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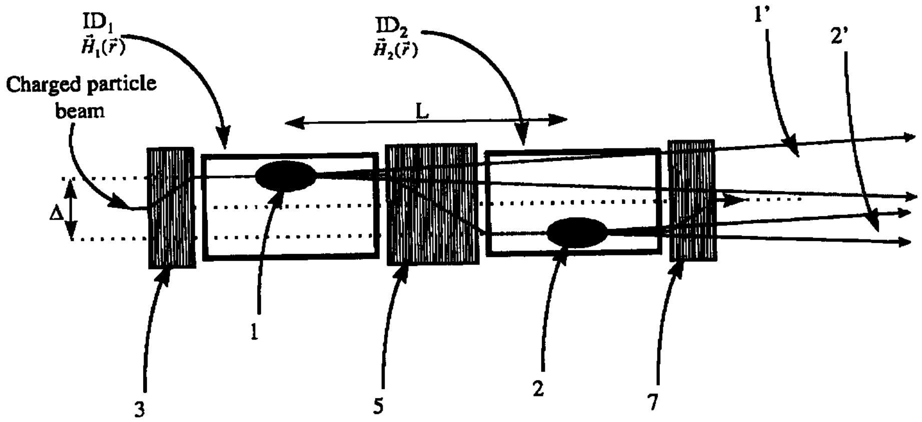
(54) Charged particle beamline with switchable photon properties using two insertion devices, parallel beam displacement and single focusing optics

(57) An arrangement for producing parallelly displaced beams of photons of different properties from a single beam of charged particles comprises at least means (ID_1, ID_2) for producing beams (1', 2') of photons of different properties with small divergence (θ) from and parallel to the single charged particle beam. In addition, the arrangement comprises means (3, 5, 7) for parallel displacement of the single charged beam into or within the means for producing the photon beams and focusing means (11) for focusing the photon beams onto the same image plane.

Figure 4



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Description

[0001] The present invention refers to an arrangement for producing two parallel photon beams of different properties from a single beam of charged particles and focusing them onto the same image plane, to an arrangement for producing at least two parallel photon beams using a Synchrotron, to a method for producing two beams of photons of different properties from a single beam of charged particles, the photon beams to be focused onto the same image plane and to the use of any of the methods for producing two photon beams from a charged particle beam of a Synchrotron with switchable photon properties.

State of the art

[0002] There are several attempts to use two separate insertion devices, following called ID's, producing two light beams of different properties which are focused into a single spot. This is done by either tilting the electron trajectory, or the ID's or both. Examples are shown in the enclosed figures 1, 2 and 3, which are described in A.T. Young et al., Rev. Sci. Instr. 67(9) Sept. 1996 and K.J.S. Sawhney et al., Nucl. Instr. Meth. A 390, 395 - 402 (1997) and T. Hara et al., J. Synchrotron Rad. 5, 426 - 427 (1998). According to the arrangements, described in the state of the art, two photon beams are created separated by φ_{tilt}. The tilt angle φ_{tilt} has to be bigger than the divergence of the photon beam θ_{div}. These two photon beams are then accepted by optical elements and later combined onto one spot, typically onto a sample.

[0003] The properties of the two photon beams depend on the magnetic field distribution $\vec{H}_1(\vec{r})$ and $\vec{H}_2(\vec{r})$ in the two ID's. Depending on these field distributions they may differ in energy, polarisation, helicity and/or phase. Ideally these two photon beams should travel identical paths. In practice this can only be achieved approximately.

[0004] In the existing arrangements, as shown in figs. 1, 2 and 3, either two separate sets of optical elements have to be used, or a single optic which is large enough to accept both photon beams. Since optical components are never perfect, the use of two sets induces differences between the two photon beams in intensity, position etc. They are also susceptible to differential drifts. If a single optic is used in the existing arrangement, it has to be about a factor of 2 larger than in a conventional beamline with a single ID and a single photon beam in order to accept the two photon beams. The photon beams do not overlap on it so that they are reflected by different parts of the optics which again causes different intensities etc. A large optic is very complicated to fabricate and very expensive. It can never be fabricated to the same precision as a smaller optic. Thus the arrangement has a poorer performance.

[0005] Therefore, it is an object of the present invention to propose an arrangement for creating two photon beams which can be processed by a single set of small optical elements and can then be focused onto a single spot.

[0006] Taking the mentioned object into consideration in this patent a double insertion device arrangement is described according to the wording of either claim 1, 2 or 3.

[0007] The double ID beamline according to the present invention operates with a single set of small optical elements. The size of which can be the same as for a conventional single ID beamline. This eliminates the above mentioned problems and reduces the cost, because the photon beams overlap on all the optical elements. Only in or nearby the image plane are they separated.

Detailed description of the invention

[0008] The invention concerns a pair of insertion devices producing two parallel photon beams which are focused onto the same image plane using a single set of small optical elements. The parallel separation only needs to be on the order of the charged particle beam diameter in the insertion devices. Therefore the footprints of the photon beams overlap on the optical elements eliminating the problems encountered when using two sets of optical elements or a single large optic.

[0009] The two photon beams can differ e.g. in energy, polarisation, helicity or phase or any combination thereof. By positioning a chopper close to or in the image plane it is possible to rapidly switch between the two beams. The arrangement therefore provides a source where the energy, polarisation or phase of the photons can rapidly be switched. This can for example be utilised in time resolved experiments.

[0010] The components are:

- Two **insertion devices** (ID's) in line creating magnetic fields $\vec{H}_1(\vec{r})$ and $\vec{H}_2(\vec{r})$ at the charged particle beam respectively. These magnetic fields may or may not be identical.

- A set of **deflectors** allowing a parallel displacement of the charged particle beam in the two ID's or a phase matching of the two photon beams produced by the two ID's.

- A **single set of small optical elements** accepting the two overlapping photon beams generated by the ID's and focusing them onto the same image plane.

- A **chopper** blocking one of the two photon beam at or near the image plane is optional.

- A **monochromator** and a **refocusing optics** are optional.

[0011] The invention shall be described in more details and with the aid of examples, which are shown in the enclosed figures, of which

Fig. 4 shows two insertion devices with deflectors, parallel displaced charged particle beam and the two photon beams,

Fig. 5 shows the focusing of the two photon sources by means of a single optical element,

Fig. 6 shows the blocking of one of the two beams by means of a chopper, and

Fig. 7 shows the charged particle trajectory without parallel displacement creating two phase matched IDs to produce a source equivalent to the combined length of the two IDs.

[0012] The invention shall be described using a synchrotron beamline as an example. It can be extended to a beamline using any kind of charged particle accelerator.

[0013] Fig. 4 shows two insertion devices, ID_1 and ID_2, with the charged particle beam displaced by an amount Δ perpendicular to the beam direction. The dark spots in Fig. 4 symbolise the two photon sources, which are designated with 1 and 2. These can produce photon beams 1' and 2' of different properties depending on the magnetic fields $\vec{H}_1(\vec{r})$ and $\vec{H}_2(\vec{r})$. In the mode, shown in Fig. 4, the deflectors 3, 5 and 7 direct the charged particle beam, so that the trajectories in the two insertion devices ID_1 and ID_2 are parallel, but displaced by an amount Δ. The separation Δ will typically be on the order of the diameter of the charged particle beam, $\Delta \sim \varnothing_{ch\text{-}beam}$. As a result one obtains two independent photon sources 1 and 2 separated by a distance Δ perpendicular to their propagation direction. The charged particle trajectory and the resultant photon beams are shown schematically in Fig. 4.

[0014] By selecting different magnetic fields $\vec{H}_1(\vec{r})$ and $\vec{H}_2(\vec{r})$ in the two ID's one obtains two photon sources 1 and 2 which differ in energy, polarisation, helicity or phase or any combination thereof.

[0015] The two photon beams 1' and 2' overlap on the optical elements which focus them. Thus imperfections of the optical system have identical consequences for both photon beams. Since many experiments use difference measurements between the two photon beams this is of great importance. In contrast to this, existing schemes shown in Figs. 1, 2 and 3 use two optical systems or non overlapping beams which results in artificial difference signals complicating the measurement. The new arrangement described according to the present invention also lowers the cost substantially. The focusing is shown schematically in Fig. 5. Fig. 5 shows the focusing of the two sources displayed by Δ in direction perpendicular to the propagation and L parallel to the propagation. The distance to the focusing element is D_{mirror}. The condition $\Delta << L << D_{mirror}$ is usually valid. Here the focusing is shown for a single focusing mirror 11. Other optical elements could also be used for focusing.

[0016] By placing an optional chopper 17 in the image plane 13 or close to it, one can selectively block one of the photon beams (see Fig. 5 and Fig. 6). If the photon beams differ in one of their properties (energy, polarisation, helicity or phase) one can thus switch this property. The arrangement is schematically shown in Fig. 6. A chopper 17 is selectively blocking one of the photon beams 1' or 2'. Fig. 6 shows an enlarged view of the image points 15 and 15', shown in Fig. 5. The separation Y between the foci is given by $Y = \Delta * M$, where M is the magnification of the focusing element 11. Since this separation can be made very small, the switching can be done at very high speed. One possible example for such a chopper 17 is a vibrating reed, which operates over a wide range of switching frequencies.

[0017] Using the chopper 17 and two photon beams 1' and 2' differing in energy, polarisation or phase one can do time resolved experiments utilising chemical, dichroic or phase contrast respectively. The time resolution is given by the inverse chopper frequency.

[0018] A great advantage of the inventive arrangement is that the two ID's can be operated as a single effective device by making $\vec{H}_1(\vec{r})$ and $\vec{H}_2(\vec{r})$ the same and by operating the intermediate deflector 5 to match the relative phase between the two photon beams produced by the two ID's. This results in an ID with an effective length equal to the combined lengths of the two ID's as shown in Fig. 7. Fig. 7 shows the two insertion devices without parallel displacement of the beam. Insertion devices and deflectors are the same as in Fig. 4, but deflector 5 is used to phase match the two ID's. Deflectors 3 and 7 are switched off.

[0019] The two photon beams produced within insertion device 1 and insertion device 2 may have the same properties or may differ in properties, like e.g. having different polarisation direction and phase which rotates the polarisation.

Optimum operation mode:

[0020] In the following we describe conditions which lead to optimum performance. However they are not required for the successful operation.

[0021] The scheme works best if the photon sources are diffraction limited. In this case the source points are within the depth of view of the optical element and the images 15 and 15' are on a plane perpendicular to the propagation direction.

[0022] The separation Δ between the charged particle beams will usually be chosen to be somewhat larger than the transverse size of the photon source σ_{source}, Δ

$\geq \sigma_{source}$.

[0023] If the distance of the source points 1 and 2 to the optical element 11 D_{mirror} is very large compared to the perpendicular separation of the two sources Δ, the footprints on the optical element overlap almost completely and the incidence angle is almost identical, resulting in almost identical reflectivities for both photon beams. Typical values are $\Delta \sim 0.5$ mm, $D_{mirror} \sim 10$ m resulting in a difference of the incidence angles in the order of $\Delta\alpha \sim \arctan(\Delta/D_{mirror}) \sim 5\ 10^{-5}$rad.

[0024] In order to reduce the amplitude of the chopper 17 and thus increase its frequency it is best placed in the image plane. If selecting a vibrating reed as a chopper the width of the reed w and its vibration amplitude A should equal the diameter of the image point 15 and 15'. The parallel shift of the charged particle beams in the IDs Δ should be chosen such that the image separation Y is equal to their diameter.

[0025] Using additional refocusing optics behind the image plane the two images can be brought to overlap in a single spot with an effective diameter only slightly larger than the diameter of a single image point. For this purpose a refocusing optics focused to infinity or at least a distance much larger than the distance to the image plane is used. Since the separation of the images is small compared to the focal length the corresponding rays can be considered parallel. Therefore they can nearly be focused into a single spot.

[0026] The above mentioned examples and given applications serve for the better understanding and explanation of the present invention.

[0027] The basic idea of the present invention and in addition the claimed arrangements can be used for the production of any kind of parallel displaced beams of photons of different properties, derived from a single beam of charged particles.

Claims

1. Arrangement for producing parallelly displaced beams of photons of different properties from a single beam of charged particles, the beams to be focused onto the same image plane, comprising:

- means (ID_1, ID_2) for producing beams (1', 2') of photons of different properties with small divergence θ from and parallel to the single charged particle beam,

- means (3, 5, 7) for parallel displacement of the single charged particle beam into or within the means for producing the photon beams, and

- focusing means (11) for focusing the photon beams onto the same image plane.

2. Arrangement according to claim 1, comprising:

- at least two insertion devices, each producing a beam of photons parallel to the single beam with a small divergence θ,

- means for parallel displacement of the single charged particle beam into the insertion devices, such that the single beam within each of the insertion devices is parallel displaced by a small distance, and

- focusing means for focusing the photon beams onto the same image plane.

3. Arrangement for producing two parallel photon beams using e.g. a synchrotron, the beams having different properties and being focused onto the same image plane, comprising:

- means for producing two photon beams of different properties from and parallel to the charged particle beam of the synchrotron with a small divergence θ,

- means for parallel displacement of the charged particle beam of the synchrotron into or within the means for producing the two photon beams, and

- focusing means for focusing the two photon beams onto the same image plane.

4. Arrangement according to claim 3, comprising:

- at least two insertion devices, each producing a photon beam parallel to the charged particle beam of the synchrotron with a small divergence θ,

- means for parallel displacement of the charged particle beam of the synchrotron into the insertion devices, such that the single beam of charged particles within each of the insertion devices is parallel displaced by a small distance, and

- focusing means for focusing the photon beams onto the same image plane.

5. Arrangement according to any one of the claims 1 to 4, wherein the means for parallel displacement include a set of deflectors, allowing parallel displacement of the single beam of charged particles into or within the insertion devices.

6. Arrangement according to one of the claims 1 to 5, wherein the focusing means comprising a set of optical elements receiving the two overlapping photon beams, generated by the insertion devices and focusing them onto the same plane.

7. Arrangement according to claim 6, wherein the optical elements comprising a focusing mirror (11).

8. Arrangement according to one of the claims 1 to 7, wherein the displacement of the two beams is such that the two beams overlap on all of the optical elements outside of or nearby the image plane.

9. Arrangement according to one of the claims 1 to 8, further comprising a chopper means near to or within the image plane blocking alternatively and/or selectively one of the two photon beams.

10. Arrangement according to one of the claims 1 to 9, in which the deflector means between the two insertion devices further include a phase matching device to match the relative phase of the two photon beams produced by the two insertion devices.

11. Method for producing two beams of photons of different properties from a single beam of charged particles, the beams to be focused onto the same image plane, characterised in that within insertion means along the beam of charged particles two beams of photons with different properties are produced, which are parallel to the single beam of charged particles and which have a small divergence and that the two photon beams overlap and are focused by means of focusing means onto the same image plane.

12. Method according to claim 11, characterised in that within at least two insertion devices the two photon beams parallel to the single beam of charged particles are produced and that the photon beams are focused onto the same image plane by means of optical elements.

13. Method according to any of the claims 11 or 12, characterised in that the single beam of charged particles is guided into the two insertion devices parallel displaced by a small distance and that within the insertion devices two photon beams parallel displaced are produced with a distance such that the two beams overlap on all of the optical elements while focused onto the same image plane.

14. Method for producing two photon beams of different properties from a single charged particle beam of a synchrotron, the two photon beams having different properties and having a small divergence θ, characterised in that along the charged particle beam the two photon beams are produced such that the two photon beams are in line to each other or are parallel displaced by a small distance and that the two photon beams are focused onto the same image plane.

15. Method according to any of the claims 11 to 14, characterised in that the two insertion devices are operated as a single effective device by switching off any means for parallel displacement of the charged particle beam and by producing the two photon beams in line with the beamline of the charged particles, one photon beam in line with the other photon beam.

16. Method according to claim 15, characterised in that between the insertion devices a deflector is used to match the relative phase of the photon beams generated in the ID's to produce a photon beam equivalent to that produced by an insertion device with an effective length equal to the combined length of the two insertion devices.

17. Use of any of the method claims for producing two photon beams from s single charged particle beam of a synchrotron with switchable photon properties using two insertion devices, one single focusing optical means to focus the two photon beams onto the same image plane, like e.g. a single spot and using optionally a chopper near to or within the image plane for block alternatively and/or selectively one of the two photon beams.

Fig. 1

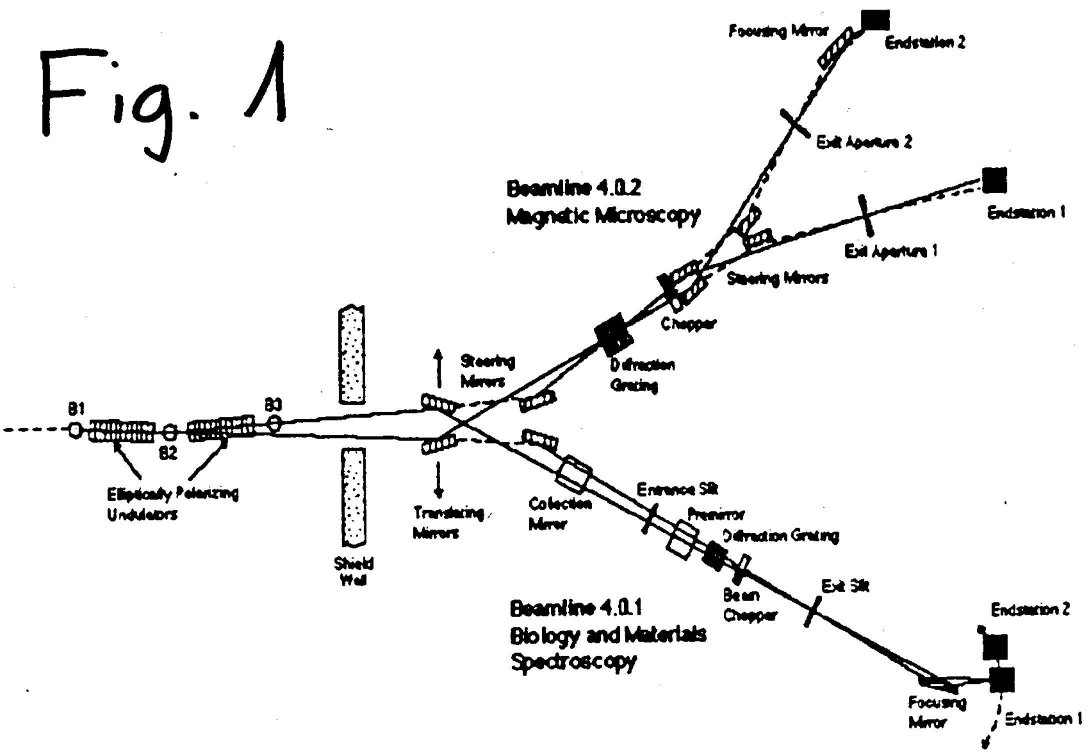


FIG.1. Conceptual design of the LBL circular polarization beamlines. Both microscopy and spectroscopy can be performed at this facility.C. Microscopy Beamline

K.J.S. Sawhney et al. / Nucl. Instr. and Meth. in Phys. Res. A 390 (1997) 395–402

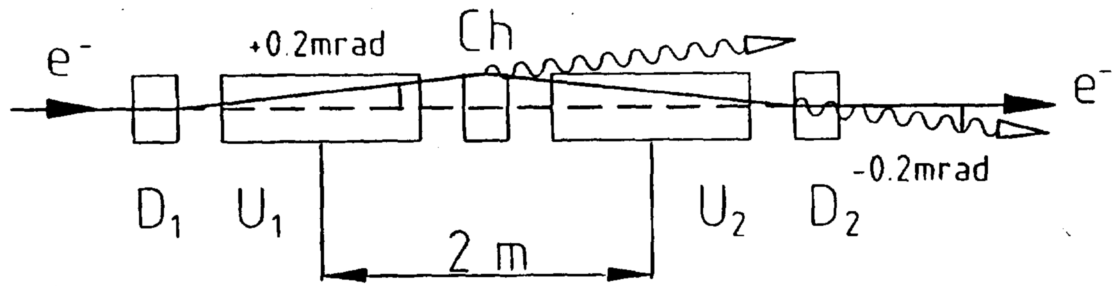


Fig 2.. Schematic of the radiation emission geometry of the double undulator UE56. U_1 and U_2 represent the two modules, D are the deflecting magnets and Ch is the magnetic chicane.

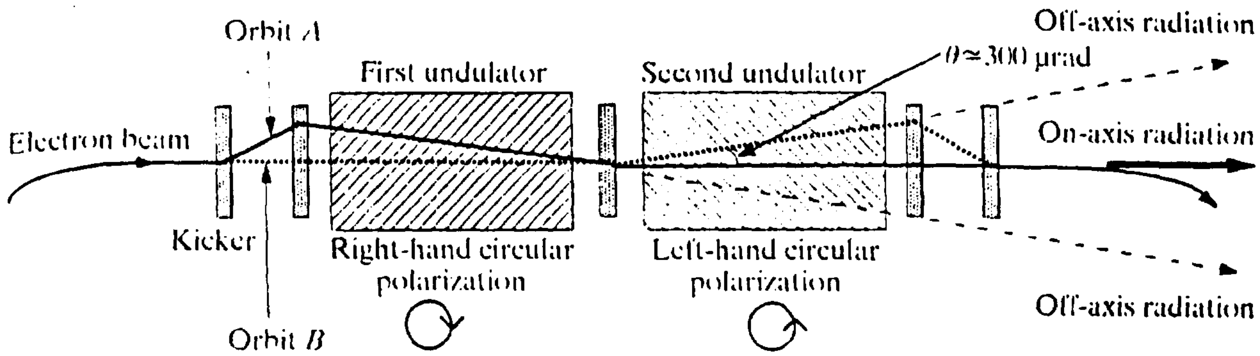
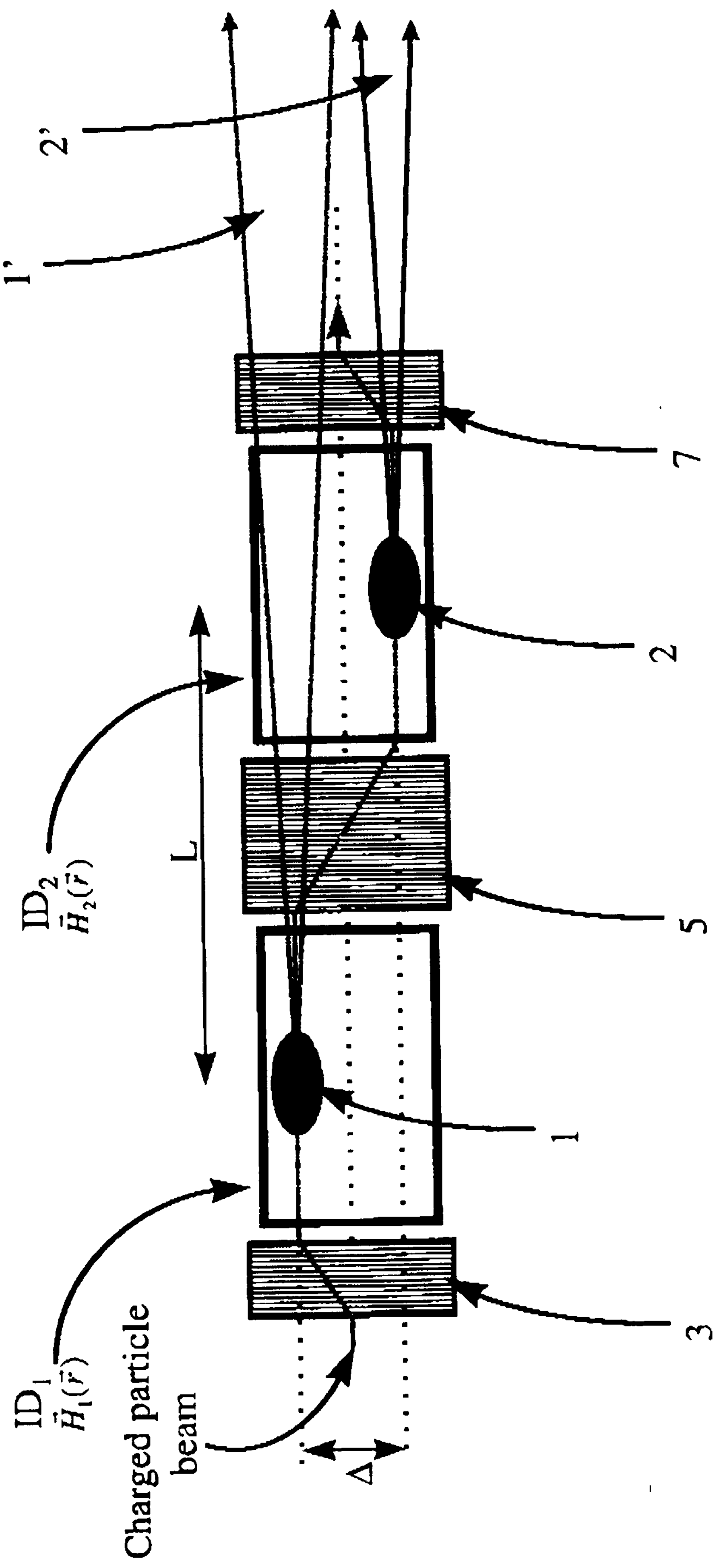


Figure 3
SPring-8 twin helical switching system.

Figure 4


ID$_2$
$\vec{H}_2(\vec{r})$
L
ID$_1$
$\vec{H}_1(\vec{r})$
Charged particle beam
Δ
1
2
3
5
7
1'
2'

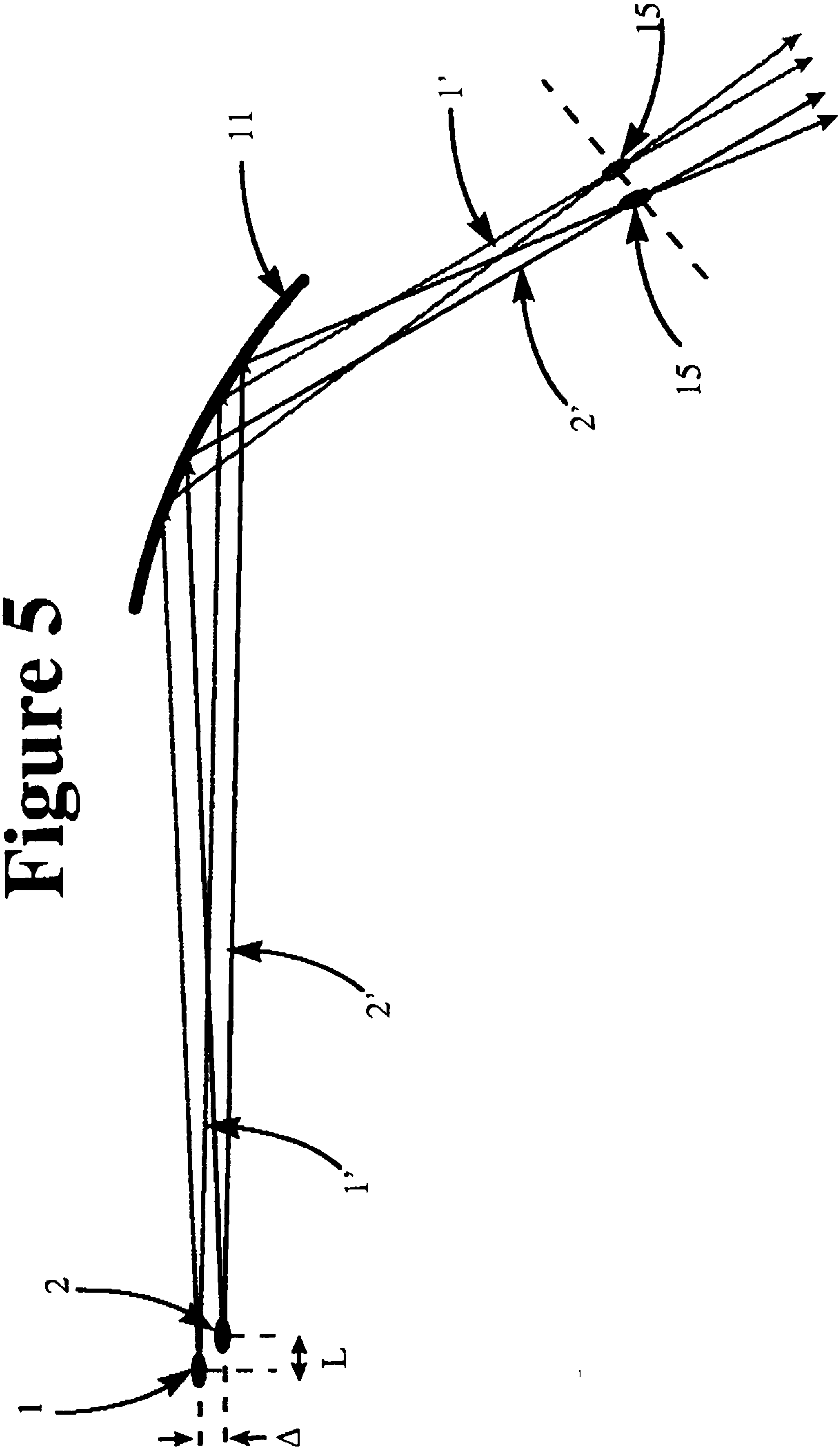


Figure 5

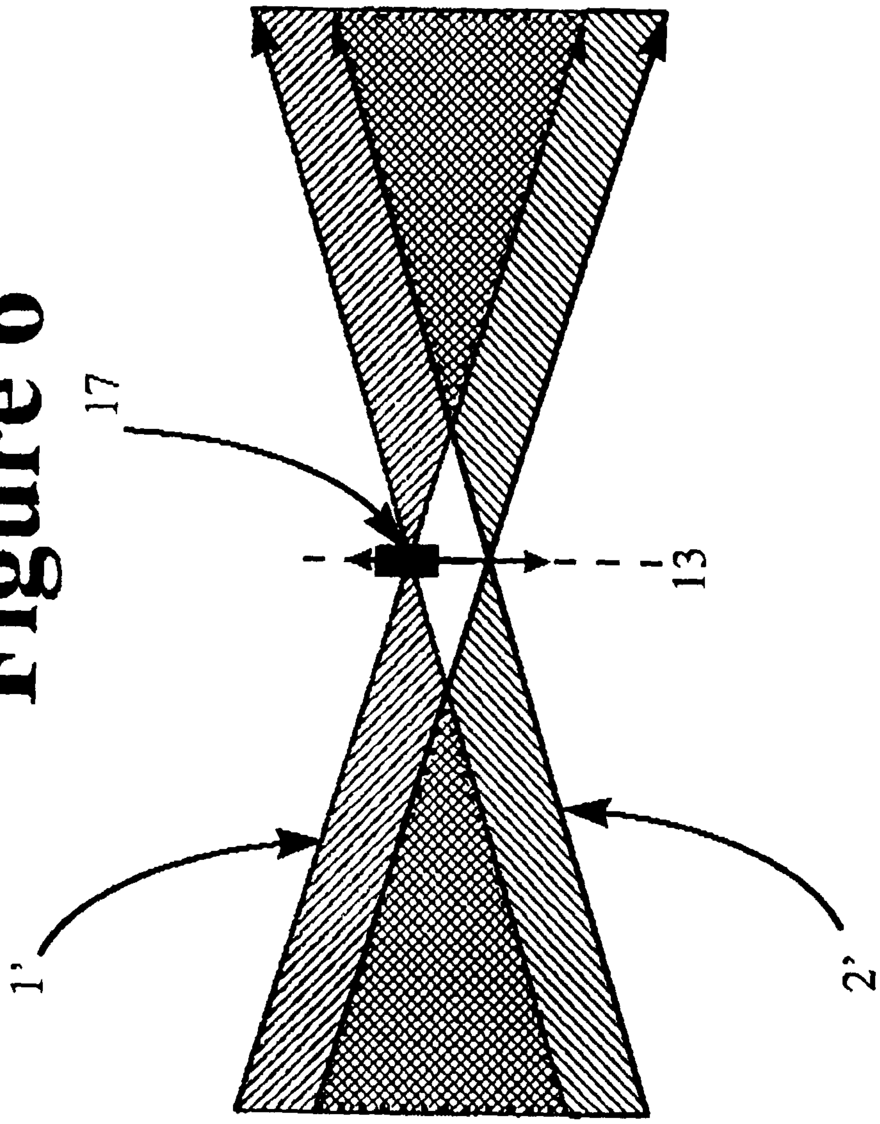


Figure 6

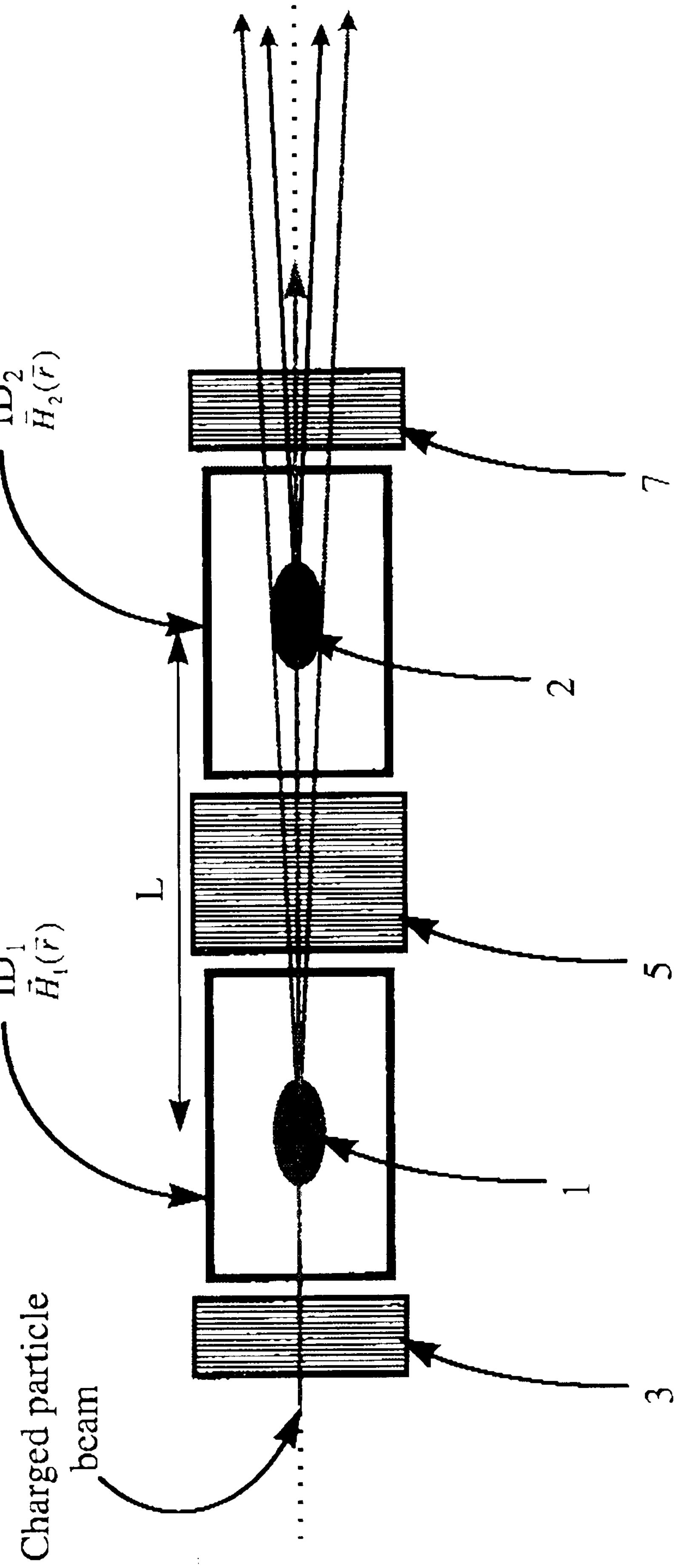


Figure 7

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EUROPEAN SEARCH REPORT

Application Number
EP 98 12 4367

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	MARTYNOV V V ET AL: "Elliptically polarizing undulator beamline 4.0.1 for magnetic spectroscopy at the Advanced Light Source" OPTICS FOR HIGH-BRIGHTNESS SYNCHROTRON RADIATION BEAMLINES II, DENVER, CO, USA, 6-7 AUG. 1996, vol. 2856, pages 289-299, XP002104582 ISSN 0277-786X, Proceedings of the SPIE - The International Society for Optical Engineering, 1996, SPIE-Int. Soc. Opt. Eng, USA * page 290, last paragraph * * page 294, last paragraph - page 297, paragraph 1; figure 5 * ---	1-4,6,9, 11,12, 15,17	H05H7/04
D,A	HARA T ET AL: "SPring-8 twin helical undulator" SRI '97. 6TH INTERNATIONAL CONFERENCE ON SYNCHROTRON RADIATION INSTRUMENTATION, HIMEJI, JAPAN, 4-8 AUG. 1997, vol. 5, pt.3, pages 426-427, XP002104583 ISSN 0909-0495, Journal of Synchrotron Radiation, 1 May 1998, Munksgaard International Booksellers and Publishers for Int. Union Crystallogr, Denmark * the whole document * --- -/--	1,11	TECHNICAL FIELDS SEARCHED (Int.Cl.6): H05H

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 June 1999	Capostagno, E

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EUROPEAN SEARCH REPORT

Application Number
EP 98 12 4367

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	CORNACCHIA M: "Advanced light source at Lawrence Berkeley Laboratory" 3RD INTERNATIONAL CONFERENCE ON SYNCHROTRON RADIATION INSTRUMENTATION, TSUKUBA, JAPAN, 29 AUG.-2 SEPT. 1988, vol. 60, no. 7, pt.2A, pages 1388-1392, XP002104584 ISSN 0034-6748, Review of Scientific Instruments, July 1989, USA * page 395, right-hand column, paragraph 1 * * page 397, right-hand column, paragraph 1 - page 398, left-hand column, last paragraph * * figures 1,2 * -----	6,7,9,17	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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