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(57) Abrégé(suite)/Abstract(continued):

whereby the cores of the glass fibers are stimulated to emit visible light. The position of the cores is determined from the measurement of an intensity distribution of the emitted light. In a second step, lighting (41, 42) is switched on in order to illuminate the optical waveguides (11, 12). The position of the cladding can be determined from the measurement of the intensity distribution of the light passing through the optical waveguides (11, 12). The eccentricity can be determined from a combination of the two measurements. After determination of the eccentricity, the two optical waveguides are aligned with one another for connection.

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Abstract

A method and an apparatus are specified for connecting optical waveguides, comprising determination of the eccentricity of the core with respect to the cladding. In a first step of the method, the optical waveguides (11, 12) are heated for a limited time interval, whereby the cores of the glass fibers are stimulated to emit visible light. The position of the cores is determined from the measurement of an intensity distribution of the emitted light. In a second step, lighting (41, 42) is switched on in order to illuminate the optical waveguides (11, 12). The position of the cladding can be determined from the measurement of the intensity distribution of the light passing through the optical waveguides (11, 12). The eccentricity can be determined from a combination of the two measurements. After determination of the eccentricity, the two optical waveguides are aligned with one another for connection.

Figure 1

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Description

Method for determining the eccentricity of a core of an optical waveguide, as well as a method and apparatus
5 for connecting optical waveguides

The invention relates to a method for determination of the eccentricity of a core of an optical waveguide. The invention also relates to a method and to an apparatus
10 for connection of optical waveguides.

Prior Art

An optical waveguide normally comprises a glass fiber
15 with a core, and cladding surrounding the core. The glass fiber has a higher refractive index within the core than within the cladding. The refractive index when plotted over the cross section of the glass fiber may have a stepped profile or a gradient profile. In
20 the case of a stepped profile, the refractive index within the core and that within the cladding each have values which are independent of the location. There is a sudden transition from one of the values to the other at the boundary between the cladding and the core. In
25 the case of a gradient profile, the refractive index decreases continuously from the inside outwards within the core, but once again has a value that is independent of the location within the cladding. The values of the refractive index merge continuously into
30 one another at the boundary between the core and the cladding.

The basic material of the core and of the cladding of the glass fiber is normally silicon dioxide. The
35 refractive index of the core may be increased in comparison to the refractive index of the cladding, for example by doping of the silicon dioxide with germanium. Alternatively, the refractive index of the

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cladding can be reduced in comparison to the refractive index of the core, for example by doping of the silicon dioxide with fluorine. Since the core is the optically denser medium and the cladding is the optically thinner medium, total internal reflection occurs for light propagating virtually in the longitudinal direction of the glass fiber, in a transitional area from the core to the cladding. An optical signal can therefore be carried in the core by multiple total internal reflections on the cladding.

In order to protect the glass fiber, the optical waveguide also contains a fiber coating surrounding the glass fiber. Before two optical waveguides can be welded to one another, this fiber coating must be removed.

When connecting two optical waveguides, the important factor is to create a junction point with as little attenuation as possible. An optical signal passing from the first to the second of the two optical waveguides at the junction point should therefore lose as little power as possible. Any lateral offset of the cores of the two optical waveguides at the junction point leads to undesirable attenuation of the optical signal. The attenuation increases as the offset increases. In order to produce a junction point with as little attenuation as possible, the cores of the optical waveguides must be aligned with respect to one another before or during the connection process. However, since the cores do not run centrally in the optical waveguide, the lateral offset of the cores cannot be determined from the lateral offset of the cladding of two glass fibers that are to be connected. Various methods are known for mutual alignment of the cores of two optical waveguides that are to be connected. In one known method, the optical waveguides are first of all joined together

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with a lateral offset at a junction point. The attenuation of the light passing through the junction point is then measured and the lateral offset of the optical waveguides is varied until the attenuation
5 reaches a value which is as low as possible.

In a group of further methods which are known from the prior art, the relative position of the cores is determined directly by optical measurements.

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In the document JP 55-096433, the optical waveguides are illuminated with X-ray radiation. In the documents US 4,690,493 and US 4,506,947, the optical waveguides are each illuminated with ultraviolet radiation.
15 Germanium atoms embedded in the core are in this way stimulated to emit visible florescent radiation, in order to increase the refractive index. The optical waveguide cores that have been made visible in this way can be aligned by visual monitoring. In all of the
20 described methods, radiation which has no components in the visible band is used to stimulate the florescence of the cores.

In the document US 4,660,972, parallel light is passed
25 through the optical waveguides from two different directions. Light entering at the edge of a core is refracted towards the core, so that the edge of the core can be seen as a dark contour in the light passing through. Two adjacent images of the core are produced
30 on an observation screen, by means of two mirrors and a beam splitter, from light beams passing through the optical waveguides in two different directions. The images of the cores are then aligned with one another by continuous direct visual checking.

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In the document US 4,067,651, a glass fiber is illuminated with coherent light from a laser. Scattered

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light is produced by scattering of the light on the glass fiber. The distribution of the refractive index over the cross section of the glass fiber as defined by a plane located transversely with respect to the longitudinal direction of the glass fibers can be determined from a measurement of the angular distribution of the intensity of the scattered light on this plane. However this method is associated with considerable mathematical complexity.

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In the documents JP 59-219707, JP 60-046509, JP 60-085350, US 4,825,092, US 4,882,497 and EP 0 256 539 light which has been refracted on optical waveguides is in each case observed from at least one direction. Structures produced by the cores in the intensity distribution are resolved by means of high-resolution optics. However, the glass fibers themselves also act as optical lenses. In order to obtain sharp imaging of the cores on the image plane of the optics, the optical waveguides must therefore be positioned relative to the optics such that the object plane of the arrangement comprising the glass fibers and optics passes through the cores. The optics must therefore be focused as a function of the position of the cores in the optical waveguides.

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In the document DE 39 39 497 A1, optical waveguides to be connected are illuminated with an arc and are caused to emit light, with the cores in general emitting more visible light than the cladding. Observation optics are focused such that the cores are sharply imaged, and can be aligned with respect to one another. This method is also used in the documents EP 0 687 928 A1 and US 5,570,446. The cores must remain visible throughout the entire adjustment process. The optical waveguides must therefore be kept throughout the entire time interval of the adjustment process at a temperature

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which is adequate to make the cores visible and to produce the arc. However, if a temperature such as this is maintained over a time interval of more than a plurality of tenths of seconds, this results in deformation of the optical waveguides, resulting in increased attenuation. Welding of optical waveguides using this method therefore requires the adjustment process to be completed within a time interval of a plurality of tenths of seconds, and at most within one second. A correspondingly high computation power must therefore be provided in a splicer which operates using the conventional method.

General Description of the Invention

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The object of the invention is to specify a method and an apparatus for connecting optical waveguides, which allow alignment and welding of optical waveguides without any optical waveguide deformation that would cause increased attenuation occurring.

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According to some aspects of the invention, the object is achieved by a method for determination of the eccentricity of the core of an optical waveguide having the features described herein, by a method for connection of at least two optical waveguides having the features described herein, and by an apparatus for connection of at least two optical waveguides having the features described herein.

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The method according to an aspect of the invention for determining the eccentricity of the core comprises a plurality of steps. An optical waveguide is provided which has a core and cladding surrounding the core. In a first step, a section of the optical waveguide is heated for

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a time interval that is defined in advance, such that a first light beam is produced by emission of light from the core and the cladding. A first intensity distribution, which is caused by the first light beam, is measured and stored. The position of the center point of the core is determined from the stored first intensity distribution. In a second step, the section is illuminated with light, and a second light beam is produced by partial refraction of the light on the core and the cladding. A second intensity distribution, which is caused by the second light beam, is measured and stored. The position of the cladding is determined from the stored second intensity distribution. The eccentricity is found from the determined position of the center point of the core and from the determined position of the cladding, with the eccentricity indicating the position of the core with respect to the position of the cladding.

In the first step of the method, the optical waveguides are thus subjected to a heat source in order to cause them to emit visible light. Depending on the dopant substances that are introduced, the core and the cladding of an optical waveguide have different emissivity. In general, the core emits more visible light than the cladding. However, it is also possible for the core to emit less light than the cladding. The position of the core is determined from the measurement of the intensity distribution of the emitted light. In the second step, illumination is switched on in order to illuminate the optical waveguide. The position of the cladding is determined from the measurement of the intensity distribution of the light passing through the optical waveguide. The relative position of the core with respect to the cladding, to be precise the eccentricity, is determined from a combination of the results of the two measurements. Using the information

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about the eccentricity, the optical waveguides can be offset laterally with respect to one another before connection and, if necessary, can also be rotated about the longitudinal axis in order to compensate for the
5 offset of the cores of the two optical waveguides.

The second intensity distribution can be measured before or after the first intensity distribution. The second step can thus be carried out before or after the
10 first step. In the first step, the optical waveguide is heated only for a few tenths of a second. The two steps can be carried out within a relatively short time interval. Only the data of the two intensity distributions need be stored in this time interval. The
15 eccentricity can be determined at any time on the basis of the stored intensity distributions.

An object plane which passes through the section of the optical waveguide is preferably imaged on an image
20 plane, with the first intensity distribution and the second intensity distribution preferably being measured using the same object plane. The two intensity distributions can therefore be measured using the same detection apparatus. In particular, the focusing of the
25 detection apparatus is not changed between the measurements.

The object plane can be chosen such that the core and the cladding are imaged with sufficient clarity on the
30 image plane. However, since the optical waveguide itself also acts as a lens, the cladding and the core that is surrounded by the cladding can in general not both be imaged with optimum clarity on the image plane. However, since the eccentricity is defined by the
35 center points of the core and cladding, fuzzy imaging of the boundaries of the core and cladding can be accepted.

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The first intensity distribution and the second intensity distribution are in each case measured by recording the intensity values in the same area which runs transversely with respect to the section of the optical waveguide. An array of sensor elements for recording of the intensity values is therefore arranged at least along a line or curve, with the line or curve running on a plane which is arranged transversely with respect to the section of the optical waveguide.

The eccentricity is preferably determined by means of the center points of the core and cladding. The position of an intensity extreme is determined from the first intensity distribution in order to define the position of a core center point. In particular, the position of the intensity extreme can be determined from the position of two flanks. The positions of two further flanks are determined from the second intensity distribution, in order to define the position of a cladding center point. The distance between the core center point and the cladding center point is determined in order to define any core eccentricity. The position of the cladding center point is varied as a function of the core eccentricity in order to move the core center point to a previously defined position.

The eccentricity can also be determined with sufficient accuracy by determination of the core and cladding center points if the width of the intensity extreme of the first intensity distribution is relatively high or the gradient of the flanks of the first or of the second intensity distribution is relatively shallow. The intensity extreme of the core may be relatively wide, particularly in the case of glass fibers with a gradient profile. The determination of the eccentricity makes it possible to define the position of the core

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center point via the position of the cladding center point. The cladding center point can be positioned, without having to supply heat to the optical waveguide, in order to make the core visible.

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The eccentricity of the core of an optical waveguide can also be determined using an alternative method. The position of a local extreme is determined from the first intensity distribution in order to define the position of a core center point. Instead of this, the positions of two flanks can also be determined from the first intensity distribution, in order to define the position of the core center point. The position of a flank is determined from the second intensity distribution in order to define the position of a cladding edge. The distance between the core center point and the cladding edge is defined from the position of the extreme or the positions of the two flanks of the first intensity distribution, and the position of the flank of the second intensity distribution. The position of the cladding edge is varied as a function of the distance in order to move the core center point to a previously defined position. The core eccentricity can be determined from the positions of the core and cladding edge, and from the diameter of the optical waveguide. Because of the limited gradient of the flank of the second intensity distribution, the position of the cladding edge is defined only roughly. Nevertheless, the cladding edges of two different optical waveguides for each of which the position of the flank of the second intensity distribution is known can be aligned relatively accurately with respect to one another on the basis of the two flanks.

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The section of the optical waveguide is preferably heated for only a short time interval, so that there is

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no deformation. If heat were to be supplied for more than a few tenths of a second, this would result in deformation of the glass fibers and diffusion of the dopants that have been introduced, and therefore in increased attenuation of optical signals. In particular, the section of the optical waveguide can be heated by production of an arc or a laser beam for a time interval of a plurality of tenths of a second, but for a maximum of one second. The precise value for the time interval required to make the core visible is dependent on the basic material and on the doping of the glass fibers, as well as the thermal power that is introduced. Only the first intensity distribution need be recorded during that time interval. The second intensity distribution can be recorded and the intensity distributions can be evaluated in order to determine the positions of the core and cladding, or the eccentricity of the core, without any further heat being supplied to that section.

20

The first and second intensity distributions are preferably measured by recording intensity values in a first area, with the first area extending in a first direction transversely with respect to the longitudinal axis of the section of the optical waveguide. Sensor elements for recording of intensity values are thus arranged at least along one line or curve which extends in the first direction at a distance from that section and transversely with respect to the longitudinal axis of that section. The section of the optical waveguide can be positioned with respect to the first direction as a function of the intensity values recorded in the first area.

35 The first and second intensity distributions are preferably measured by in each case recording intensity values in a second area, with the second area extending

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in a second direction transversely with respect to the longitudinal axis of the section and transversely with respect to the first area. Sensor elements for recording of intensity values are therefore are also
5 arranged along a line or curve which extends in the second direction, transversely with respect to the longitudinal axis of the section, at a distance from that section of the optical waveguide. The section of the optical waveguide can be positioned with respect to
10 the second direction as a function of the intensity values recorded in the second area.

By way of example, the first direction and the second direction may be at right angles to one another.
15 However, the first direction and the second direction may also include some other angle. Recording of intensity values along the first direction and along the second direction makes it possible to position the section of the optical waveguide on a plane at right
20 angles to the longitudinal axis.

The intensity values are preferably recorded simultaneously in the first area and in the second area. However, the intensity values may also be
25 recorded in the first area first of all, and then in the second area. Two appropriately arranged arrays of sensor elements are required for simultaneous recording of the intensity values in the first area and in the second area. A single array of sensor elements is
30 sufficient for successive recording of the intensity values in the first area and in the second area. The array of sensor elements can be arranged in the first area first of all, and then in the second area. Alternatively, the light which is incident on the first
35 area can first of all be recorded with the aid of an optical system which, for example, comprises a mirror which can pivot, with the light which is incident on

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the second area then being guided to the array of sensor elements. However, when the first intensity distribution is measured successively in the first area and then in the second area, the section of the optical waveguide must be heated twice, successively.

The method according to an aspect of the invention for connection of at least two optical waveguides is carried out in a plurality of steps. At least two optical waveguides are provided, which each have a core and cladding surrounding the core. In a first step, sections of the at least two optical waveguides are heated for a limited time interval, such that first light beams are produced, with one of the first light beams in each case being produced by emission of light from the core and the cladding of in each case one of the sections. First intensity distributions are measured and stored, with in each case one of the first intensity distributions being produced by in each case one of the first light beams. Respective positions of center points of the cores of the at least two optical waveguides are determined from the stored first intensity distributions. In a second step, the sections of the optical waveguides are illuminated with light such that second light beams are produced, with in each case one of the second light beams being produced by partial refraction of the light on the core and on the cladding of in each case one of the sections. Second intensity distributions are measured and stored, with in each case one of the second intensity distributions being produced by in each case one of the second light beams. Respective positions of the cladding of the at least two optical waveguides are determined from the stored second intensity distributions. Any relative eccentricity is determined from the determined respective positions of the center points of the cores of the at least two optical waveguides and the

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determined respective positions of the cladding on the at least two optical waveguides, with the relative eccentricity indicating any offset of the respective cores with respect to any offset of a respective cladding on the sections of the at least two optical waveguides. The offset between the cladding on the respective two sections is then set as a function of the relative eccentricity, in order to define the offset between the cores of the respective two sections. The respective sections of the at least two optical waveguides are then connected.

Thus, in the first step, the optical waveguides are heated for a limited time interval, and the first intensity distributions are measured. As soon as the intensity values of the first intensity distributions have been stored, the supply of heat is interrupted. This makes it possible to avoid deformation of the optical waveguides in the vicinity of the junction point. In the second step, the sections of the optical waveguides are illuminated, and the second intensity distributions are measured. As soon as the intensity values of the second intensity distribution have been recorded, the illumination can also be switched off. The relative eccentricity is given by the difference between the offset of the cores, to be more precise the offset of the core center points, and the offset of the cladding, to be more precise the offset of the cladding center points, and thus allows the offset of the cores to be set via the offset of the cladding.

The position of a local extreme is preferably determined from in each case one of the first intensity distributions, in order to define the position of in each case one core center point. The position of the local extreme, for example, of an intensity peak, can be determined in particular from the positions of two

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flanks. The positions of two further flanks are determined from in each case one of the second intensity distributions, in order to define the position of in each case one cladding center point. In
5 order to define the relative eccentricity of in each case two of the sections, a first offset is determined between the core center points of the respective two of the sections, a second offset is determined between the cladding center points of the respective two of the
10 sections, and the difference between the first offset and the second offset is formed. The offset of the cladding center points is set in order to define the offset of the core center points.

15 The flanks of the first and second intensity distributions, which result from the edges of the cores and cladding, in general have only a limited gradient because of the unclear imaging of the optical waveguides. The edges of the cores and cladding can
20 therefore not be defined very precisely. However, the positions of the core and cladding center points can be determined more reliably since a rising flank and a falling flank are in each case arranged essentially axially symmetrically about the position of a core or
25 cladding center point.

The in each case one first intensity distribution and the in each case one second intensity distribution of one of the sections are preferably measured by
30 recording intensity values in the same area, which extends transversely with respect to one of the sections. It is therefore possible to use the same array of sensor elements in order to record the first intensity distribution and the second intensity
35 distribution for in each case one of the sections.

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The first intensity distribution and the second intensity distribution are preferably measured by recording the intensity values in first areas, with in each case one of the first areas receiving light from one of the sections, and extending transversely with respect to the longitudinal axis of that one of the sections in a first direction. An array of sensor elements for recording of the intensity values is arranged at a distance from the optical waveguides, and extends in a first direction transversely with respect to the longitudinal axis of one of the sections.

The first intensity distributions and the second intensity distributions are preferably measured by recording intensity values in second areas, with in each case one of the second areas receiving light from one of the sections, extending transversely with respect to the longitudinal axis of that one of the sections, and extending in a second direction transversely with respect to one of the first areas. An array of sensor elements for recoding of the intensity values is arranged at a distance from the optical waveguides, and extends in a second direction transversely with respect to the longitudinal axis of one of the sections.

The first direction and the second direction may be at right angles to one another, or may include some other angle. Since the first intensity distribution and the second intensity distribution are recorded for in each case one of the sections in the first area and in the second area, the positions of the core and of the cladding can be defined on a plane which runs transversely with respect to the longitudinal axis of in each case one of the sections.

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The apparatus according to an aspect of the invention for connection of at least two optical waveguides which each have a core and cladding surrounding the core comprises a plurality of components. A heat source is provided in order to heat respective sections of the optical waveguides and in order to produce first light beams, which are in each case produced by emission of light through the core and through the cladding on one of the sections. A holding apparatus is provided in order to fix the sections of the optical waveguides, with the holding apparatus also being designed for positioning of the sections. An illumination device is provided for illumination of the sections of the optical waveguides and in order to produce second light beams, which are each produced by refraction of light on the core and the cladding of one of the sections. A detection device is provided in order to measure first intensity distributions, which are produced by the first light beams, and in order to measure second intensity distributions, which are produced by the second light beams. Furthermore, a memory unit is provided for storage of the first and second intensity distributions. A control device is provided in order to control the holding apparatus, and is designed to set an offset of the cladding as a function of the stored first and second intensity distributions, in order to produce a previously defined offset between the cores.

The apparatus according to an aspect of the invention is therefore designed to determine a first intensity distribution and a second intensity distribution in two successive steps, and to position the ends of two optical waveguides relative to one another as a function of the first intensity distribution and the second intensity distribution. The heat source supplies heat to the optical waveguides only during the measurement of the first intensity distribution. In contrast, the heat

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source is switched off during the measurement of the second intensity distribution, during the evaluation of the measurement results, and during the positioning of the optical waveguides. The illumination device
5 illuminates the optical waveguides with visible light during the measurement of the second intensity distribution, and is switched off during the measurement of the first intensity distribution. The illumination device is preferably switched on during
10 the evaluation of the measurement results and the positioning of the optical waveguides since the cladding edges are preferably aligned by visual inspection. However, fully automatic positioning, which is carried out with the illumination device switched
15 off, is likewise feasible, on the basis of the measurements of the first and second intensity distributions. The measurement of the second intensity distribution, the evaluation of the measurement results and the positioning of the optical waveguides are
20 carried out without any thermal load on the optical waveguides, because the heat source is switched off. The requirements for the speed of evaluation and the positioning speed for a splicer which contains the apparatus according to the invention are
25 correspondingly reduced.

The heat source is preferably designed to produce an arc. In particular, the heat source comprises welding electrodes for production of the arc. The heat source
30 can therefore be used not only for production of the first light beams but also for the welding of the optical waveguides.

The holding apparatus is preferably designed for
35 positioning of the sections of the optical waveguides in a longitudinal direction and in two lateral directions. The longitudinal direction is defined by

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longitudinal axes of the optical waveguides to be connected. The two lateral directions are oriented transversely with respect to the longitudinal direction, preferably at right angles to it, and
5 include any desired angle, but preferably 60° or 90° . An appropriate number of actuators are provided in the holding apparatus for the positioning of the end sections in the three directions, and in this case the actuators can be operated by the control device.

10

The detection device preferably has at least one detection apparatus with imaging optics and with a sensor which comprises an array of sensor elements. The imaging optics have an object plane, which passes
15 through the sections of the optical waveguides, and an image plane, which passes through the array of sensor elements. The object plane is set such that the cores and the cladding of the sections are imaged with sufficient clarity on the image plane.

20

In general, it is not possible to completely clearly image both the cores and the cladding. This is because the optical waveguides themselves also act as lenses. The beam path which describes the imaging of the
25 cladding depends only on the optical characteristics of the imaging optics. The beam path which describes the imaging of the core in contrast depends on the optical characteristics of the imaging optics and on the optical characteristics of the cladding, surrounding
30 the core, of the optical waveguide. Since there is no need for completely clear imaging of the cores and of the cladding for determination of the eccentricity or of the relative eccentricity, the first intensity distribution and the second intensity distribution can
35 be measured using the same setting for the object plane, that is to say using the same imaging optics focusing. It is advantageous to measure the first

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intensity distribution and the second intensity distribution using the same focusing because, in this case, the imaging characteristics, that is to say the association between areas on the object plane and areas
5 on the image plane, are the same for both measurements.

The sensor preferably contains an array of sensor elements arranged over an area, in order to record intensity values of the first and second intensity
10 distributions. A longitudinal section through the sections of the optical waveguides can be imaged on an array such as this. The intensity values of the first and second intensity distributions for in each case one of the sections are determined using those sensor
15 elements which are arranged along a line running transversely with respect to the longitudinal direction of the section.

The sensor may also just contain an array, arranged in
20 the form of a line, of sensor elements for recording of intensity values of the first and second intensity distributions. One such sensor can record only intensity values for a first or a second intensity distribution relating to in each case one of the
25 sections. The first and second intensity distributions of different sections must therefore be measured successively.

The detection device preferably has at least two
30 detection apparatuses, each having one optical axis. The optical axes of a first and second of the at least two detection apparatuses are preferably oriented transversely with respect to one another and transversely with respect to the longitudinal axis of
35 the sections. The use of the at least two detection apparatuses makes it possible to unambiguously define the positions of the core and of the cladding on a

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plane running transversely with respect to the longitudinal axis.

The sections of the at least two optical waveguides are preferably arranged in beam paths which each run between the light source of the illumination device and one of the at least two optical imaging systems. A dedicated light
5 source can be provided for each of the optical imaging systems. However, it is also possible to provide one illumination device with only one light source and a corresponding number of mirrors for production of the desired beam paths.

According to one aspect of the present invention, there is provided a method for determining the eccentricity of a core of an optical waveguide,
10 comprising the following steps: providing an optical waveguide which has a core and a cladding surrounding the core; heating of a section of the optical waveguide for a predetermined time interval such that a first light beam is produced by emission of light from the core and from the cladding; measuring a first intensity distribution, which is produced by the first light beam, and storing a measurement
15 of the first intensity distribution; determining a position of a center point of the core from the stored first intensity distribution measurement; illuminating the section with light such that a second light beam is produced by partial refraction of the light on the core and the cladding; measuring a second intensity distribution which is produced by the second light beam, and storing a measurement of the second
20 intensity distribution; determining a position of the cladding from the stored second intensity distribution measurement; and determining the eccentricity from the determined position of the center point of the core and from the determined position of the cladding, with the eccentricity indicating the position of the core with respect to the position of the cladding.

25 According to another aspect of the present invention, there is provided a method for connecting at least two optical waveguides, comprising the following steps: providing the at least two optical waveguides, respectively comprising a core and a cladding surrounding the core; heating of respective sections of the at least two optical waveguides for a limited time interval, such that first light beams are

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produced, with one of the first light beams in each case being produced by emission of light from the core and the cladding of in each case one of the sections; measuring first intensity distributions, with in each case one of the first intensity distributions being produced by in each case one of the first light beams and storing
5 measurements of the first intensity distributions; determining respective positions of center points of the cores of the at least two optical waveguides from the stored first intensity distributions measurements; illuminating the sections of the optical waveguides with light such that second light beams are produced, with in each case one of the second light beams being produced by partial refraction of the light on
10 the core and on the cladding of in each case one of the sections; measuring second intensity distributions, with in each case one of the second intensity distributions being produced by in each case one of the second light beams, and storing measurements of the second intensity distributions; determining respective positions of the cladding of the at least two optical waveguides from the stored
15 second intensity distributions measurements; determining a relative eccentricity from the determined respective positions of the center points of the cores of the at least two optical waveguides and the determined respective positions of the cladding of the at least two optical waveguides, with the relative eccentricity indicating an offset of the respective cores with respect to an offset of the respective
20 cladding of the sections of the at least two optical waveguides; subsequently adjusting the offset of the respective cladding between the claddings as a function of the relative eccentricity in order to define the offset between the cores; and subsequently connecting the respective sections of the at least two optical waveguides.

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Brief Description of the Figures

Figure 1 shows a refinement of the apparatus for connection of two optical waveguides according to the present invention.

Figure 2A shows an arrangement for recording of intensity values of the first intensity distribution according to one refinement of the present invention.

Figure 2B shows an arrangement for recording of intensity values of the second intensity distribution according to one refinement of the present invention.

Figure 3A shows a cross section through an optical waveguide.

Figure 3B shows a longitudinal section through an arrangement of two optical waveguides.

Figure 4A shows a first intensity distribution determined using the method according to the invention.

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Figure 4B shows a second intensity distribution determined using the method according to the invention.

Explanation of Exemplary Embodiments

5

Figure 1 shows one refinement of the apparatus for connection of two optical waveguides. The figure shows a splicer for fusion welding of two optical waveguides. Each of the optical waveguides 11 and 12 comprises a glass fiber with a core and cladding surrounding the core. The splicer comprises a holding apparatus, which is designed for fixing and positioning of the optical waveguides 11 and 12, with the holders 51, 52 and 53. The optical waveguides 11 and 12 which are inserted into the holding apparatus have sections 110 and 120, on which the glass fibers are exposed by removal of the fiber coatings. The end areas 1101 and 1201 of the sections 110 and 120 are arranged opposite one another. The holders 51 and 52 each have V-shaped grooves, which are used to secure the optical waveguides 11 and 12 against horizontal sliding. The holder 51 is designed for positioning of the optical waveguide 11 in a vertical lateral direction Y. The holder 52 is designed for positioning of the optical waveguide 12 in a horizontal lateral direction X. The holder 53 is designed for positioning of the optical waveguide in a longitudinal direction Z by movement along the groove in the holder 52. The splicer also comprises a heat source for heating of the respective sections 110 and 120. The heat source comprises two welding electrodes 21 and 22, which are arranged opposite one another, for

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production of an arc around the end areas 1101 and 1201 of the optical waveguides 11 and 12. The radiation power of the arc is sufficient to weld the optical waveguides. The splicer also comprises a detection
5 device with the detection apparatuses 31 and 32. Each of the two detection apparatuses 31 and 32 is designed to record first and second light beams, which originate from the sections 110 and 120 of the optical waveguides 11 and 12. The splicer also comprises an illumination
10 device with light sources 41 and 42. The sections 110 and 120 are arranged in the beam paths between a respective one of the light sources 41 and 42 and one of the detection apparatuses 31 and 32. The splicer furthermore comprises the control device 60 for
15 controlling the heat source, the illumination device, the detection apparatus and the holding apparatus. The control device 60 is designed for positioning of the optical waveguides 11 and 12 as a function of intensity distributions recorded by the detection apparatuses.

20

According to the invention, the control device is designed to carry out a method having a plurality of steps. In a first step, the heat source is switched on for a short time interval. A voltage which leads to the
25 formation of an arc is therefore applied to the welding electrodes 21 and 22. Dopants, for example, germanium or fluorine, are incorporated in the glass fibers in order to produce different refractive indexes in the core and cladding. The emissivity also varies as a
30 function of the doping, so that the cores and cladding of the glass fibers are caused to emit light to different extents in the sections 110 and 120. At the same time, the sections 110 and 120 are heated by the radiation power of the arc. The arc is switched off
35 again after just a few tenths of a second, in order to avoid deformation of the optical waveguides 11 and 12, which would result in increased attenuation of optical

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signals. In the time interval in which the heat source is switched on and the cores of the optical waveguides are caused to emit visible light, first intensity distributions of the light emitted from the cores and
5 cladding in the sections 110 and 120 are measured by the two detection apparatuses 31 and 32, and are stored in memory units 71 and 72.

In a second step, the illumination device is switched
10 on for a specific time interval. The light produced by the light sources 41 and 42 is refracted on the cores and cladding of the exposed glass fibers. While the illumination device is switched on, the two detection apparatuses 31 and 32 measure second intensity
15 distributions of the light which is partially refracted by the cores and cladding on the sections 110 and 120, and store them in the memory units 71 and 72.

In a third step, the successively measured and stored
20 first and second intensity distributions are evaluated, and the cladding on the sections 110 and 120 is aligned relative to one another in order to set an offset, defined in advance, between the cores of the sections 110 and 120.

25
Figures 2A and 2B each show an arrangement for recording of intensity values. The sections 110 and 120 are arranged on the object plane 3111 of the imaging optics 311. The sensor 312 is arranged on the image
30 plane 3112 of the imaging optics 311. The imaging optics 311 are shown in the form of a convex lens, but may also comprise an arrangement of lenses and mirrors. The object plane 3111 runs in the longitudinal direction of the optical waveguide 11 or 12. The
35 imaging optics 311 image an area, in the form of a line, of the object plane 3111 on an area, in the form of a line, of the image plane 3112. Light beams from in

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each case one of the cross sections of the sections 110 and 120 are thus respectively imaged on an area, in the form of a line, on the image plane 3112. The sensor 312 comprises a two-dimensional, that is to say area, arrangement of sensor elements for recording of intensity values. The sensor can thus record at least the intensity values of light beams from first and second cross sections of the sections 110 and 120. In order to align the sections 110 and 120 with respect to one another on the basis of the intensity values recorded by the sensor 312, first and second intensity distributions are measured for light beams from first and second cross sections, with in each case one of the first and second cross sections being arranged in a respective one of the sections 110 and 120. A first and a second intensity distribution are therefore in each case measured for each of the two sections 110 and 120. An offset of the cladding 112 and 122 on the optical waveguides 11 and 12 is then set, in order to define an offset of the cores 111 and 121.

Figure 2A shows a beam path for measurement of a first intensity distribution. The object plane 3111 of the imaging optics 311 passes through the cores 111 and 121 of the sections 110 and 120 which are heated by a heat source and caused to emit light. First light beams L11 and L12 originating from the cores 111 and 121 are refracted only slightly because they strike the edges of the cladding 112 and 122 virtually at right angles, and, in consequence, they are focused on the image plane 3112. Light which originates from areas of the object plane 3111 located outside the core are in contrast refracted to a greater extent by the edges of the cladding 112 and 122, and are not focused on the image plane 3112.

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Figure 2B shows a beam path for the measurement of a second intensity distribution. The object plane 3111 of the imaging optics 311 passes through the cladding 112 and 122 of the sections 110 and 120 illuminated by the light source 41 or 42. Second light beams L21 and L22 originating from the edges of the cladding 112 and 122 are focused by the imaging optics 311 on the image plane 3112. Light which is refracted by the sections 110 and 120 is not focused on the image plane 3112. However, this light leads to central maxima in the center of the second intensity distributions, whose positions do not depend on the positions of the cores 111 and 121.

The focusing of the imaging optics 311 is not changed between the measurement of the first intensity distribution and the measurement of the second intensity distribution. That is to say, since both intensity distributions are based on the same imaging of the object plane 3111 on the image plane 3112, it is possible to associate spatially resolved structures with one another in the two intensity distributions.

Figure 3A shows one of the optical waveguides 11 and 12 and one of the sections 110 and 120, in the form of a cross section. A respective one of the cores 111 and 121 is surrounded by respective cladding 112 and 122. A respective one of the cores 111 and 121 has one of the core center points K1 and K2. A respective one of the claddings 112 and 122 has one of the cladding center points M1 and M2. The cores K1 and K2 have the eccentricities or offsets E1 and E2 with respect to the cladding M1 and M2. Respective coordinates for lower core edges K11 and K21, upper core edges K12 and K22, lower cladding edges M11 and M21 and upper cladding edges M12 and M22 are illustrated with respect to a

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first direction X and a second direction Y on the cross-sectional plane.

If the eccentricities E1 and E2 and the positions of the cladding M1 and M2 are known, then the positions of the cores K1 and K2 are defined. A respective one of the eccentricities E1 and E2 can be determined from the first and second intensity distributions for light beams from a cross section of one of the sections 110 and 120.

The cores K1 and K2 can then be positioned via the cladding M1 and M2.

Figure 3B shows a longitudinal section through the two sections 110 and 120. The two sections 110 and 120 are illustrated with a considerable offset in one of the lateral directions X and Y. The eccentricities E1 and E2 are given by the differences between in each case one of the core center points K1 and K2 and the corresponding one of the cladding center points M1 and M2. The difference between the offset ΔK of the core center points K1 and K2 and the offset ΔM of the cladding center points M1 and M2 is the relative eccentricity ΔE . If the relative eccentricity ΔE and the offset of the cladding center points ΔM are known, then the offset ΔK of the core center points K1 and K2 is defined. The relative eccentricity ΔE can be determined from the first and second intensity distributions of the two sections 110 and 120. An offset ΔK of the cores K1 and K2 can then be defined via the offset ΔM of the cladding M1 and M2. Instead of the eccentricities, the distances D1 and D2 between in each case one of the core center points K1 and K2 and one of the cladding edges M11, M12, M21 and M22 can also be used in order to align the cores 111 and 121 via the cladding edges M11, M12, M21 and M22.

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The sensors 311 and 312 illustrated in figures 2A and 2B are arranged in first and second areas B1 and B2, which each extend the sections 110 and 120 over a certain distance in the longitudinal direction Z and in one of the lateral directions X and Y.

Figure 4A shows one of the first intensity distributions I11 and I12. That one of the first intensity distributions I11 and I12 is produced by a first light beam from a cross section of one of the sections 110 and 120. The first light beam is produced by light which is emitted from one of the cores 111 and 121 and from the corresponding cladding 112 and 122 on one of the sections 110 and 120. The light is caused to be emitted by heat being supplied to the sections 110 and 120. That one of the first intensity distributions I11 and I12 is plotted against one of the directions X and Y. This results in the illustrated profile with a central intensity peak KE1, which is bounded by two flanks KF1 and KF2. The position of one of the core center points K1 and K2 with respect to one of the directions X and Y can be determined from the position of the intensity peak KE1.

Figure 4B illustrates one of the second intensity distributions I21 and I22. The one of the second intensity distributions I21 and I22 is produced by a second light beam from a cross section of one of the sections 110 and 120. The second light beam is produced by light which is produced by an illumination device and is refracted on the sections 110 and 120, or passes by at the side. The one of the second intensity distributions I21 and I22 is plotted against one of the directions X and Y. This results in the illustrated profile with the two flanks MF1 and MF2. The position of one of the cladding center points M1 and M2 with

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respect to one of the directions X and Y can be determined from the position of the flanks MF1 and MF2.

The intensity peak R which is also illustrated in Figure 4B is caused by scattered light from the illumination device, which has entered the beam path of the detection apparatus by being reflected on the glass fibers. In the case of the apparatus used for this graph, the directions X and Y include only an angle of 60°. The reflection is shifted towards the center if the angle is 90°.

If the first intensity distributions I11 and I12 for each of the two directions X and Y are known, it is possible to define the positions of the core center points K1 and K2 and their offset ΔK on the plane covered by X and Y. If the second intensity distributions I21 and I22 for each of the two directions X and Y are known, the positions of the cladding center points M1 and M2 and their offset ΔM can be defined on the plane covered by X and Y. If the first and second intensity distributions I11, I12, I21 and I22 for each of the two directions X and Y are known, the eccentricities E1 and E2 and the relative eccentricity ΔE can be defined. The relative eccentricity ΔE is given by the difference between the offset ΔK of the core center points K1 and K2 and the offset ΔM of the cladding center points M1 and M2.

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In one possible variation of the method, the positions of the cores 111 and 112 and of the cladding 112 and 122 can be determined from the first intensity
5 distributions. However, in general, the cladding is illuminated less strongly than the core, so that the position of a cladding edge can be determined with less accuracy than the position of a core edge. Furthermore,
10 the optical waveguide, and make it more difficult to determine the position of the cladding edge.

List of Reference Symbols

	11,12	Optical waveguide
	110,120	Sections of the optical waveguide
5	1101,1201	End surfaces of the sections
	111,121	Cores of the glass fibers
	112,122	Cladding of the glass fibers
	21,22	Heat source, welding electrodes
	31,32	Detection device, detection apparatuses
10	311	Imaging optics
	313	Optical axis of a detection apparatus
	3111	Object plane
	3112	Image plane
	312	Sensor
15	3121	Array of sensor elements
	41,42	Illumination device, light sources
	51,52,53	Holding apparatus, holders
	60	Control device
	71,72	Memory units
20	X,Y	Lateral directions
	Z	Longitudinal direction
	L11, L12	First light beam
	L21, L22	Second light beam
	B1, B2	First and second areas
25	I11, I12	First intensity distributions
	I21, I22	Second intensity distributions
	K1, K2	Core center points
	K11, K21	Lower/left core edges
	K12, K22	Upper/right core edges
30	M1, M2	Cladding center points
	M11, M21	Lower/left cladding edges
	M12, M22	Upper/right cladding edges
	KE1	Intensity peaks of I11 and I12
	KF1, KF2	Flanks produced by edges of the cores
35	MF1, MF2	Flanks produced by edges of the cladding
	D1, D2	Distance from the core center point to the cladding edge

R Reflection

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CLAIMS:

1. A method for determining the eccentricity of a core of an optical waveguide, comprising the following steps:

5 providing an optical waveguide which has a core and a cladding surrounding the core;

heating of a section of the optical waveguide for a predetermined time interval such that a first light beam is produced by emission of light from the core and from the cladding;

10 measuring a first intensity distribution, which is produced by the first light beam, and storing a measurement of the first intensity distribution;

determining a position of a center point of the core from the stored first intensity distribution measurement;

illuminating the section with light such that a second light beam is produced by partial refraction of the light on the core and the cladding;

15 measuring a second intensity distribution which is produced by the second light beam, and storing a measurement of the second intensity distribution;

determining a position of the cladding from the stored second intensity distribution measurement; and

20 determining the eccentricity from the determined position of the center point of the core and from the determined position of the cladding, with the eccentricity indicating the position of the core with respect to the position of the cladding.

2. The method as claimed in claim 1, wherein the step of measuring the second intensity distribution is carried out before or after the step of measuring
25 the first intensity distribution.

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3. The method as claimed in claim 1 or 2, wherein the steps of measuring the first and second intensity distributions are carried out with a short time interval between them.

4. The method as claimed in claims 1 to 3, further comprising the
5 following step:

imaging of an object plane, which passes through the section of the optical waveguide, on an image plane, with the step of measuring the first intensity distribution and the step of measuring the second intensity distribution using the same object plane.

10 5. The method as claimed in claim 4, wherein the object plane is chosen such that the core and the cladding are imaged with sufficient clarity on the image plane.

6. The method as claimed in one of claims 1 to 5, wherein the steps of measuring the first and second intensity distributions each comprise recording of
15 intensity values in the same area which runs transversely with respect to the section of the optical waveguide.

7. The method as claimed in one of claims 1 to 6, further comprising:

determining the position of a local extreme of the first intensity distribution in order in this way to define the position of a core center point;

20 determining the positions of two flanks of the second intensity distribution in order in this way to define the position of a cladding center point;

determining the distance between the core center point and the cladding center point in order in this way to define the core eccentricity; and

25 varying the position of the cladding center point as a function of the core eccentricity in order in this way to move the core center point to a previously defined position.

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8. The method as claimed in one of claims 1 to 6, further comprising the following steps:

determining the position of a local extreme of the first intensity distribution in order in this way to define the position of a core center point;

5 determining the position of a flank of the second intensity distribution in order in this way to define the position of a cladding edge;

determining the distance between the core center point and the cladding edge; and

10 varying the position of the cladding edge as a function of the distance in order in this way to move the core center point to a previously defined position.

9. The method as claimed in one of claims 1 to 8, wherein the step of heating of the section is carried out within a short time interval so that the optical waveguide is deformed only slightly.

15 10. The method as claimed in one of claims 1 to 9, wherein the heating of the section comprises producing an arc for a time interval of a plurality of tenths of seconds.

20 11. The method as claimed in one of claims 1 to 9, wherein the heating of the section comprises producing a laser beam for a time interval of a plurality of tenths of seconds.

12. The method as claimed in one of claims 1 to 11, wherein the measurement of the first and second intensity distributions in each case comprises recording of intensity values in a first area with the first area extending in a first direction transversely with respect to the longitudinal axis of the section.

25 13. The method as claimed in claim 12, wherein the measurement of the first and second intensity distributions in each case comprises recording of intensity values in a second area with the second area extending in a second

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direction transversely with respect to the longitudinal axis of the section, and transversely with respect to the first area.

14. The method as claimed in claim 12 or 13, wherein the recording of the intensity values is carried out simultaneously in the first and second areas.

5 15. The method as claimed in claim 12 or 13, wherein the recording of the intensity values is carried out successively in the first and second areas.

16. A method for connecting at least two optical waveguides, comprising the following steps:

providing the at least two optical waveguides, respectively
10 comprising a core and a cladding surrounding the core;

heating of respective sections of the at least two optical waveguides for a limited time interval, such that first light beams are produced, with one of the first light beams in each case being produced by emission of light from the core and the cladding of in each case one of the sections;

15 measuring first intensity distributions, with in each case one of the first intensity distributions being produced by in each case one of the first light beams and storing measurements of the first intensity distributions;

determining respective positions of center points of the cores of the at least two optical waveguides from the stored first intensity distributions
20 measurements;

illuminating the sections of the optical waveguides with light such that second light beams are produced, with in each case one of the second light beams being produced by partial refraction of the light on the core and on the cladding of in each case one of the sections;

25 measuring second intensity distributions, with in each case one of the second intensity distributions being produced by in each case one of the second light beams, and storing measurements of the second intensity distributions;

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determining respective positions of the cladding of the at least two optical waveguides from the stored second intensity distributions measurements;

5 determining a relative eccentricity from the determined respective positions of the center points of the cores of the at least two optical waveguides and the determined respective positions of the cladding of the at least two optical waveguides, with the relative eccentricity indicating an offset of the respective cores with respect to an offset of the respective cladding of the sections of the at least two optical waveguides;

10 subsequently adjusting the offset of the respective cladding between the claddings as a function of the relative eccentricity in order to define the offset between the cores; and

subsequently connecting the respective sections of the at least two optical waveguides.

17. The method as claimed in claim 16, comprising the following steps:

15 determining the position of a local extreme from in each case one of the first intensity distributions, in order in this way to define the position of in each case one core center point;

determining the position of two flanks from in each case one of the second intensity distributions, in order to define the position of in each case one
20 cladding center point;

determining the relative eccentricity by determination of a first offset between the core center points of a first and of a second of the sections, determining a second offset between the cladding center points of the first and of the second of the sections, and determining the difference between the first offset
25 and the second offset; and

adjusting the second offset of the cladding center points in order to define the first offset of the core center points.

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18. The method as claimed in claim 16 or 17, wherein the steps of measuring the respective one first intensity distribution and of the respective one second intensity distribution of one of the sections in each case comprise recording of intensity values in the same area.

5 19. The method as claimed in claim 17 or 18, wherein the measurement of the first and second intensity distributions comprises recording of intensity values in first areas, with in each case one of the first areas receiving light from one of the sections and extending transversely with respect to the longitudinal axis of that one of the sections in a first direction.

10 20. The method as claimed in claim 19, wherein the measurement of the first and second intensity distributions comprises recording of intensity values in second areas, with in each case one of the second areas receiving light from one of the sections, extending transversely with respect to the longitudinal axis of that one of the sections, and extending transversely with respect to one of the first
15 areas in a second direction.

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PATENT AGENTS

FIG 1

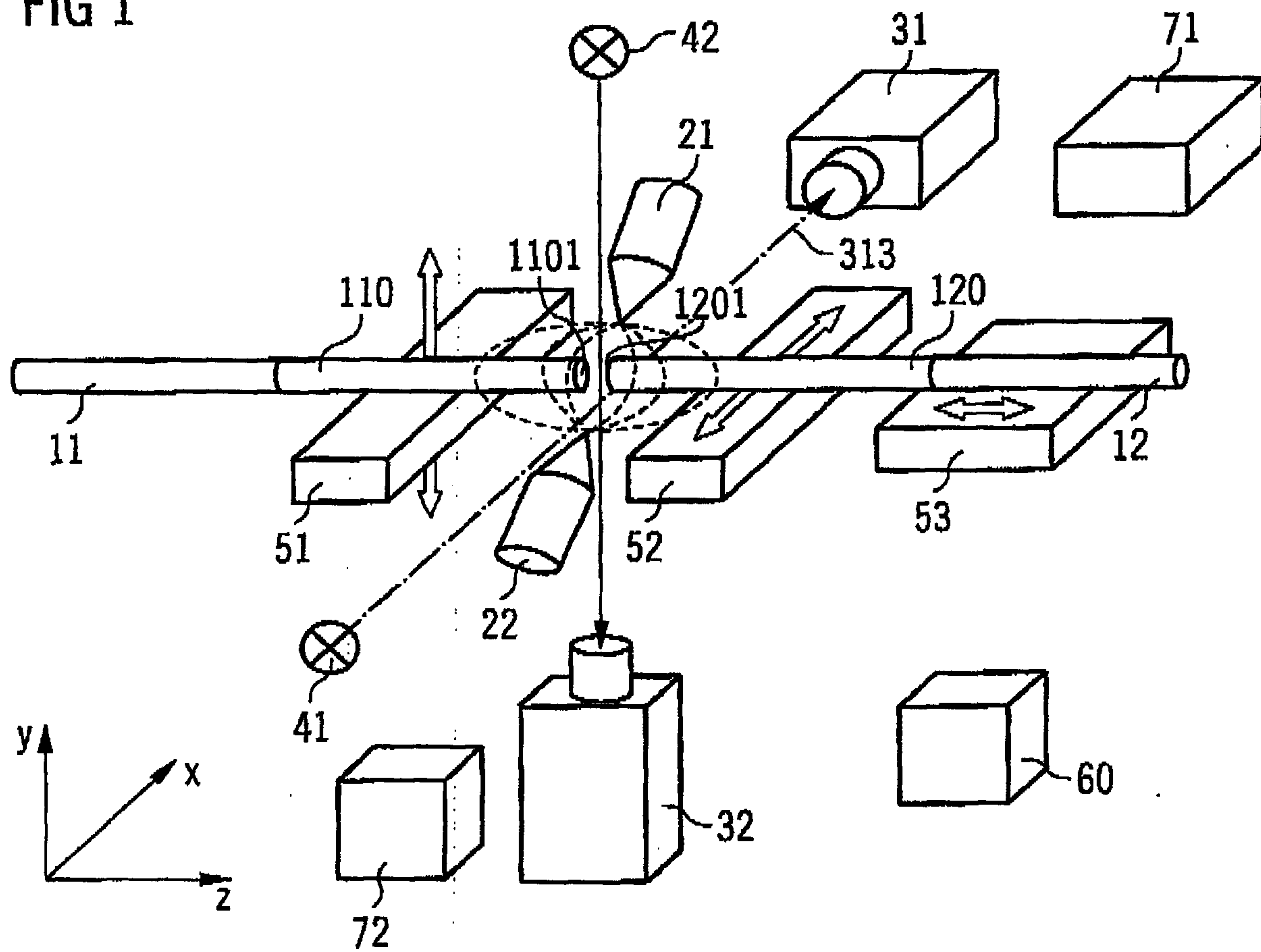


FIG 2A

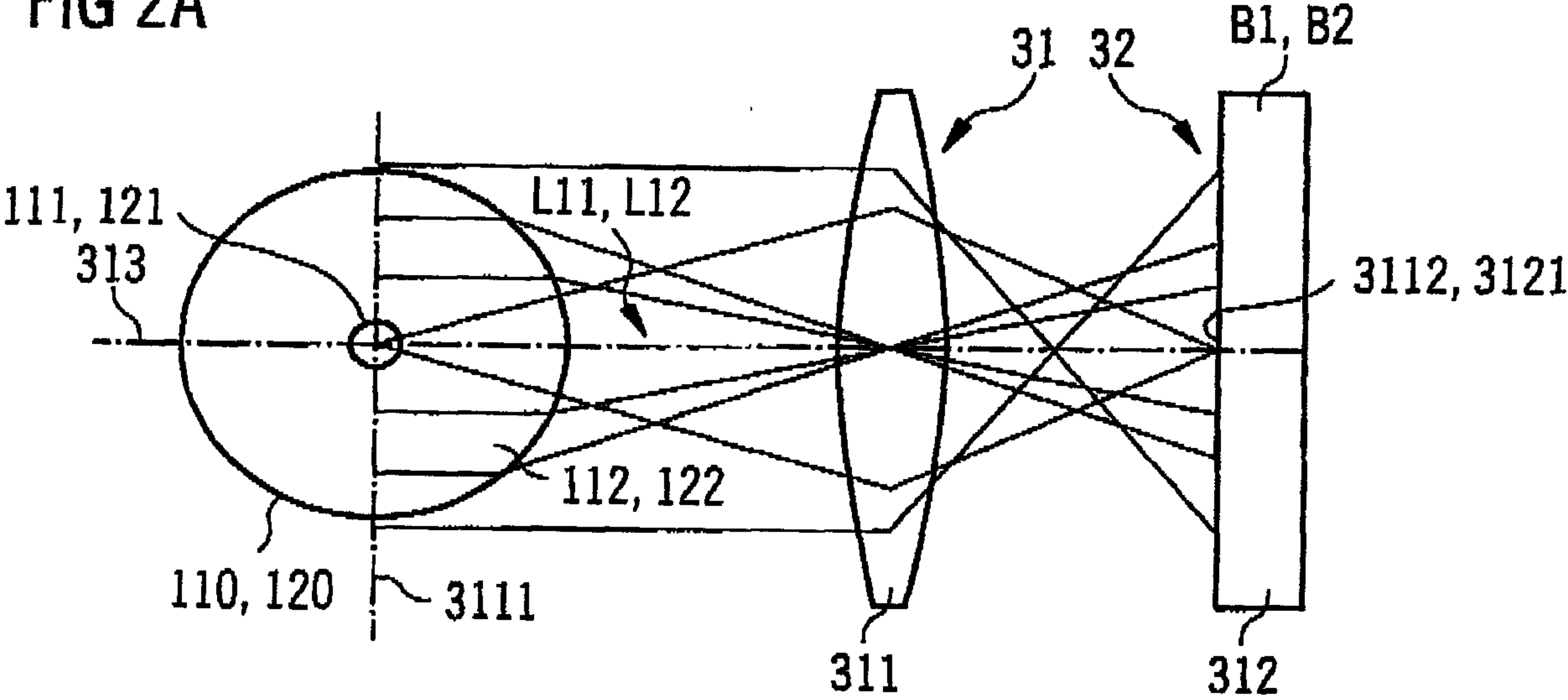


FIG 2B

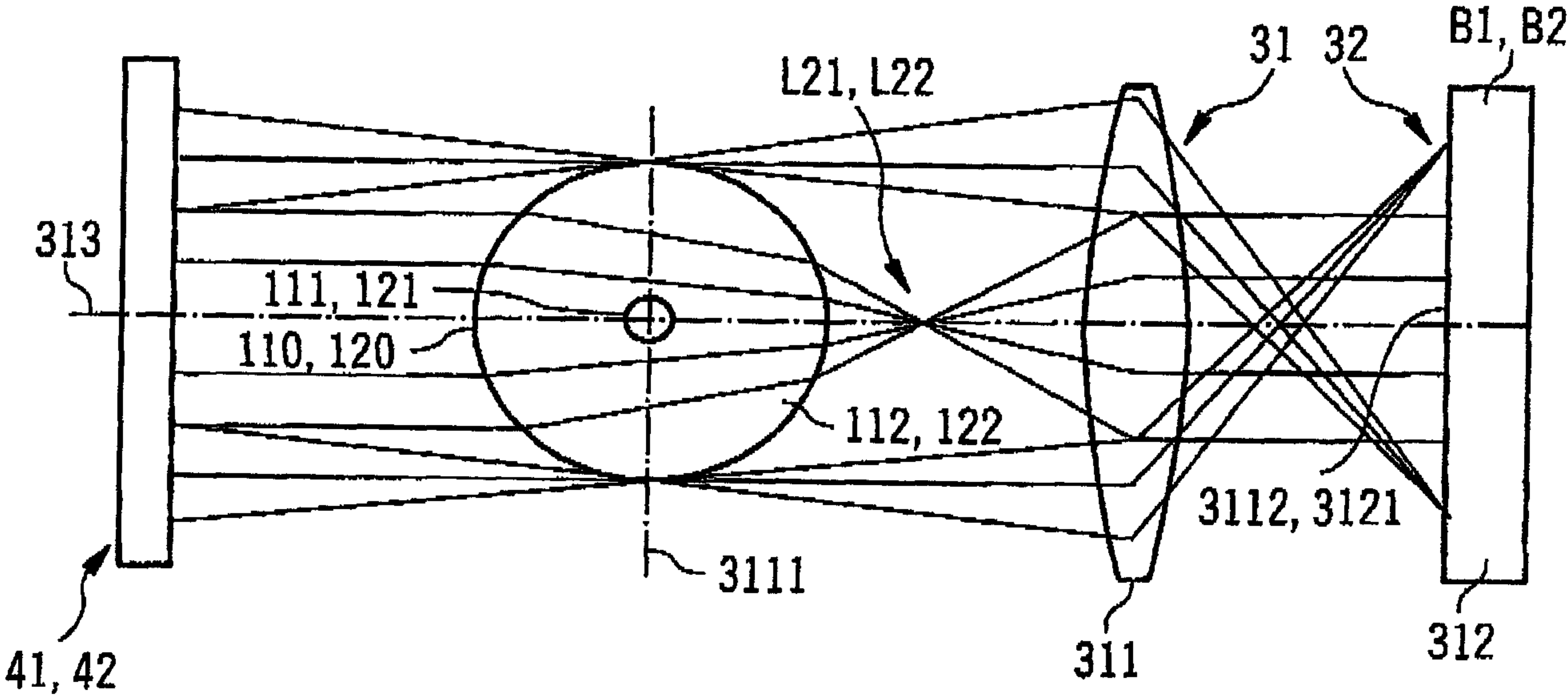


FIG 3A

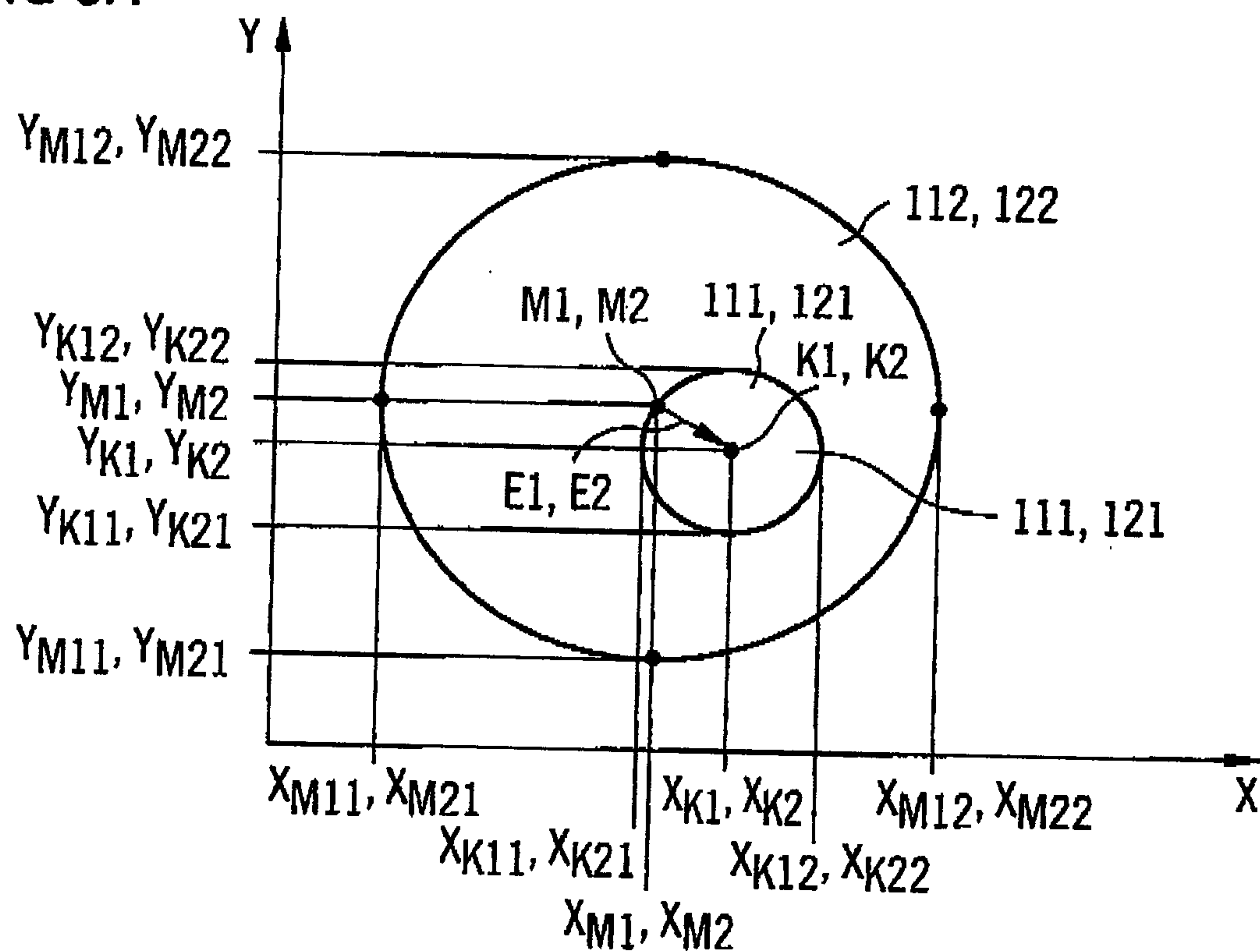
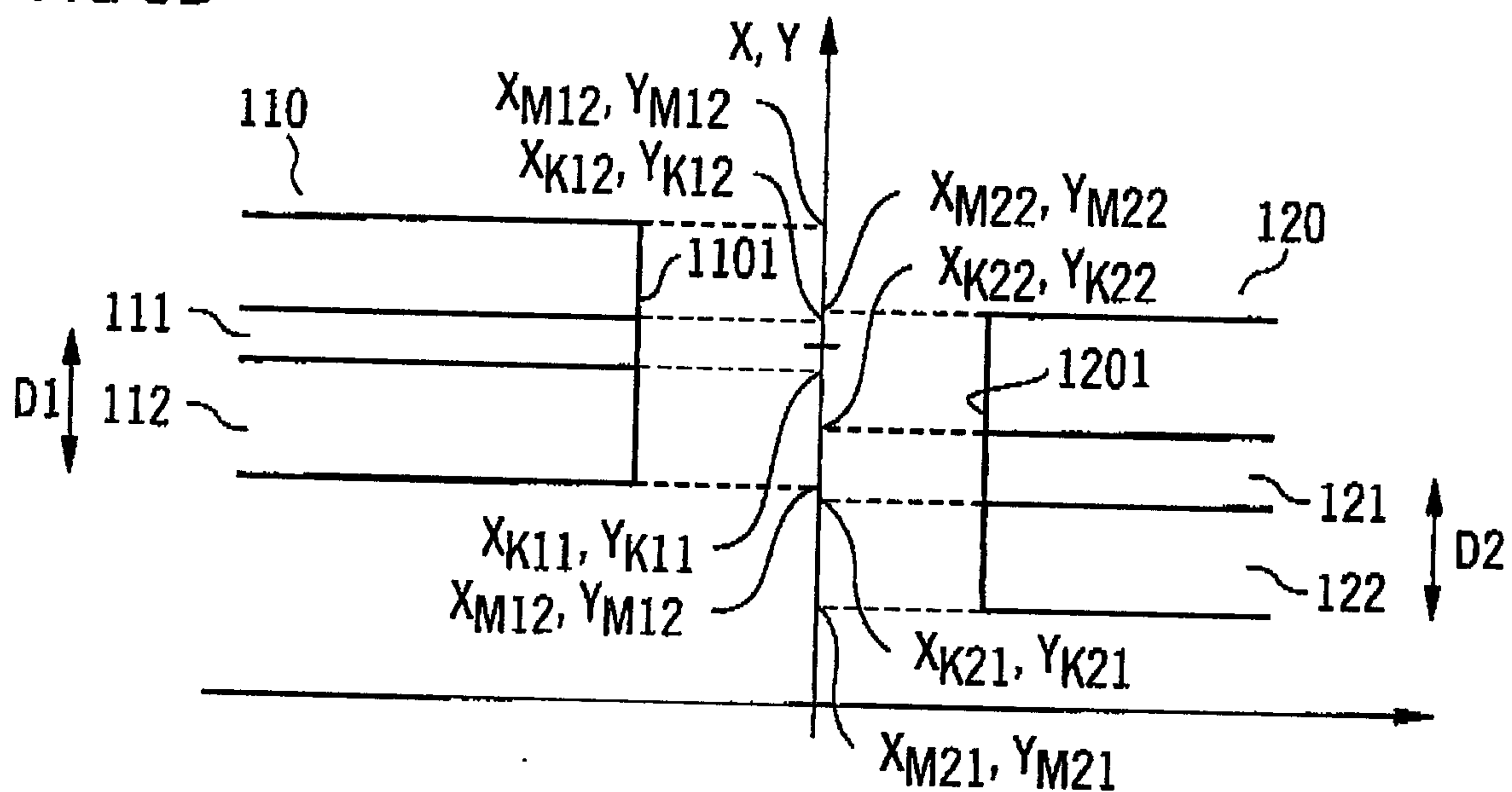


FIG 3B



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FIG 4A

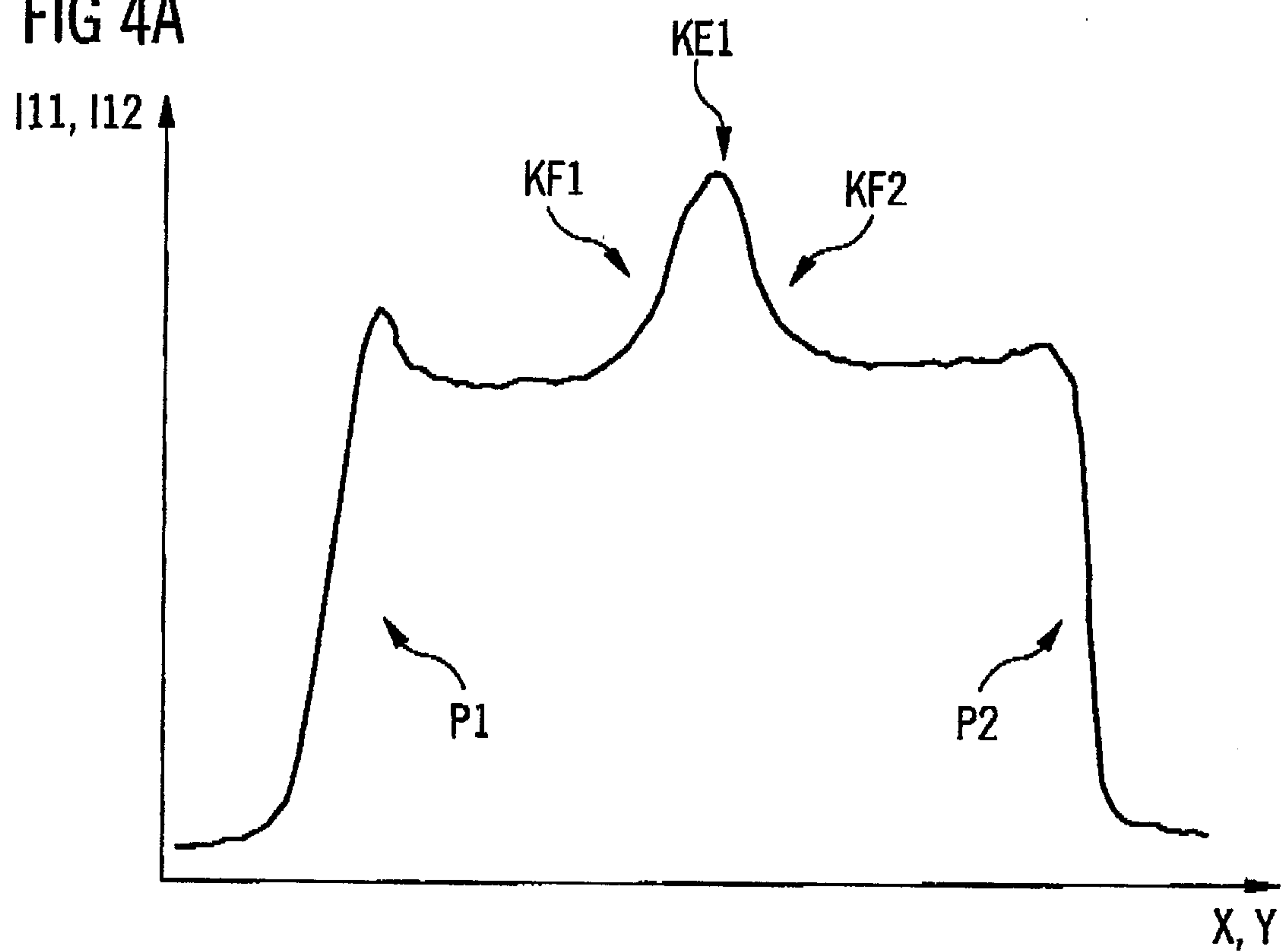


FIG 4B

