PCT WORLD INTELLE

INTERNATIONAL APPLICATION PUBLISH

WO 9603675A1

(51) International Patent Classification 6 :
G02F 1/37

A1

(43) International Publication Date: 8 February 1996 (08.02.96)

(21) International Application Number: PCT/EP95/02982

(22) International Filing Date: 25 July 1995 (25.07.95)

(30) Priority Data:
94202188.2 27 July 1994 (27.07.94) EP
(34) Countries for which the regional or international application was filed: AT et al.

(71) Applicant *(for all designated States except US)*: AKZO NOBEL N.V. [NL/NL]; Velperweg 76, NL-6824 BM Arnhem (NL).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: HORSTHUIS, Winfried, Henri, Gerard [NL/NL]; Oostveenweg 56, NL-7533 VV Enschede (NL).

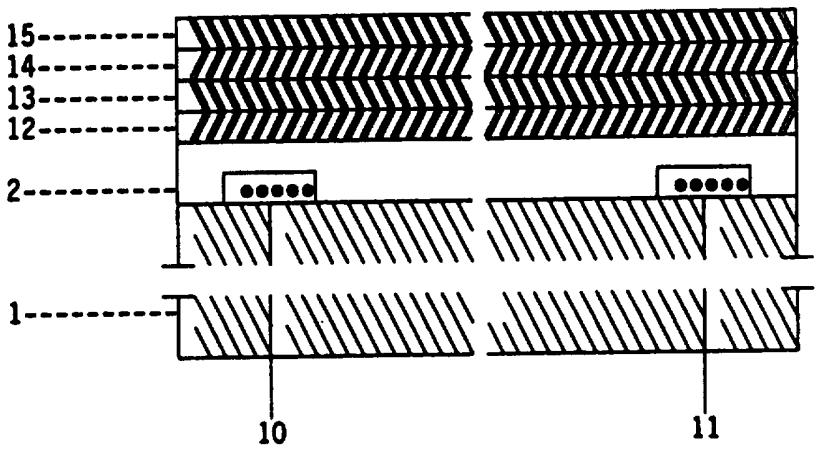
(74) Agent: SCHALKWIJK, Pieter, Cornelis; Akzo Nobel N.V., Patent Dept. (Dept. Apta), P.O. Box 9300, NL-6800 SB Arnhem (NL).

(81) Designated States: CA, CN, JP, KR, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: POLYMERIC MULTILAYER OPTICAL WAVEGUIDE SUITABLE FOR FREQUENCY DOUBLING

(57) Abstract



The invention concerns an optical waveguide component comprising a layered polymeric optical waveguide structure comprising a light guiding layer (3) of an optically non-linear polymer (NLO polymer) sandwiched between two deflection layers (2, 4) of a lower refractive index than the light guiding layer (3), the NLO polymer being poled in-plane, in a direction perpendicular to the light guiding direction. Such a waveguide can be used to generate surface emitted second harmonic light as a result of the interaction of counterpropagating waves. In order to enable phase-matching by providing a periodic structure of alternatingly poled NLO polymer, the light guiding layer (3) consists of a plurality of sublayers (8, 9), said sublayers alternately being of a first and a second NLO polymer, with one of the NLO polymers (the "HS polymer") having a higher softening temperature than the other (the "LS polymer").

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**GB**	United Kingdom	**MR**	Mauritania
AU	Australia	**GE**	Georgia	**MW**	Malawi
BB	Barbados	**GN**	Guinea	**NE**	Niger
BE	Belgium	**GR**	Greece	**NL**	Netherlands
BF	Burkina Faso	**HU**	Hungary	**NO**	Norway
BG	Bulgaria	**IE**	Ireland	**NZ**	New Zealand
BJ	Benin	**IT**	Italy	**PL**	Poland
BR	Brazil	**JP**	Japan	**PT**	Portugal
BY	Belarus	**KE**	Kenya	**RO**	Romania
CA	Canada	**KG**	Kyrgystan	**RU**	Russian Federation
CF	Central African Republic	**KP**	Democratic People's Republic of Korea	**SD**	Sudan
CG	Congo			**SE**	Sweden
CH	Switzerland	**KR**	Republic of Korea	**SI**	Slovenia
CI	Côte d'Ivoire	**KZ**	Kazakhstan	**SK**	Slovakia
CM	Cameroon	**LI**	Liechtenstein	**SN**	Senegal
CN	China	**LK**	Sri Lanka	**TD**	Chad
CS	Czechoslovakia	**LU**	Luxembourg	**TG**	Togo
CZ	Czech Republic	**LV**	Latvia	**TJ**	Tajikistan
DE	Germany	**MC**	Monaco	**TT**	Trinidad and Tobago
DK	Denmark	**MD**	Republic of Moldova	**UA**	Ukraine
ES	Spain	**MG**	Madagascar	**US**	United States of America
FI	Finland	**ML**	Mali	**UZ**	Uzbekistan
FR	France	**MN**	Mongolia	**VN**	Viet Nam
GA	Gabon				

POLYMERIC MULTILAYER OPTICAL WAVEGUIDE SUITABLE FOR FREQUENCY DOUBLING

(a) Field of the Invention

The invention concerns an optical waveguide component comprising a layered optical waveguide structure comprising a light guiding layer of an optically non-linear polymer (NLO polymer) sandwiched between two deflection layers of a lower refractive index than the light guiding layer, the NLO polymer being poled in-plane, in a direction perpendicular to the light guiding direction. The invention particularly pertains to components suitable for generating second harmonic light.

Optically non-linear materials, also called non-linear optical (NLO) materials, are known. In such materials non-linear polarisation occurs under the influence of an external field of force (such as an electric field). Non-linear electric polarisation may give rise to several optically non-linear phenomena, including the generation of second harmonics, i.e., frequency doubling.

Polymeric NLO materials also are known. Obtaining the desired NLO effect in these macroscopically requires that first the groups present in such a material, mostly hyperpolarisable sidegroups, be aligned (poled). Such poling is usually effected by exposing the polymeric material to electric (dc) voltage, the so-called poling field, with such heating as will render the polymeric chains sufficiently mobile for orientation. In most cases the poling field will be directed such that the obtained orientation of the NLO groups is in the z-direction, i.e. perpendicular to a plane parallel to the layers (the layers all being in the xy plane) and perpendicular to the light guiding direction (which is either the x- or the y direction). However, since it is desired to provide optical waveguide components in which the

interaction of counterpropagating light results in out-of-plane emission (surface emission), plane-parallel poling needs to be developed. Plane-parallel poling (in-plane poling) means that an orientation of the NLO groups is obtained which is parallel to the plane of the layers, i.e., in the xy plane. The direction is perpendicular to the light guiding direction, i.e., if the light is guided in the x-direction, the orientation is in the y-direction.

(b) Background Art

In Appl. Phys. Lett. 63(25), 1993, pages 3405-3407, surface emitted second harmonic generation (SHG) is demonstrated. The SHG occurs as a result of the mixing of counterpropagating waves in in-plane poled channel waveguides of a single film of an NLO polymer. In the document, it is suggested to employ multiple layer films with alternate films of zero activity is suggested in order to enhance the efficiency of the waveguide.

In order to provide an optical component on the basis of an in-plane poled NLO polymer waveguide suitable for being used in practice as a frequency doubling device, it is required that light subjected to frequency doubling is prevented from being wholly or partially extinguished prior to leaving the frequency doubler. Such extinction is connected with the so-called "coherence length". This is the distance between two spaced apart points A and B, with the frequency doubled component of the light of the original wavelength travelling through the frequency doubler generated at point B being in counterphase to a frequency doubled component of the original light already generated at point A. To prevent such extinction, it is known to provide a periodic structure of alternatingly poled polymeric NLO material. The periodicity should be equal to twice the coherence length. This is known int. al. from US US 5,282,078 and US 5,289,308, in which second harmonics are generated in a waveguide channel that

comprises discrete portions of alternatingly poled NLO polymer. Said US patent specifications disclose methods of making such a frequency doubling structure in the optically non-linear polymeric material.

According to US'078, the structure is made by forming a layer of a first NLO polymer, partially removing it by etching after it has been poled with the aid of a first electric field or not, such that a grating structure is formed composed of etched grooves in the polymer, and applying a layer of a second NLO polymer, such that the etched grooves are backfilled, after which the resulting alternating structure of the two NLO polymers is subjected either to a second electric field oppositely directed to the first one, or in the case of poling of the first polymer not yet having taken place, to two oppositely directed electric fields in succession. The second electric field is applied at a temperature which will not affect the poling of one NLO polymer effected by the first electric field.

According to US'308 the structure is made by forming a layer of NLO polymer, effecting poling in it with the use of an electric field, partially removing the layer of NLO polymer by etching, such that in the polymer a grating structure is formed composed of etched grooves and projecting polymer parts, the width of the grooves matching that of the polymer parts, dividing the polymer layer containing the grating structure into at least two sections, and placing the two sections one on top of the other, such that grooves of the one section are backfilled by projecting polymer parts of the other section. These disclosures do not provide any method for making a frequency doubler that works on the basis of counterpropagating waves.

Layered waveguides in which surface emitted second harmonic generation is possible have been known in inorganic NLO materials, such as GaAs. See Appl. Phys. Lett. 59(8), 1991, pages 896-898, and 62(2), 1993, pages 118-120; Electronics Letters, Vol.29, No.11 27th May 1993, page

975; IEEE Journal of Quantum Electronics Vol.27, No.6 (June 1991), pages 1520-1530; Optics Letters Vol.17, No.23 (December 1, 1992), pages 1718-1720, Vol.18, No.8, 1993, pages 589-591, and Vol.4, No.2 (1979), pages 58-59. Since the nature of these intrinsic NLO materials is quite different from that of NLO polymers, which require poling, none of these documents offers any teaching on the making of layered polymeric NLO waveguides.

(c) Disclosure of the Invention

The invention now has for its object to provide a polymeric optical waveguide component that leads to efficient non-linear optics for TE guided modes. More particularly, the aim of the invention is to provide a polymeric optical waveguide component that can be used for frequency doubling of counterpropagating waves (i.e., the surface emission of second harmonics) and in which it is possible to provide a periodic structure of alternatingly poled NLO polymer. To this end, the invention consists therein that in an optical waveguide component of the type described in the opening paragraph, the light guiding layer consists of a plurality of sublayers, said sublayers alternately being of a first and a second NLO polymer, one of the NLO polymers (the "HS polymer") having a higher softening temperature than the other one (the "LS polymer").

The term "softening temperature" is employed to indicate the temperature point or range above which an electric field will cause alignment of the NLO groups. This temperature is dependent on the period of time over which the polymer is exposed to the electric field. For clarity, this description speaks always of temperature (assuming the fiction of a fixed period of time). Within the scope of the invention varying the time must be regarded as a technique for changing the temperature to be employed for a particular NLO polymer. If two polymers are said to have different softening temperatures,

this means that one of the two polymers can be aligned under conditions of temperature and time at which the orientation of the NLO groups in the other polymer is not affected.

The structure of the polymeric optical waveguide component according to the invention thus permits alternate poling by making successive use of a first electric field and a second, oppositely directed electric field, such that the guiding layer consisting of alternating sublayers of the two NLO polymers is subjected to the second electric field at a temperature below the softening temperature of the HS polymer and above that of the LS polymer.

The maximum temperature at which the alternating sublayers of the two NLO polymers can be subjected to the second poling field is dependent on the individual polymers. However, in actual practice it is relatively easy for the skilled man to determine above which temperature the alignment of a particular NLO polymer will be affected by an electric field. One way of determining this is by carrying out such a relaxation measurement as described by C.P.J.M. van der Vorst and C.J. van Weerdenburg in Proc. SPIE-Int. Soc. Opt. Eng. 1337 (1990), p. 246. For instance, a fixed time period may be adhered to to study different temperatures/temperature ranges. Alternatively, of course, it is also possible to vary the period of exposure to the poling field at a particular temperature.

By way of a general guideline it can be stated that the temperature at which the alignment of a polymer is not affected will as a rule be a temperature below the glass transition temperature T_g. For a thermoplastic polymer T_g in this case stands for the glass transition temperature as it can be determined by the conventional techniques. These techniques are known to the skilled man and require no further elucidation here. In the case of a thermosetting polymer, there is no question of an actual T_g above which flow will occur, but rather of an

"apparent T_g" above which the polymer chains and the present hyperpolarisable groups will become so mobile as to have their orientation influenced by an electric poling field. Within the scope of the invention the term "NLO polymer" always refers to thermoplastic, generally amorphous polymers, as well as to thermosets. Also comprised by the term "NLO polymer" according to the invention are suitable oligomers, copolymers, mixtures of polymers, and other suitable organic NLO materials out of which a layer can be made. The term "NLO polymers" includes guest-host systems of conventional polymers, such as PMMA, that are doped with NLO-active molecules.

The division of the guiding layer into alternating sublayers makes it possible to apply two oppositely directed poling fields in succession, and thus to provide the required alternated poling.

It should further be noted that the electric voltage generated by the poling field generally is d.c. voltage, but that it has also proved possible, under certain conditions described in the literature, to make use of a.c. voltage, cf. Paul R. Ashley and Thomas E. Tumolillo, Opt. Soc. Am. Technical Digest Series Vol. 8 (1991), p. 87.

The layered polymeric optical waveguide structure can be formed conveniently by applying the various subsequent layers (deflection layer, NLO polymer sublayers) in the form of a solution, e.g. by means of spincoating, followed by evaporating the solvent. The deflection layers may be polymeric layers, but can also be made of (inorganic) glass. The top deflection layer may also be a gas or liquid or vacuum. The lower deflection layer preferably is applied onto a substrate, e.g. a silicon wafer. Suitable substrates are known to the skilled man, and the type of substrate is not essential to the present invention. The lower deflection layer may also serve as the substrate itself, particularly in the case of an inorganic glass or a thermoset polymer.

A method of making an optical waveguide component such as described above may comprise the following steps:

- Forming a deflection layer.
- Forming an NLO polymer stack comprising a plurality of layers of NLO polymer by forming on the deflection layer a first layer of a first NLO polymer, forming on the first layer of the first NLO polymer a first layer of a second NLO polymer, forming on said first layer of the second NLO polymer a second layer of the first NLO polymer, forming on said second layer of the first NLO polymer a second layer of the second NLO polymer, and, optionally, forming subsequent alternating layers of the first and second NLO polymers;
- Optionally forming a polymeric deflection layer on the top layer of NLO polymer. The top deflection layer may also be gas, liquid or glass.

In this method, electrodes are applied in such a manner that the NLO polymer stack is subjected to a first and a second poling field, said first and second poling fields being in a plane parallel to the layers and having opposite directions perpendicular to the light guiding direction, with the alternating structure of the two NLO polymers being subjected to the second electric field at a temperature which will not affect the poling of one NLO polymer effected by the first electric field. The electrodes for generating the respective electric fields preferably are each placed on one side of the same layer (e.g. the lower deflection layer). They may also be placed in different layers. When all the sublayers of the guiding layer have been applied, one or more waveguide channels can be formed in the guiding layer, e.g. by irradiation such as described in US 5,142,605.

It is not critical which of the two NLO polymers is the HS polymer and which the LS polymer, as long as the two polymers alternate. Of course, it is conceivable that a third NLO polymer is employed, or a fourth, and so on, as long as layers of polymers with higher softening

temperatures alternate with layers of polymers with lower softening temperatures. Using only two NLO polymers is the most convenient option.

It should be noted that it is also possible to carry through separate poling of each individual sublayer before applying the next sublayer. This is necessary if one of the two NLO polymers is a true thermoset, since such a thermoset has to be poled during the formation of the thermoset network, and generally the network will be formed before a next layer is applied. In this respect it is preferred that the NLO polymers be thermoplastic. However, it is envisaged, and actually preferred, if each layer of thermoplastic NLO polymer is slightly cross-linked. Such slight cross-linking, however, merely serves to enhance the sturdiness of the layer, and particulary facilitates the application of a subsequent layer. It does not affect the polymer's ability to be poled. See, e.g., EP 350 112.

The optical waveguide component according to the invention particularly is suitable for generating second harmonic light, i.e., it can be used as a frequency doubler.

Using solid state lasers, it is possible in many optical techniques to employ electromagnetic radiation of which the wavelength falls at the near-by infrared end of the electromagnetic spectrum or even within that region thereof in which there is question of visible light (red). However, for many optical applications it is desired to have the use of light of a wavelength which falls within the middle region of the visible light range or at the far removed (blue) end thereof. Examples of applications for which this is particularly desired include optical data storage, optical communication technics, scanning, and medical applications of optics. To provide a light source emitting a single wavelength in the desired region, it is known to pass electromagnetic radiation emitted by an existing light source, e.g. a laser having a

wavelength in the range of, say, approximately 700 to approximately 1300 nm, through a frequency doubler, which will give a light source emitting a wavelength of half that length, i.e., in the range of approximately 350 to 650 nm. In such a method it is known to employ optically non-linear materials as a frequency doubling structure.

Of vital importance to the frequency doubling action of the optical waveguide component according to the present invention is the division of the guiding layer into sublayers of alternating NLO polymers. As has been indicated above, the periodicity of the alternating structure should be equal to twice the coherence length. As appears from, int. al., US Patent Specification 4 971 416 mentioned hereinbefore, the following can be said to hold for the spatial periodicity Λ:

$\Lambda = 2\ l_c = 2\pi/\Delta k$

wherein l_c equals the coherence length and Δk stands for the difference in wave vectors between the frequency doubled optical wavefront and the original (frequency generating) optical wavefront.

On the basis of the wavelength of the counterpropagating waves employed, the skilled man is able to select the correct thickness for the alternating sublayers of the two NLO polymers. For maximum phase matching, the thickness of each sublayer should be equal to the coherence length.

To obtain a well-defined alternating structure of the two NLO polymers, the greatest possible effort must be made to prevent part of the first polymer from being dissolved in any solvent used to apply the second NLO polymer. By making use of a volatile solvent, optionally with rapid heating, so that the solvent may be removed before it can cause the aforementioned drawback, such dissolution may be obviated. It is preferred, however, to employ a solvent for the second polymer which will not cause the first polymer to be dissolved or even to swell. More particularly, it is preferred that the first

NLO polymer be a thermosetting composition, since the resulting cured polymeric network will usually prove resistant to most of the solvents employed for NLO polymers.

Poling the NLO polymers in the method according to the invention is by means of the application in a known manner of an electric field. To this end the material to be poled, which is commonly deposited on a substrate, is provided with electrodes connected to a rectified voltage feed and, e.g., placed on a controlled temperature table. Voltages of some tens to several hundreds of volts per μm of polymer layer thickness are common. The period of exposure to the electric field is generally in the range of a few seconds to several minutes, but may also be from some tens of minutes to one hour - notably when use is made of a thermosetting NLO composition. The period of time required is further dependent on the temperature at which poling takes place. As has been stated above, this temperature is dependent on the NLO polymers used, but as a rule it will be in the range of about 50° to about 350°C, more particularly in the range of 150° to 250°C. The poling field is maintained as the poled material is cooled down to ambient temperature.

Representative poling temperatures and the appropriate periods of time required are known, int. al., from patent publications. Thus, it is known from EP 378 185 to expose an NLO copolymer described therein to an electric field strength of 8×10^5 V/cm for a period of 20 minutes at a temperature of 85°C. In US 4 865 406 an NLO polymer described therein is exposed for 10 minutes to an electric field strength of 70 V/μm at a temperature of 90°C. EP 396 172 describes the alignment of an NLO polymer by means of corona discharge at a temperature of 127°C. In EP 445 864, in which there is question of an NLO thermoset, a thermosetting composition is cured and poled at a temperature of 145°C over a period of 15 to 45 minutes. In EP 359 648 there is poling under the influence of an electric field of 50 V/μm at a temperature of 100°C for a few seconds.

Together with other patent and technical literature, said publications provide guidelines for poling under the influence of an electric field for a wide range of polymeric NLO materials. On the basis of the prescribed step according to the invention of the alternating structure of the two NLO polymers being subjected to a second electric field which will not affect the alignment of one already poled NLO polymer, the skilled man, given the literature, is in a position to determine which polymers to use as the HS polymer and which as the LS polymer.

It is advantageous to avoid the processing of poled material by first making the desired alternating structure of layers of HS and LS polymer, and then carrying through the oppositely directed poling of the two NLO polymers. This can be done by applying a poling field in one direction at a temperature sufficient to orient both NLO polymers, i.e., above the softening temperature of the HS polymer, and applying an oppositely directed poling field at a lower temperature, i.e., below the softening temperature of the HS polymer and above that of the LS polymer, so as to reverse the poling of the LS polymer.

As indicated above, the structure of alternatingly poled NLO polymer according to the invention is sandwiched between two deflection layers having an index of refraction lower than that of the two NLO polymers. Depending on the NLO polymers used, it is also possible to realise a waveguide by creating in the NLO polymer a channel having a higher index of refraction than the surrounding material, e.g. by the method set forth in EP 358 476.

Use can be made of known NLO polymers. Examples of such NLO polymers include those described in EP 350 112, EP 350 113, EP 358 476, EP 445 864, EP 378 185, EP 359 648, as well as those described in the US patent specifications mentioned hereinbefore. The invention is not restricted to any particular type of NLO polymer. Its essence lies in

the use of two different NLO polymers. The term "different" refers primarily to such a difference in physical properties that the temperature below which the alignment of the hyperpolarisable groups present is not affected is different for the two NLO polymers, preferably by at least about 10°C, more particularly by about 20°-40°C, while the optical properties are virtually identical. The desired difference in softening temperatures depends on the absolute values thereof. The higher the softening temperature of one polymer, the larger the desired difference from the softening temperature of the other polymer will be. E.g., if the LS polymer has a Tg of 100°C, the HS polymer may have a Tg of 110°C. If the LS polymer has a Tg of 180°C, it is desirable for the HS polymer to have a Tg of 220°C.

According to a preferred embodiment of the present invention, the first and second NLO polymers used are similar, hence compatible polymers differing only with respect to T_g. Such NLO polymers include the polyurethanes described in US 5 001 209. These polyurethanes are prepared from a hyperpolarisable group-containing diol and a diisocyanate. The T_g can be set by varying the diisocyanate. For instance, a disclosed polyurethane based on IPDI (isophorone diisocyanate) and a particular diol has a T_g of 130°C, whereas a polyurethane based on the same diol in which the diisocyanate is THMDI (2,2,4-trimethyl hexamethylene diisocyanate) has a T_g of 75°C. By using mixtures of diisocyanates it is generally possible to set the T_g of these polyurethanes as desired. Of course, it is also possible to use a plasticizer to set the T_g of the NLO polymers. Plasticizers, such as dioctyl phthalate, and their effect on the softening temperature of polymers are known to the skilled man and require no further elucidation here.

When use is made of NLO polymers of different T_g in which the hypolarisable groups are the same and the other monomers wholly or partially different, the optical properties of the two different NLO

polymers will generally be virtually identical. Because of this dominance on the part of hyperpolarisable groups it is possible to employ NLO thermosets and non-crosslinked (linear or branched) NLO polymers of virtually identical optical properties.

The optical waveguide component of the present invention can be used not only for generating second harmonic waves, but also for any other conceivable application involving the interaction of counterpropagating waves having identical or different wavelengths.

The invention is further illustrated with reference to the drawings. These drawings are presented for purposes of explanation only, and should not be considered limitative in any way.

In Figure 1 a cross section perpendicular to the light guiding direction is shown of an optical waveguide which is built up of the following consecutive layers:

(4) top deflection layer
(3) guiding layer
(2) bottom deflection layer
(1) silicon wafer (substrate)

The guiding layer (3) contains a waveguide channel (5) made by bleaching, i.e. irradiating the surrounding material (6) so as to lower the index of refraction. Arrow (7) indicates the direction in which the NLO polymer of the guiding layer is poled (in-plane poling).

In Figure 2 an enlargement is given of a similar cross-section of an optical waveguide according to the invention. The guiding layer (3) is shown to be built up of sublayers (8,9) of alternatingly poled NLO polymer. The poling directions are indicated by arrows (→) and (←) pointing in the respective poling directions.

Figure 3 shows a cross-section of the same optical waveguide, this time along the axis of the waveguide channel (5), i.e., orthogonal to the cross-section depicted in Fig. 2. The ">" and "<" signs (10) and (11) indicate the counterpropagating waves, both of which are of the same wavelength, coupled in into the waveguide channel through conventional coupling means (not shown). The arrow (12) indicates the surface emitted second harmonics (i.e., the frequency doubled light) resulting from the interaction of the counterpropagating waves in the in-plane poled NLO polymer.

Figures 4-8, which all depict the same structure as in Figure 1, show several possible positions for the electrodes (10,11) that are used to generate the successive, alternating poling fields.

In Figure 4, the two electrodes (10,11) are placed on the substrate.

In Figure 5, the two electrodes (10,11) are placed on the lower deflection layer.

In Figure 6, the two electrodes (10,11) are placed on the guiding layer.

In Figure 7, the two electrodes (10,11) are placed on the top deflection layer.

In Figure 8, one electrode (10) is placed on the substrate, while the other electrode (11) is placed on the guiding layer.

In Figure 9, several steps in a method for making an optical waveguide component according to the invention are shown in cross-section.

9a: a substrate (1) is provided with electrodes (10,11);
9b: a deflection layer (2) is formed on the substrate;

9c: a first layer (12) of a first NLO polymer is formed on the deflection layer;

9d: a first layer (13) of a second NLO polymer is formed on said first layer of the first NLO polymer;

9e: a second layer (14) of the first NLO polymer is formed on said first layer of the second NLO polymer;

9f: a second layer (15) of the second NLO polymer is applied on said second layer of the first NLO polymer;

Claims:

1. An optical waveguide component comprising a layered optical waveguide structure (1) comprising a light guiding layer (2) of an optically non-linear polymer (NLO polymer) sandwiched between two deflection layers (3,4) of a lower refractive index than the light guiding layer (2), the NLO polymer being poled in-plane, in a direction perpendicular to the light guiding direction, characterized in that the light guiding layer (2) consists of a plurality of sublayers (8,9), said sublayers alternately being of a first and a second NLO polymer, with one of the NLO polymers having a higher softening temperature than the other.

2. An optical waveguide component according to claim 1, characterized in that the two NLO polymers are amorphous, thermoplastic polymers with glass transitions temperatures (T_g) differing by at least 10°C.

3. An optical waveguide component according to claim 1 or 2, characterized in that the sublayers (8,9) of the two NLO polymer have been poled alternatingly in opposite directions.

4. An optical waveguide component according to claim 3, characterized in that the thickness of each sublayer (8,9) is equal to the coherence length of the second harmonic light waves generated when two beams of the same wavelength are led through the guiding layer in opposite directions.

5. An optical waveguide component according to any one of the preceding claims, characterized in that the two NLO polymers comprise identical hyperpolarisable groups.

6. A method of making an optical waveguide component such as claimed in claim 1, the method comprising the following steps:

- forming a deflection layer;
- forming an NLO polymer-stack comprising a plurality of layers of NLO polymer by forming on the deflection layer a first layer of a first NLO polymer, forming on the first layer of the first NLO polymer a first layer of a second NLO polymer, forming on said first layer of the second NLO polymer a second layer of the first NLO polymer, forming on said second layer of the first NLO polymer a second layer of the second NLO polymer, and, optionally, forming subsequent alternating layers of the first and second NLO polymers;
- optionally forming a deflection layer on the top layer of NLO polymer;

electrodes being applied, and the NLO polymer stack being subjected to a first and a second poling field, said first and second poling fields being in a plane parallel to the layers and having opposite directions perpendicular to the light guiding direction, with the alternating structure of the two NLO polymers being subjected to the second electric field at a temperature which will not affect the poling of one NLO polymer effected by the first electric field.

FIG. 1

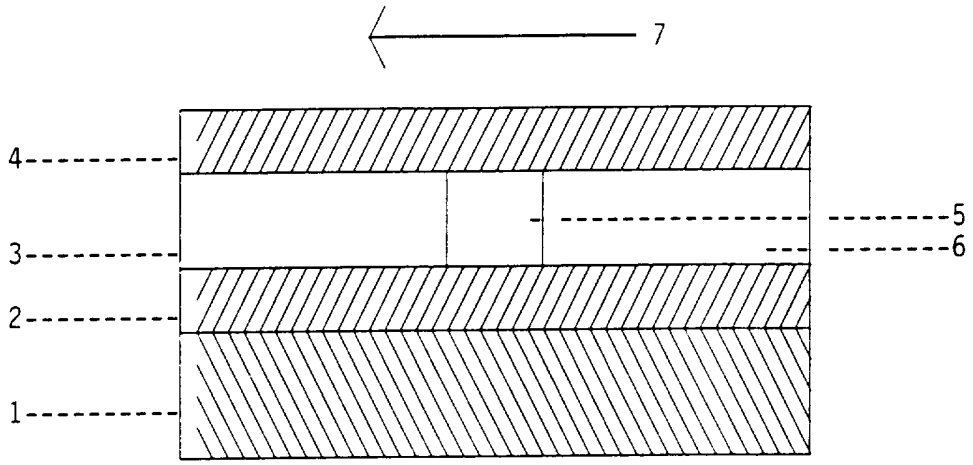


FIG. 2

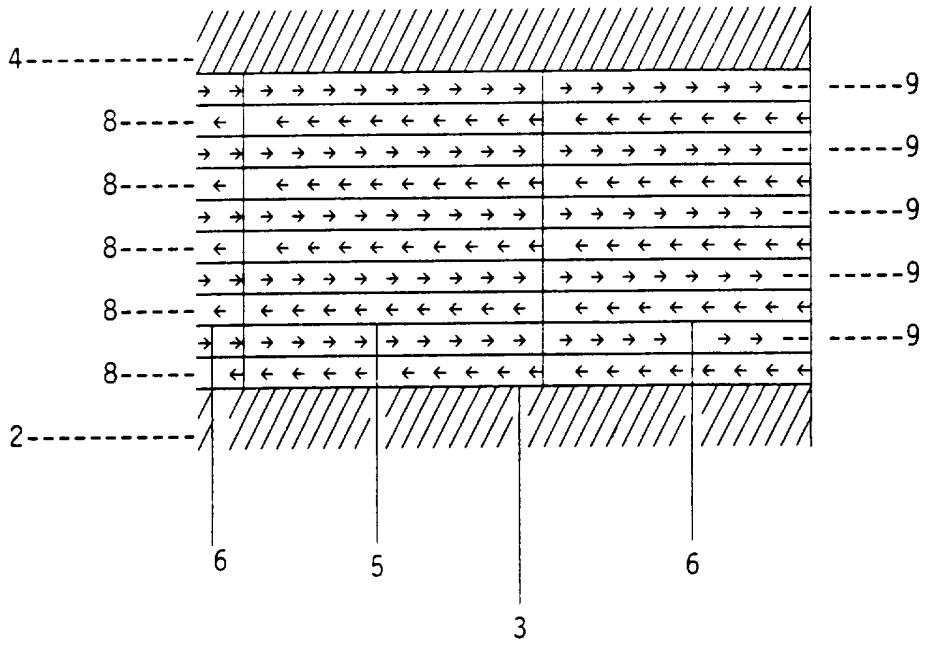


FIG. 3

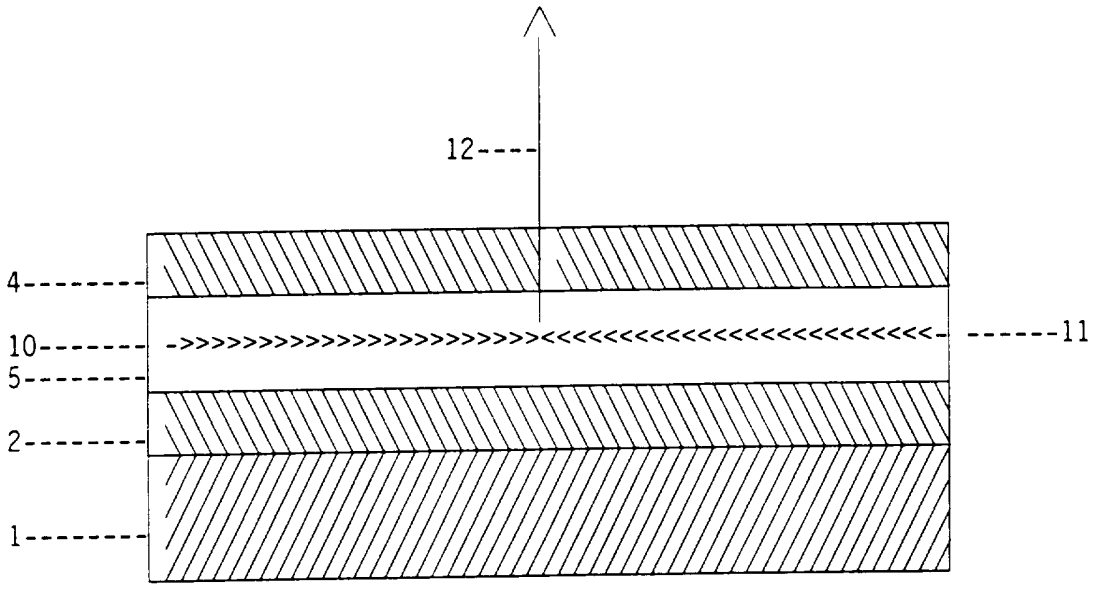


FIG. 4

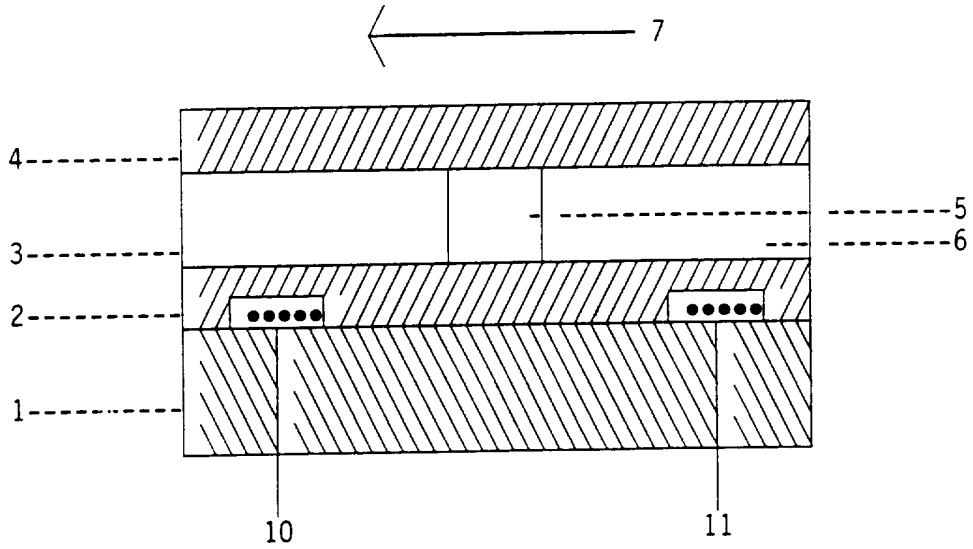


FIG. 5

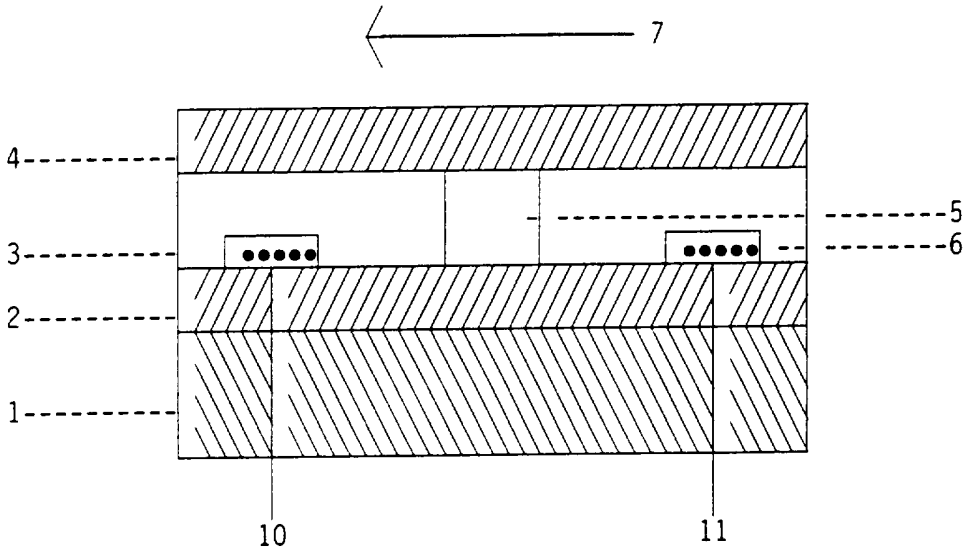


FIG. 6

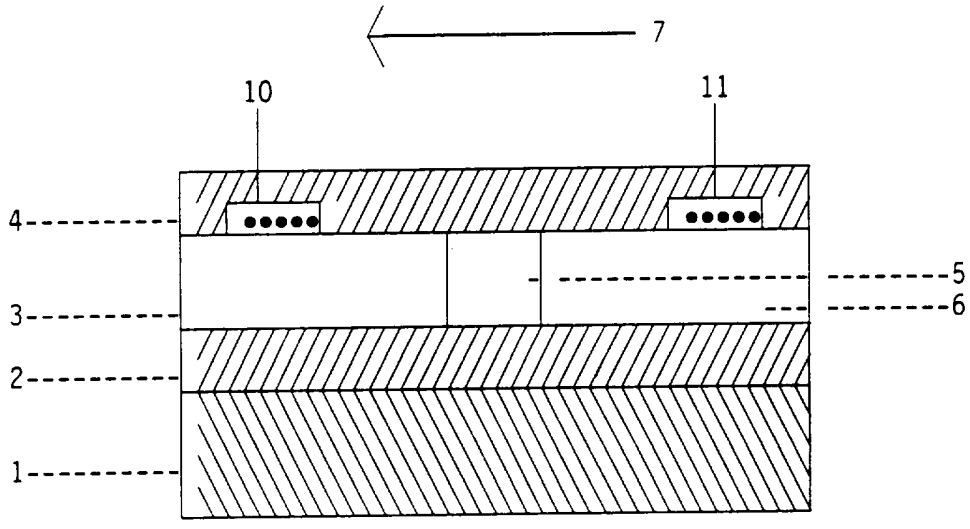


FIG. 7

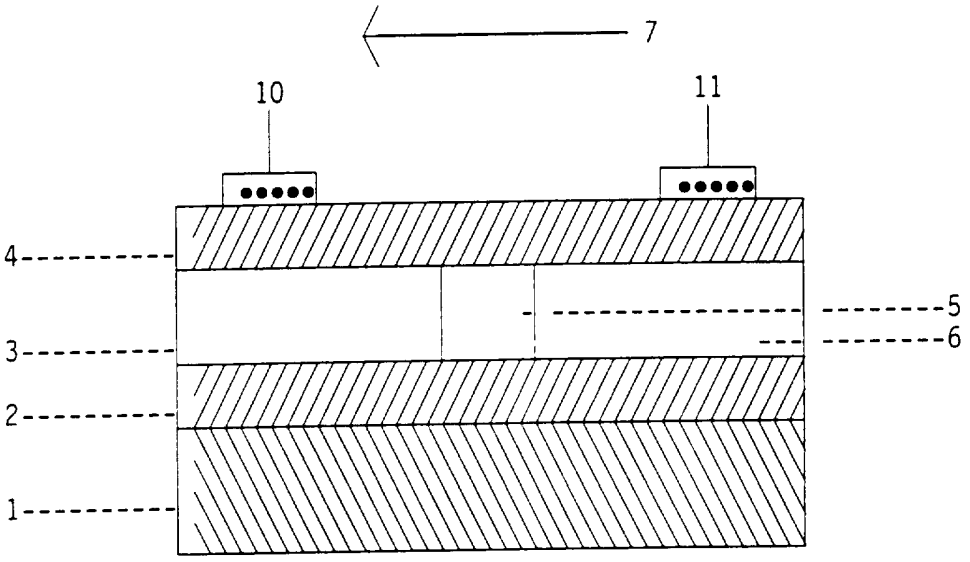


FIG. 8

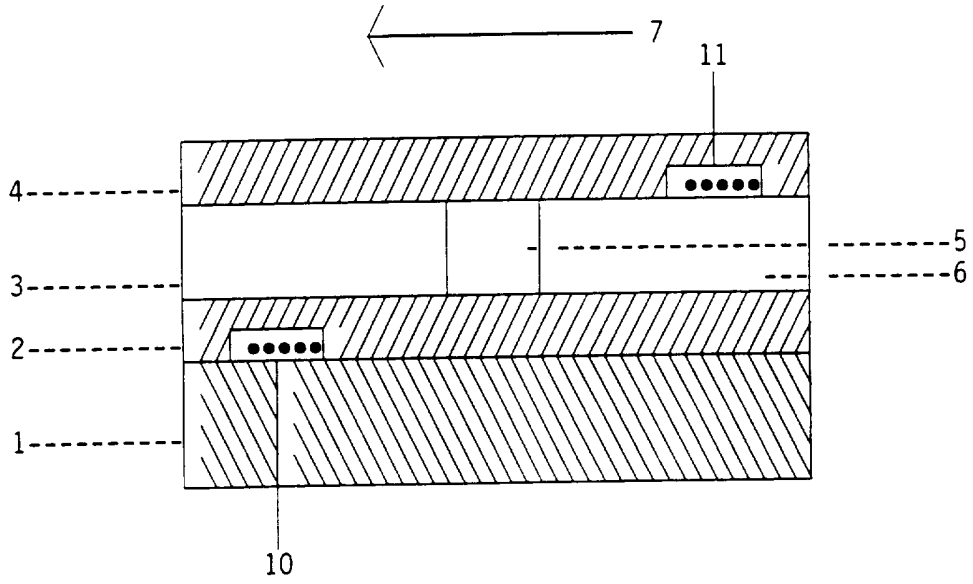


FIG. 9a

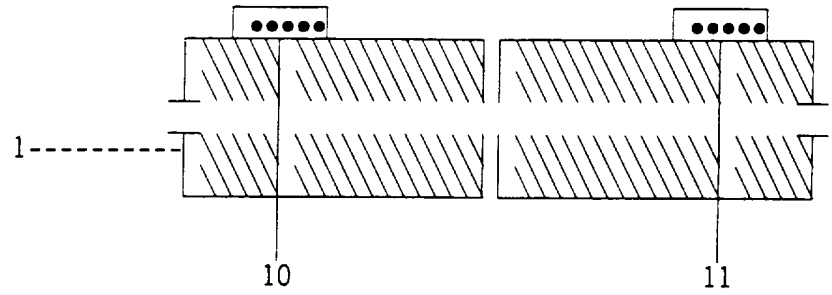


FIG. 9b

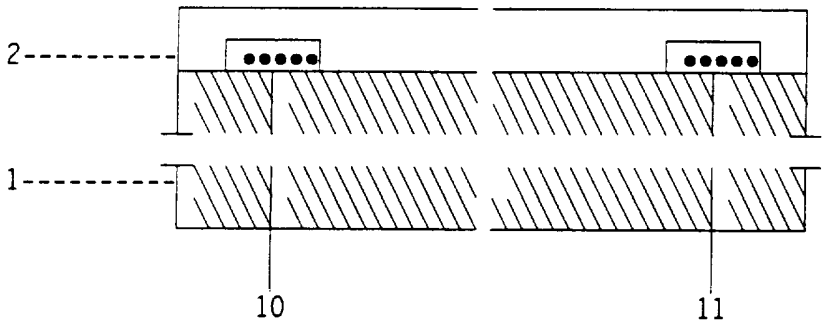


FIG. 9c

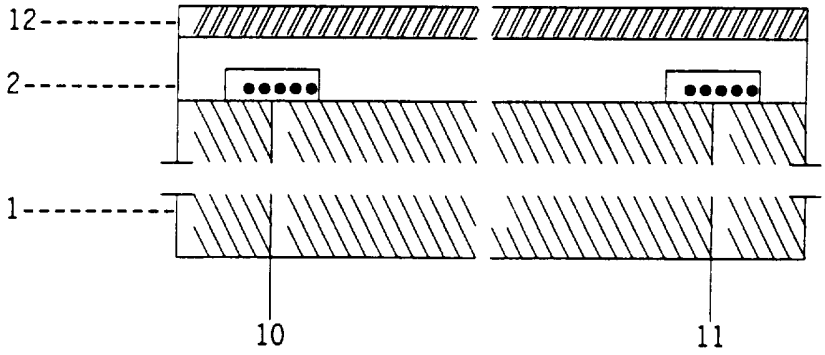


FIG. 9d

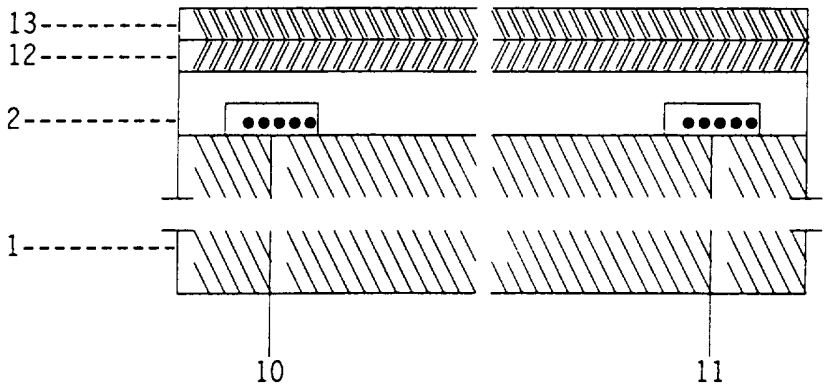


FIG. 9e

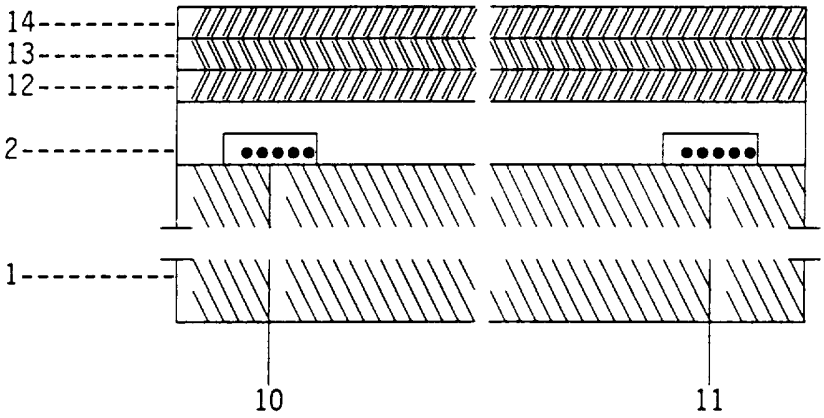
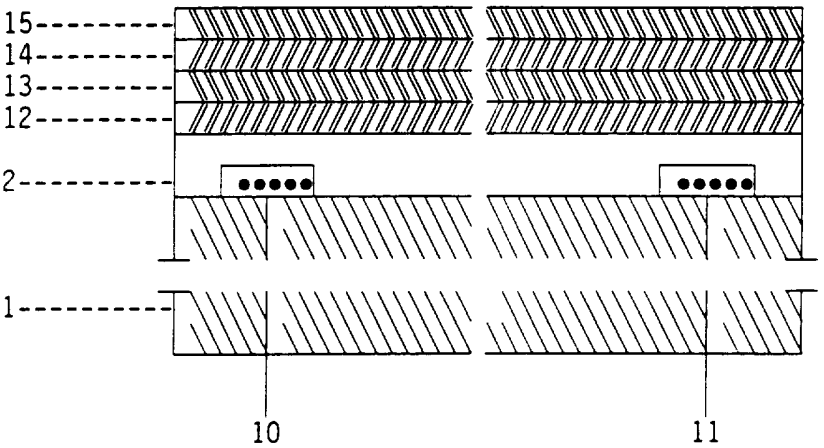


FIG. 9f



INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/EP 95/02982

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G02F1/37

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G02F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	APPLIED PHYSICS LETTERS., vol. 63, no. 25, 20 December 1993 NEW YORK US, pages 3405-3407, XP 000416550 A.OTOMO ET AL. 'Second harmonic generation by counter propagating beams in 4-dimethylamino-4'-nitrostilbene side-chain polymer channel waveguides' cited in the application see abstract see page 3407, column 1, line 36 - column 2, line 2 --- -/--	1-3,6

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

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 1995	22. 11. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Galanti, M

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JOURNAL OF APPLIED PHYSICS., vol. 72, no. 10, 15 November 1992 NEW YORK US, pages 4521-4528, XP 000322393 N.ASAI ET AL. 'An optical waveguide with a non linear optical susceptibility inversion structure in the thickness direction' see page 4526, paragraph IIIB; figure 10 ---	1-3,6
A	APPLIED PHYSICS LETTERS., vol. 64, no. 16, 18 April 1994 NEW YORK US, pages 2076-2078, XP 000440694 CH.BOSSHARD ET AL. 'Surface-emitted green light generated in Langmuir-Blodgett film' see abstract ---	1-6
A	APPLIED PHYSICS LETTERS., vol. 62, no. 20, 17 May 1993 NEW YORK US, pages 2483-2485, XP 000303620 G.L.J.A.RIKKEN ET AL. 'Efficient modal dispersion phase-matched frequency doubling in poled polymer waveguides' see abstract ---	1
A	EP,A,0 549 037 (AKZO N.V.) 30 June 1993 see abstract & US,A,5 282 078 cited in the application ---	1
A	EP,A,0 549 036 (AKZO N.V.) 30 June 1993 see abstract & US,A,5 289 308 cited in the application -----	1

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/EP 95/02982

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0549037	30-06-93	CA-A-	2085762	21-06-93
		JP-A-	5249524	28-09-93
		US-A-	5282078	25-01-94
EP-A-0549036	30-06-93	CA-A-	2085759	21-06-93
		JP-A-	5249523	28-09-93
		US-A-	5289308	22-02-94