only one of said first and second major surfaces is divided into a number of electrically unconnected regions.

14. Gas-electron multiplier according to claim 12 wherein both of said first and second major surfaces are each divided into a number of electrically unconnected regions.

15. Gas-electron multiplier according to any of claims 12 to 14 wherein each group in the matrix of active GEM through holes has a diameter of less than or equal to 0.6 mm and greater than or equal to 0.2 mm.

16. Gas-electron multiplier according to any of claims claim 12 to 17 wherein the diameter of each active GEM through hole is greater than or equal to 10 μm and less than or equal to 100 μm.

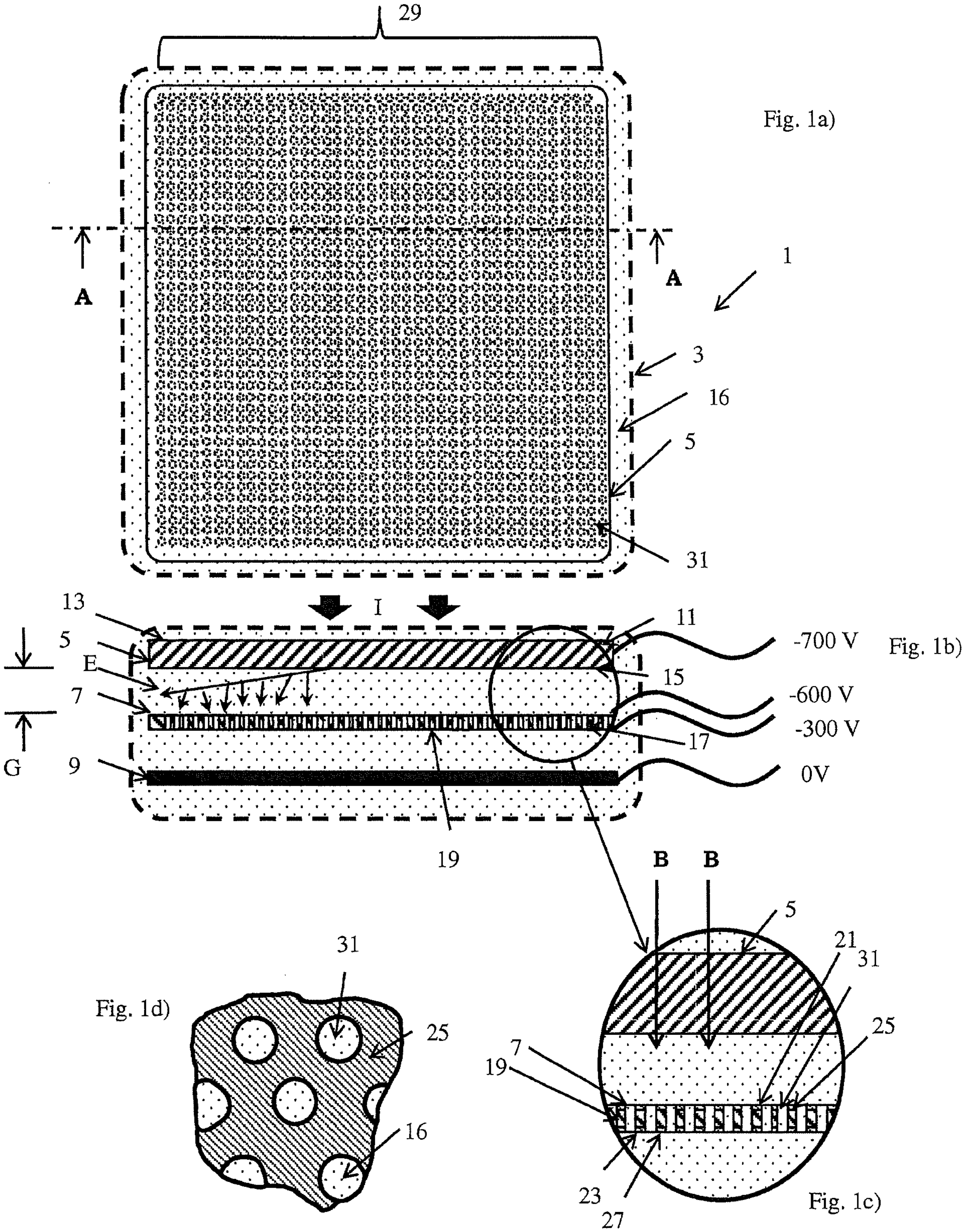
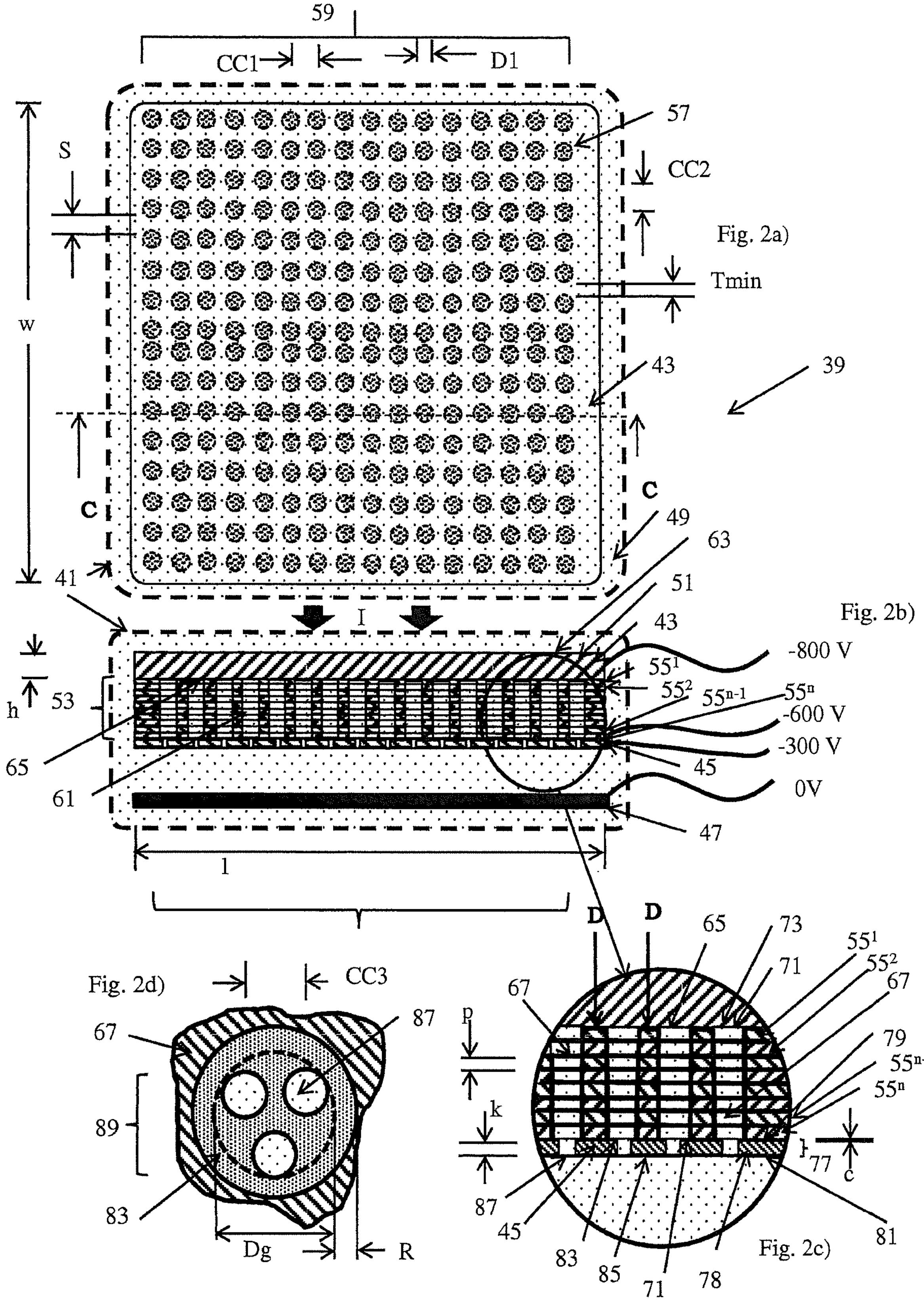


Fig. 1a)

Fig. 1b)

Fig. 1c)

Fig. 1d)


59
CC1
D1
57
S
CC2
Fig. 2a)
Tmin
w
43
39
C
C
49
63
41
51
Fig. 2b)
I
43
-800 V
55^1
h
53
55^2
55^{n-1}
55^n
-600 V
65
-300 V
45
61
0V
47
l
D
D
65
73
55^1
Fig. 2d)
CC3
71
55^2
67
87
67
67
p
79
55^{n-1}
55^n
k
89
77
c
83
87
45
81
Dg
R
83
85
71
78
Fig. 2c)

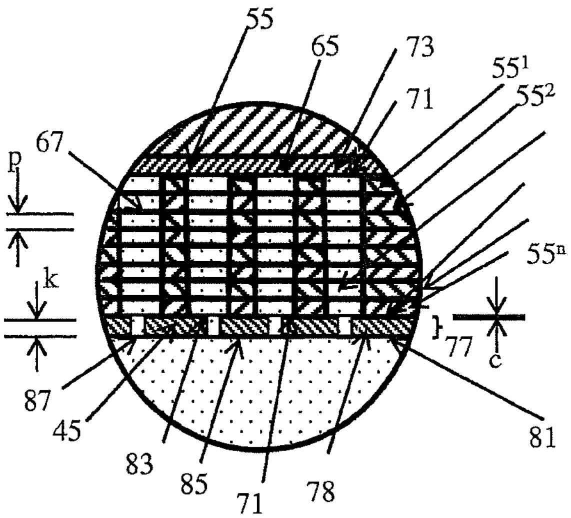


Fig. 3

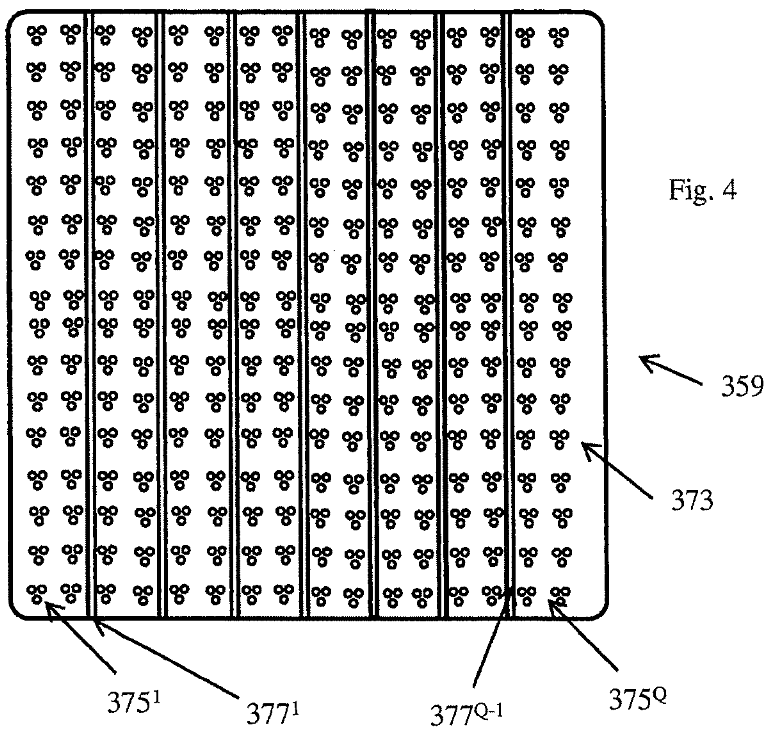


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/054429

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01T1/29
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01T H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007/061235 A1 (NAT UNIV CHANGWON IND ACADEMY [KR]; HAHN CHANG HIE [KR]; KIM IL-GON [K) 31 May 2007 (2007-05-31) cited in the application	12,15,16
Y	abstract	13,14
A	figures 1, 2, 13-15 paragraph [0101] paragraph [0114] paragraphs [0038] - [0039] paragraph [0059] paragraph [0133] -----	1-11

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 June 2016	15/06/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Santen, Nicole

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 2015/034419 A1 (C RAD IMAGING AB [SE]) 12 March 2015 (2015-03-12) abstract figures 1, 2, 5, 7-9 page 5, line 1 - page 6, line 7 page 6, line 27 - page 7, line 2 page 7, lines 29-32 page 9, line 15 - page 10, line 8 page 12, line 11 - page 14, line 11 page 16, lines 4-6 -----	1,5,6,12
Y	WO 2014/146673 A1 (CERN EUROPEAN ORGANIZATION NUCLEAR RESEARCH [CH]) 25 September 2014 (2014-09-25) figure 5 page 23, lines 21-33 -----	13,14
A	US 3 971 942 A (SEIDMAN ADY ET AL) 27 July 1976 (1976-07-27) abstract figures 1, 4 column 2, line 66 - column 3, line 16 column 3, line 63 - column 4, line 40 -----	1-16

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/054429

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2007061235 A1	31-05-2007	US 2008283725 A1 WO 2007061235 A1	20-11-2008 31-05-2007
WO 2015034419 A1	12-03-2015	US 2015060685 A1 WO 2015034419 A1	05-03-2015 12-03-2015
WO 2014146673 A1	25-09-2014	EP 2976778 A1 WO 2014146673 A1	27-01-2016 25-09-2014
US 3971942 A	27-07-1976	IL 43166 A US 3971942 A	31-01-1977 27-07-1976

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En part kan anslutningsöverklaga inom en extra vecka från det att överklagandetiden har gått ut. Ett anslutningsöverklagande måste alltså komma in inom 4 veckor från domens datum.

Ett anslutningsöverklagande upphör att gälla om det första överklagandet dras tillbaka eller av något annat skäl inte går vidare.

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1. Skriv Patent- och marknadsdomstolens namn och målnummer.
2. Förklara varför du tycker att domen ska ändras. Tala om vilken ändring du vill ha och varför du tycker att Patent- och marknadsöverdomstolen ska ta upp ditt överklagande (läs mer om prövningstillstånd längre ner).
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Anvisningar för överklagande PMD-02 - Dom i tvistemål • Producerat av Domstolsverket, Avd. för domstolsutveckling • 2018-11

Om överklagandet kommit in i tid, skickar domstolen överklagandet och alla handlingar i målet vidare till Patent- och marknadsöverdomstolen.

Har du tidigare fått brev genom förenklad delgivning, kan även Patent- och marknadsöverdomstolen skicka brev på detta sätt.

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- Domstolen behöver ta upp målet för att ge andra domstolar vägledning i rättstillämpningen.
- Domstolen bedömer att det finns synnerliga skäl att ta upp målet av någon annan anledning.

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