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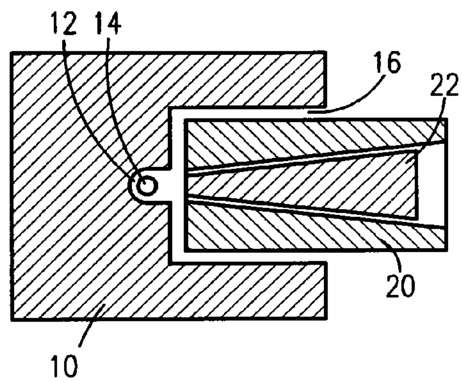
# (54) Collimators

(57) A collimator (20) for use in radiosurgery including material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path. A method is also provided for radiosurgery including the steps of providing an irradiating device including at least one source of radiation (14) arranged to irradiate a target, and at least one collimator (20) disposed between the at least one source of radiation and the target and including material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path, producing radiation beams with the irradiating device, and directing the radiation beams at a target volume from a multiplicity of orientations.

FIG. 1B

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## Description

### FIELD OF THE INVENTION

The present invention relates to radiosurgery generally, and particularly to collimators used in stereotactic radiosurgery.

### BACKGROUND OF THE INVENTION

Stereotactic radiosurgery involves dose accumulation in a target volume by irradiating the target from a multiplicity of orientations with finely collimated beams.

The use of stereotactic radiosurgery to render tissue necrotic is well established and various systems are currently used for stereotactic radiosurgery. The prior art recognizes the need to confine radiation as much as possible to the target volume being treated. Generation of a desired dose pattern in and out of the target volume is the objective of a treatment plan. Such a plan takes into account limitations of the particular radiosurgical system used. System types include a Gamma Unit which utilizes a multiplicity of Cobalt-60 sources arranged on a spherical surface, a linear accelerator (LINAC) which utilizes a proton beam source mounted on a rotating gantry, and a stationary generator for a charged particles beam. These radiosurgical systems, as well as associated methods, characteristics and performance are described in various publications, e.g., <u>Stereotactic Radiosurgery</u>, Alexander E. et al., McGraw-Hill, 1993, and <u>Neurosurgery Clinics of North America</u>, vol. 3, no. 1, Lunsford L.D. (editor), W.B. Saunders Co., Jan. 1992.

Treatment planning capabilities include selecting a dose level to the target, choosing collimators for beam shaping and a determination of beam orientations from which radiation is deposited in the target volume. In order to reduce the dose deposited in healthy tissue outside the target volume, it is generally desirable to spread beam orientations over a wide range and to employ collimators which confine the radiation to the target volume.

Prior art stereotactic radiosurgery systems incorporate point sources for generating radiation beams (a point source is a radiation source which is significantly smaller than the target). A collimator associated with a point source produces a diverging beam, i.e., the beam width increases with increased distance from the source. Such a diverging collimator, of the type used in conjunction with a LINAC or with a Gamma Unit, is made of a radiation impervious material configured to define a diverging radiation path.

The collimators associated with prior art stereotactic radiosurgery systems incorporate clear (non-blocked) radiation paths. The intensity of a radiation beam produced by such a clear path collimator, in any plane perpendicular to the beam axis, decreases monotonically with radial distance from the axis. One of the consequences of such a beam profile is that prior art stereotactic radiosurgery methods are restricted for treating targets smaller than about 50 millimeters in diameter. The apparent reason is the increased radiation to healthy tissue.

### SUMMARY OF THE INVENTION

The present invention seeks to provide improved apparatus and techniques for radiosurgery which represent a radical departure from the prior art.

The present invention includes a hollow path collimator, diverging or converging, which is capable of producing a hollow radiation beam at the target, thus providing an ability to irradiate mainly the target boundary. Causing tissue to be necrotic by irradiation mainly at the target boundary may have adequate clinical results while reducing the radiation dosage to healthy tissue. The prior art does not describe a collimator for stereotactic radiosurgery incorporating a hollow radiation path.

The prior art does not describe a stereotactic radiosurgery system utilizing a converging collimator, i.e., one with a converging radiation path. In the present invention, a converging collimator may be used to produce a hollow radiation path.

The prior art does not describe a system utilizing an area source for generating radiation beams for stereotactic radiosurgery. An area source or a large source is a radiation source which is comparable in size or larger than the target. An area source, e.g., a Co-60 pack used for conventional radiotherapy, could be much cheaper for stereotactic radiosurgery than a LINAC or an array of 201 sources incorporated in the Gamma Unit.

In the present invention, a hollow radiation path collimator may be used to reduce the penumbra associated with a radiation beam produced by an area source. Since a single hollow radiation path reduces also the beam intensity (by blocking an internal portion of the beam), it may be advantageous to incorporate several hollow radiation paths in a single collimator. However, increasing the number of radiation paths may also increase the penumbra, suggesting that a desirable compromise between increasing beam intensity and increasing penumbra be reached. Such a compromise, for a given source and a given collimator material, may be obtained by selecting optimally the number of hollow paths and the associated geometrical properties. The prior art does not describe the use of an area source and a collimator incorporating one or more hollow paths for stereotactic radiosurgery.

There is thus provided in accordance with a preferred embodiment of the present invention, a collimator for use in radiosurgery including material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path.

In accordance with a preferred embodiment of the present invention, the collimator further includes a shield which is generally radiation impervious, the shield having formed therein a beam passageway, and at least one beam blocker which is generally radiation impervious, the at least one beam blocker being located in the beam passageway so as to form the at least one at least partially hollow radiation path.

There is also provided in accordance with a preferred embodiment of the present invention, a collimator for use in radiosurgery including material which is generally radiation impervious and which is configured to define a converging radiation path.

There is also provided in accordance with a preferred embodiment of the present invention, an irradiating device for use in radiosurgery including at least one source of radiation arranged to irradiate a target, and at least one collimator disposed between the at least one source of radiation and the target and including material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path.

In accordance with a preferred embodiment of the present invention, the at least one collimator includes a shield which is generally radiation impervious, the shield having formed therein a beam passageway, and at least one beam blocker which is generally radiation impervious, the at least one beam blocker being located in the beam passageway so as to form the at least one at least partially hollow radiation path.

There is also provided in accordance with a preferred embodiment of the present invention, an irradiating device for use in radiosurgery including at least one source of radiation arranged to irradiate a target, and at least one collimator disposed between the at least one source of radiation and the target and including material which is generally radiation impervious and which is configured to define at least one converging radiation path.

There is also provided in accordance with a preferred embodiment of the present invention, a method for radiosurgery including the steps of providing an irradiating device including at least one source of radiation arranged to irradiate a target, and at least one collimator disposed between the at least one source of radiation and the target and including material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path, producing radiation beams with the irradiating device, and directing the radiation beams at a target volume from a multiplicity of orientations.

There is also provided in accordance with a preferred embodiment of the present invention, a method for radiosurgery including the steps of providing an irradiating device including at least one source of radiation arranged to irradiate a target, and at least one collimator disposed between the at least one source of radiation and the target and including material which is generally radiation impervious and which is configured to define at least one converging radiation path, producing radiation beams with the irradiating device, and directing the radiation beams at a target volume from a multiplicity of orientations.

There is also provided in accordance with a preferred embodiment of the present invention, a method for radiosurgery including the steps of providing at least one radiation source, collimating radiation from the at least one source to produce radiation beams which are at least partially hollow at the location of a target, and directing the at least partially hollow radiation beams at the target from a multiplicity of orientations to produce a radiation dose pattern having a substantially higher dose level at the boundary of the target and a substantially lower dose level at the interior of the target.

In accordance with a preferred embodiment of the present invention, the method further includes the steps of collimating radiation from the at least one source to produce non-hollow radiation beams at the location of the target, and directing the non-hollow radiation beams at the target from a multiplicity of orientations to produce an additional radiation dose pattern having a substantially higher dose level at the interior of the target and a substantially lower dose level at the boundary of the target.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1A is an illustration of a prior art radiation collimator;

Figs. 1B, 1C and 1D illustrate three radiation collimators, constructed and operative in accordance with three alternative preferred embodiments of the present invention; and

Figs. 2A, 2B and 2C are illustrations of three different cross beam profile configurations of radially symmetric beams in planes perpendicular to the corresponding beam axis;

wherein Fig. 2A illustrates a non-hollow cross beam profile produced either by a prior art collimator according to Fig. 1A, a collimator of the present invention according to Fig. 1C or a collimator of the present invention according to Fig. 1D, at its focus;

Fig. 2B illustrates a hollow cross beam profile produced either by a collimator of the present invention according to Fig. 1B, or a collimator of the present invention according to Fig. 1D at a distance from its focus; and

Fig. 2C illustrates a superposition of a hollow beam profile and a non-hollow beam profile.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is now made to Fig. 1A, which illustrates a prior art radiation collimator, and to Figs. 1B, 1C and

1D which illustrate three alternative embodiments of radiation collimators constructed and operative in accordance with a preferred embodiment of the present invention. The radiation collimators of Figs. 1A - 1D are characterized in that they are formed of material which is generally radiation impervious. The radiation collimator shown in Fig. 1A is configured to define a non-hollow and diverging radiation pathway. Radiation collimators shown in Figs. 1B and 1D are configured to define an at least partially hollow radiation path. The radiation collimator shown in Fig. 1C is configured to define a non-hollow and converging radiation pathway.

The hollow radiation path is useful for precise radiation treatment of targets in accordance with a preferred embodiment of the present invention whereby it is desired to irradiate the periphery of the target without substantially irradiating the center thereof, or whereby it is desired to irradiate a target using a large source of radiation. It is noted that throughout the specification and claims, the terms large source of radiation and small source of radiation refer to the relative size of the radiation source compared to the size of the irradiated target. A large source of radiation is comparable in size or larger than the target, while a small source of radiation is significantly smaller than the target.

Fig. 1A illustrates a collimator assembly including an exterior shield 10 defining a location 12 for a source of radiation, indicated by reference numeral 14. The exterior shield 10 is formed with a bore 16 extending outwardly from location 12. Preferably a collimating unit 20 is disposed in the bore 16.

In the embodiment of Fig. 1A, the collimating unit 20 defines an unblocked diverging radiation beam pathway. It is noted that throughout the specification and claims the terms blocked and unblocked refer to the presence or absence of a substantial central beam obstruction, as distinct from the presence or absence of a material used for beam filtering.

The embodiment of Fig. 1B is preferably generally identical to that of Fig. 1A but, unlike the prior art, includes a beam blocker 22, which is generally radiation impervious, disposed within collimating unit 20. Blocker 22 may have any arbitrary shape, such as conical. The at least partially hollow radiation pathway in the collimator defines a diverging hollow beam outside the collimator.

Fig. 1C illustrates a collimator assembly including an exterior shield 30 defining a location 32 for a large source of radiation, indicated by reference numeral 34. The source 34 is typically a pack of radioactive material, such as cobalt-60. The exterior shield 30 is formed with a bore 36 extending outwardly from location 32. Preferably a collimating unit 40 is disposed in the bore 36.

In the embodiment of Fig. 1C, the collimating unit 40 is configured to form a non-hollow and converging radiation beam pathway. This pathway defines a non-hollow beam converging towards the focal point and diverging away from the focal point outside the collimator.

The embodiment of Fig. 1D is identical to that of Fig. 1C but also includes a beam blocker 42, which is generally radiation impervious, disposed within collimating unit 40. Blocker 42 may have any arbitrary shape such as conical. The at least partially hollow and converging radiation pathway in the collimator defines a beam outside the collimator which is converging and hollow near the collimator exit, non-hollow at the focus away from the collimator exit, and diverging and hollow at a distance from the focus.

It is appreciated that any of the collimators of Figs. 1A - 1D may be used to form an interchangeable collimator radiation generator. Any of the collimator elements may be simply removed from the shield and another collimator element inserted in its place. Alternatively, the collimator elements may be rigidly embedded in a movable shield, wherein a particular collimator element may be selected by suitably moving the shield.

Reference is now made to Figs. 2A, 2B and 2C which illustrate three different cross beam profile configurations of radially symmetric beams in planes perpendicular to the corresponding beam axis.

Fig. 2A illustrates a cross beam profile of a non-hollow beam produced either by a prior art collimator according to Fig. 1A, a collimator of the present invention according to Fig. 1C or a collimator of the present invention according to Fig. 1D, at its focus. It is noted that the beam profile is characterized by a relatively high level of radiation near the center of the target, and the radiation level falls off rapidly at a certain distance from the center.

Fig. 2B illustrates a cross beam profile produced either by a collimator of the present invention according to Fig. 1B, or a collimator of the present invention according to Fig. 1D at a distance from its focus. It is noted that the beam profile is characterized by a relatively negligible level of radiation near the center of the profile, and a relatively high level generally at the periphery of the profile.

Fig. 2C illustrates a combined cross beam profile of a non-hollow beam and a hollow beam. It is noted that the beam profile of Fig. 2C is distinguished from the profile of Fig. 2A, in that the beam profile of Fig. 2C has a generally sharper or steeper fall off than that of Fig. 2A, when the hollow beam is produced by a collimator according to Fig. 1D. The steeper fall off may be useful in protecting neighboring tissue from unwanted radiation.

It is appreciated that various features of the invention which are, for clarity, described in the contexts of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment may also be provided separately or in any suitable subcombination.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention is defined only by the claims that follow:

## Claims

1. A collimator for use in radiosurgery comprising material which is generally radiation impervious and characterized by said material being configured to define at least one at least partially hollow radiation path.

2. A collimator according to claim 1 and comprising:

   a shield (10) which is generally radiation impervious, said shield having formed therein a beam passageway; and
   at least one beam blocker (22) which is generally radiation impervious, said at least one beam blocker (22) being located in said beam passageway so as to form said at least one at least partially hollow radiation path.

3. A collimator for use in radiosurgery comprising material which is generally radiation impervious and characterized by said material being configured to define a converging radiation path.

4. An irradiating device for use in radiosurgery comprising:

   at least one source of radiation (14) arranged to irradiate a target;
   and characterized by
   at least one collimator (20) disposed between said at least one source of radiation and said target and comprising material which is generally radiation impervious and which is configured to define at least one at least partially hollow radiation path.

5. An irradiating device according to claim 4 and wherein said at least one collimator comprises:

   a shield (10,30) which is generally radiation impervious, said shield having formed therein a beam passageway; and
   at least one beam blocker (22,42) which is generally radiation impervious, said at least one beam blocker (22,42) being located in said beam passageway so as to form said at least one at least partially hollow radiation path.

6. An irradiating device for use in radiosurgery comprising:

   at least one source of radiation (34) arranged to irradiate a target;
   and characterized by
   at least one collimator (40) disposed between said at least one source of radiation (34) and said target, and comprising material which is generally radiation impervious and which is configured to define at least one converging radiation path.

7. A method for radiosurgery comprising the steps of:

   providing an irradiating device comprising at least one source of radiation (14) arranged to irradiate a target, and at least one collimator (20) disposed between said at least one source of radiation and said target and comprising material which is generally radiation impervious and characterized by said material being configured to define at least one at least partially hollow radiation path;
   producing radiation beams with said irradiating device; and
   directing said radiation beams at a target volume from a multiplicity of orientations.

8. A method for radiosurgery comprising the steps of:

   providing an irradiating device comprising at least one source of radiation (34) arranged to irradiate a target, and at least one collimator (40) disposed between said at least one source of radiation and said target and comprising material which is generally radiation impervious and characterized by said material being configured to define at least one converging radiation path;
   producing radiation beams with said irradiating device; and
   directing said radiation beams at a target volume from a multiplicity of orientations.

9. A method for radiosurgery comprising the steps of:

   providing at least one radiation source (14,34);
   collimating radiation from said at least one source to produce radiation beams which are at least partially hollow at the location of a target; and
   directing said at least partially hollow radiation beams at said target from a multiplicity of orientations to produce a radiation dose pattern having a substantially higher dose level at the boundary of said target and a substantially lower dose level at the interior of said target.

10. A method according to claim 9 and further comprising the steps of:

   collimating radiation from said at least one source (14,34) to produce non-hollow radiation beams at the location of said target; and
   directing said non-hollow radiation beams at said target from a multiplicity of orientations to

produce an additional radiation dose pattern having a substantially higher dose level at the interior of said target and a substantially lower dose level at the boundary of said target.

FIG. 1A
PRIOR ART

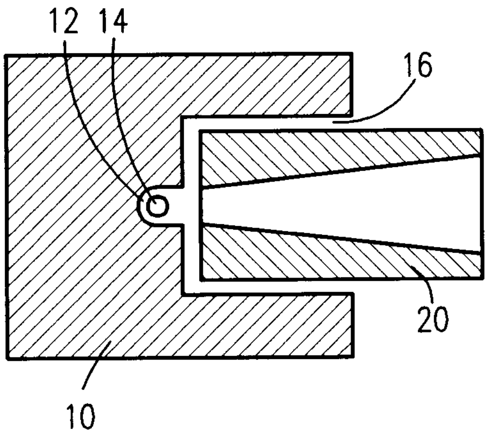



FIG. 1B

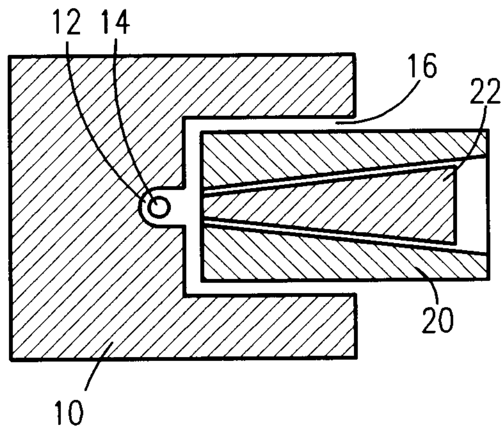



FIG. 1C

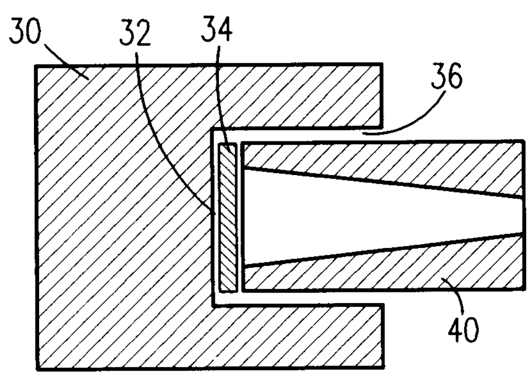



FIG. 1D

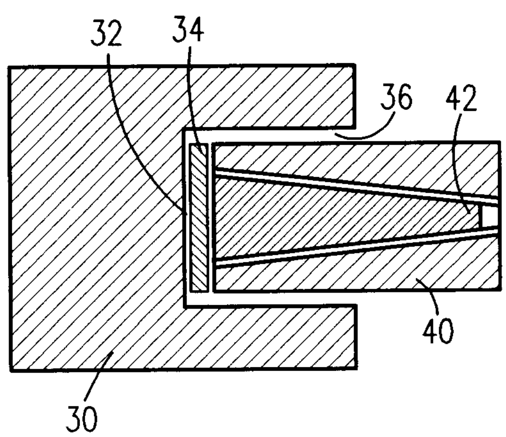


FIG. 2A

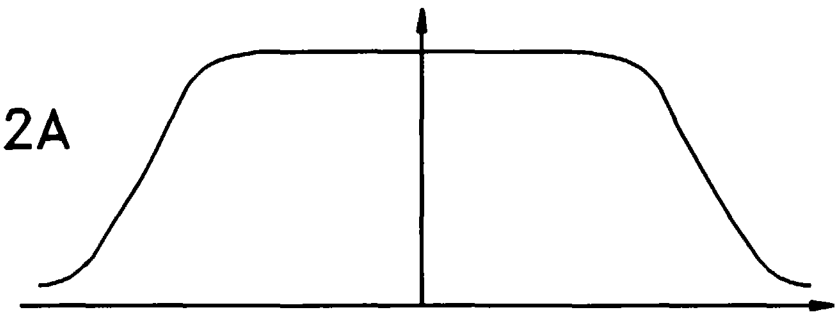


FIG. 2B

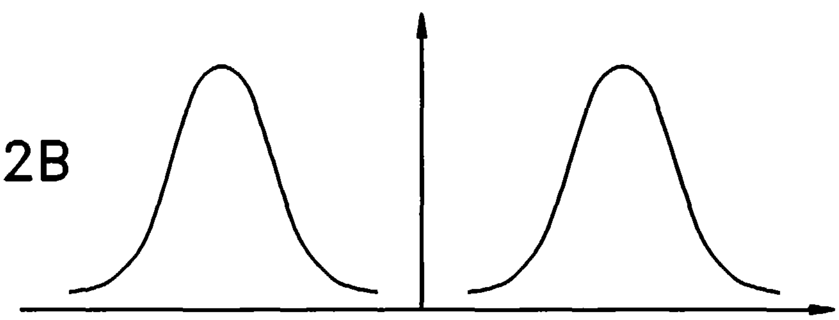
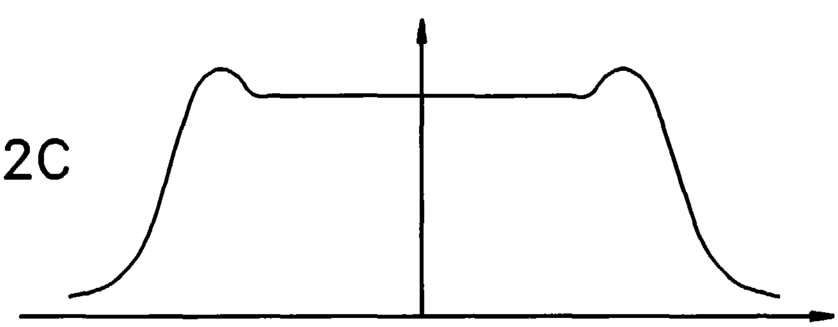


FIG. 2C



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# EUROPEAN SEARCH REPORT

Application Number
EP 97 30 2218

## 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) |
|---|---|---|---|
| X | DE 41 30 039 A (PHILIPS PATENTVERWALTUNG) 11 March 1993<br>* column 1, line 29 - line 48 *<br>* column 2, line 53 - column 3, line 5 *<br>* column 4, line 21 - line 34 *<br>* claims 1,2,6; figure 1 *<br>--- | 1,2,4,5,7 | G21K1/02 |
| X | US 4 991 189 A (BOOMGAARDEN JONATHAN C ET AL) 5 February 1991<br>* column 4, line 56 - column 5, line 21 * | 3,6 | |
| A | * figures 4A-5 *<br>--- | 8 | |
| A | DE 35 34 686 C (BROWN BOVERI REAKTOR) 7 May 1987<br>* column 3, line 36 - line 63 *<br>* figure 2 *<br>--- | 1,2,4,5,7 | |
| A | DE 39 34 321 A (SIEMENS AG) 18 April 1991<br>* column 1, line 66 - column 2, line 27 *<br>* figure 1 *<br>--- | 3,6,8 | TECHNICAL FIELDS SEARCHED (Int.Cl.6) |
| A | US 5 332 908 A (WEIDLICH GEORG A) 26 July 1994<br>* column 5, line 12 - line 23 *<br>* figure 1A *<br>--- | 9 | G21K |
| A | FR 2 331 867 A (COMMISSARIAT ENERGIE ATOMIQUE) 10 June 1977<br>* page 4, line 1 - line 39 *<br>* figure 2 *<br>----- | 3,6 | |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 8 September 1997 | Capostagno, E |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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E : earlier patent document, but published on, or after the filing date
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