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(54) **LASER FOR GENERATING NARROW-BAND RADIATION**

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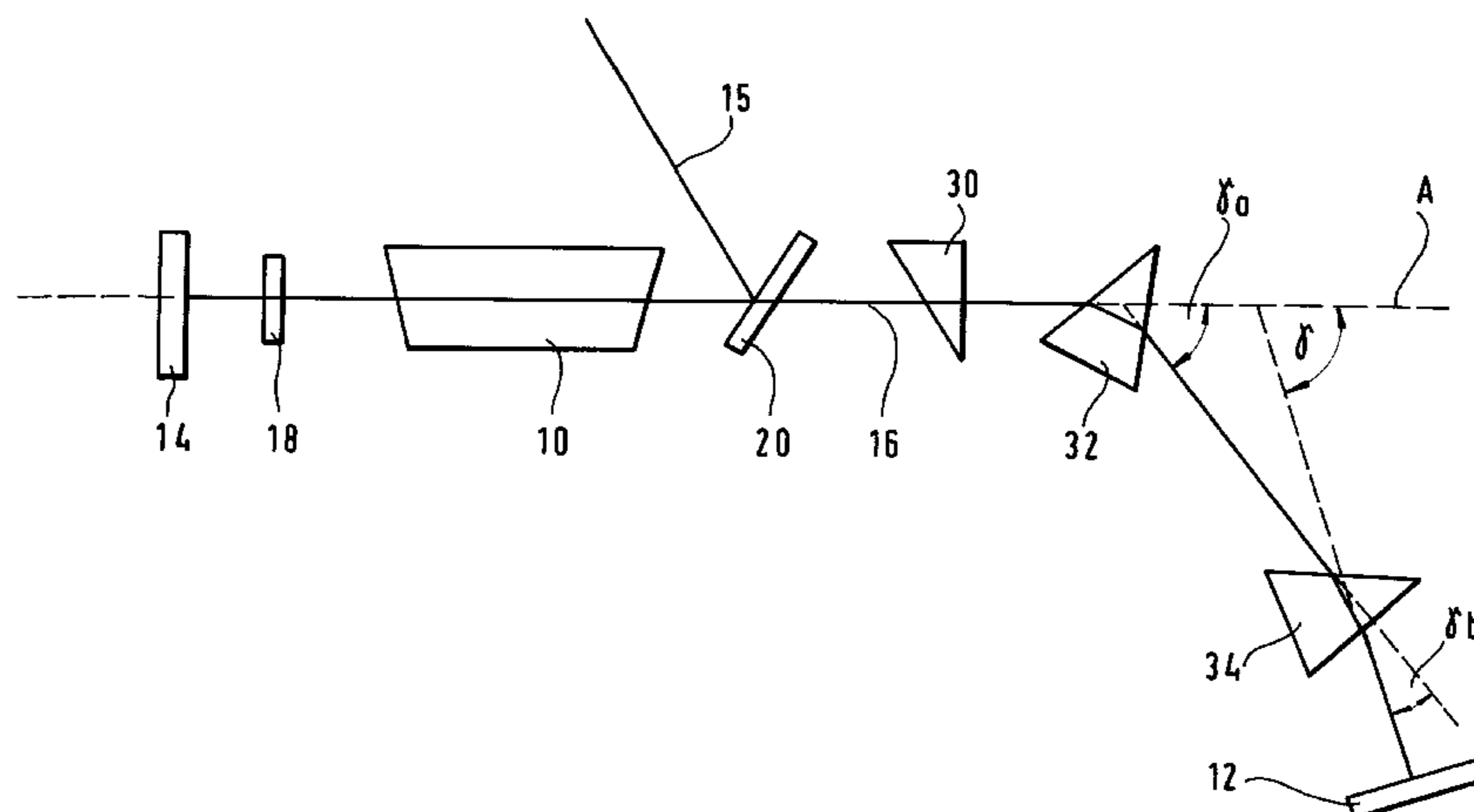
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(57) **ABSTRACT**

A laser, especially an excimer laser, is designed to generate narrow-band radiation and comprises a laser resonator, including two reflecting elements (12, 14) between which there is disposed a laser active medium (10), and further comprises a group of several refractive dispersive elements (32, 34) arranged in the laser beam path and each deflecting, incident light at an angle γ_a, γ_b which is specific of the wavelength of the incident light. It is provided to reduce variations of the emission wavelength which are temperature responsive and time dependent during burst operation by giving at least one of the refractive dispersive elements (32) a refractive index which increases as the temperature goes up and at least one of these elements (34) a refractive index which drops as the temperature rises.

51 Claims, 4 Drawing Sheets



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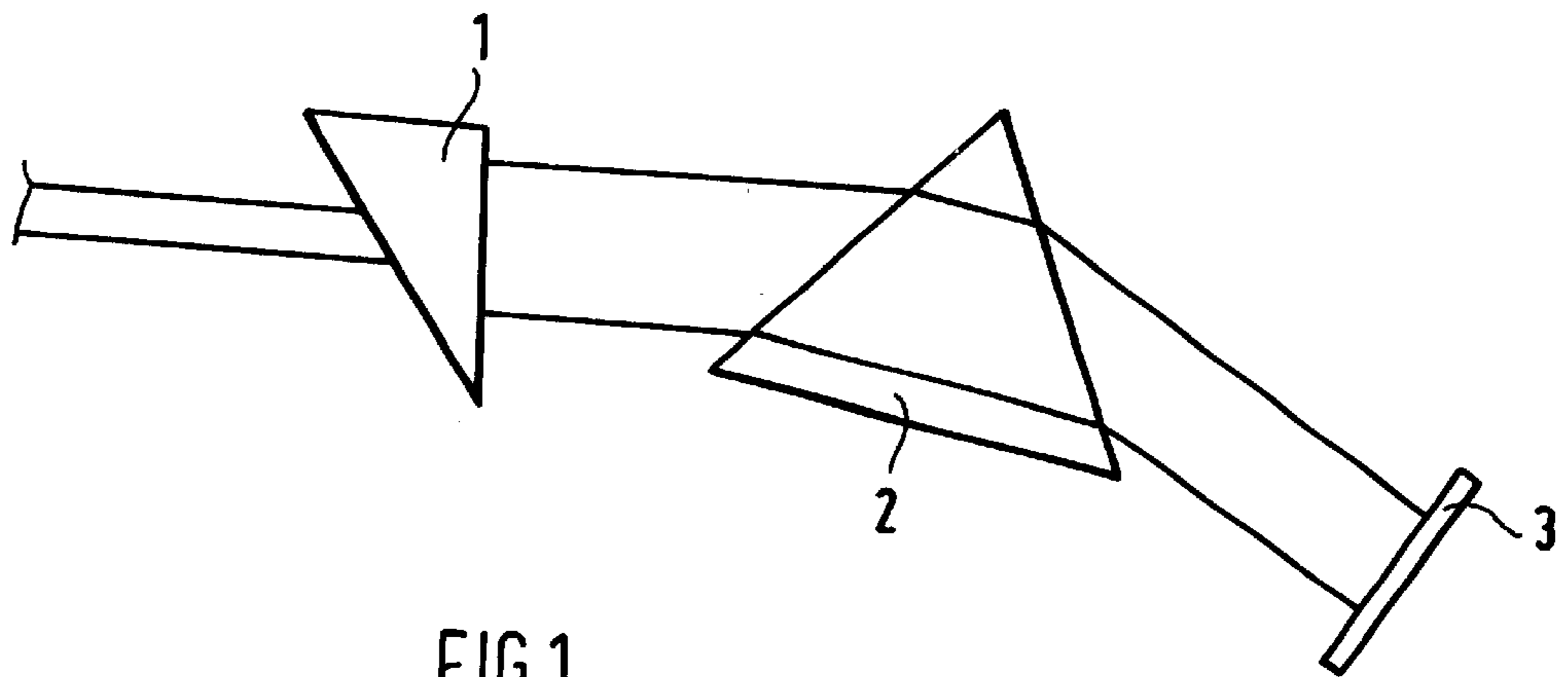


FIG. 1

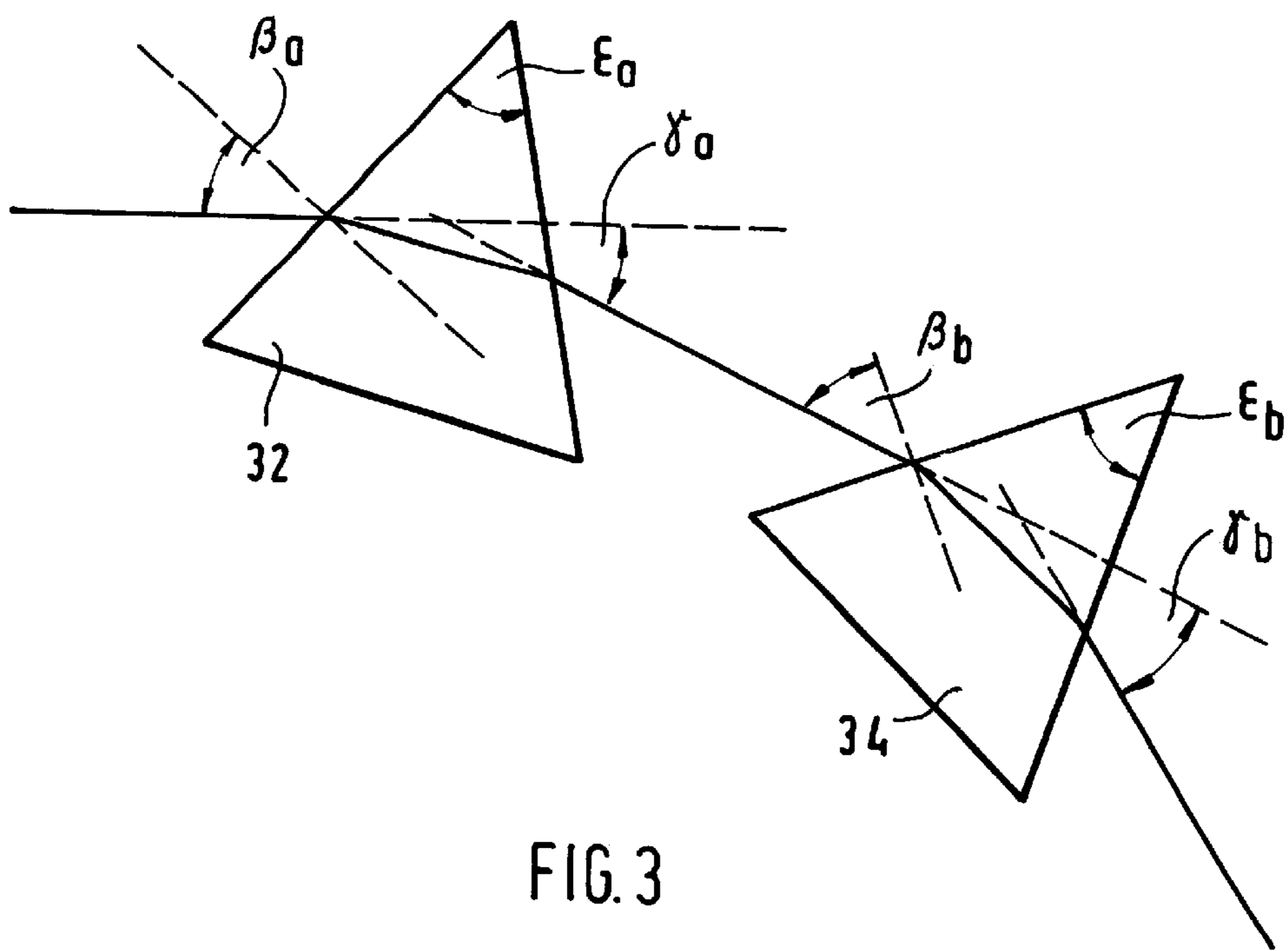


FIG. 3

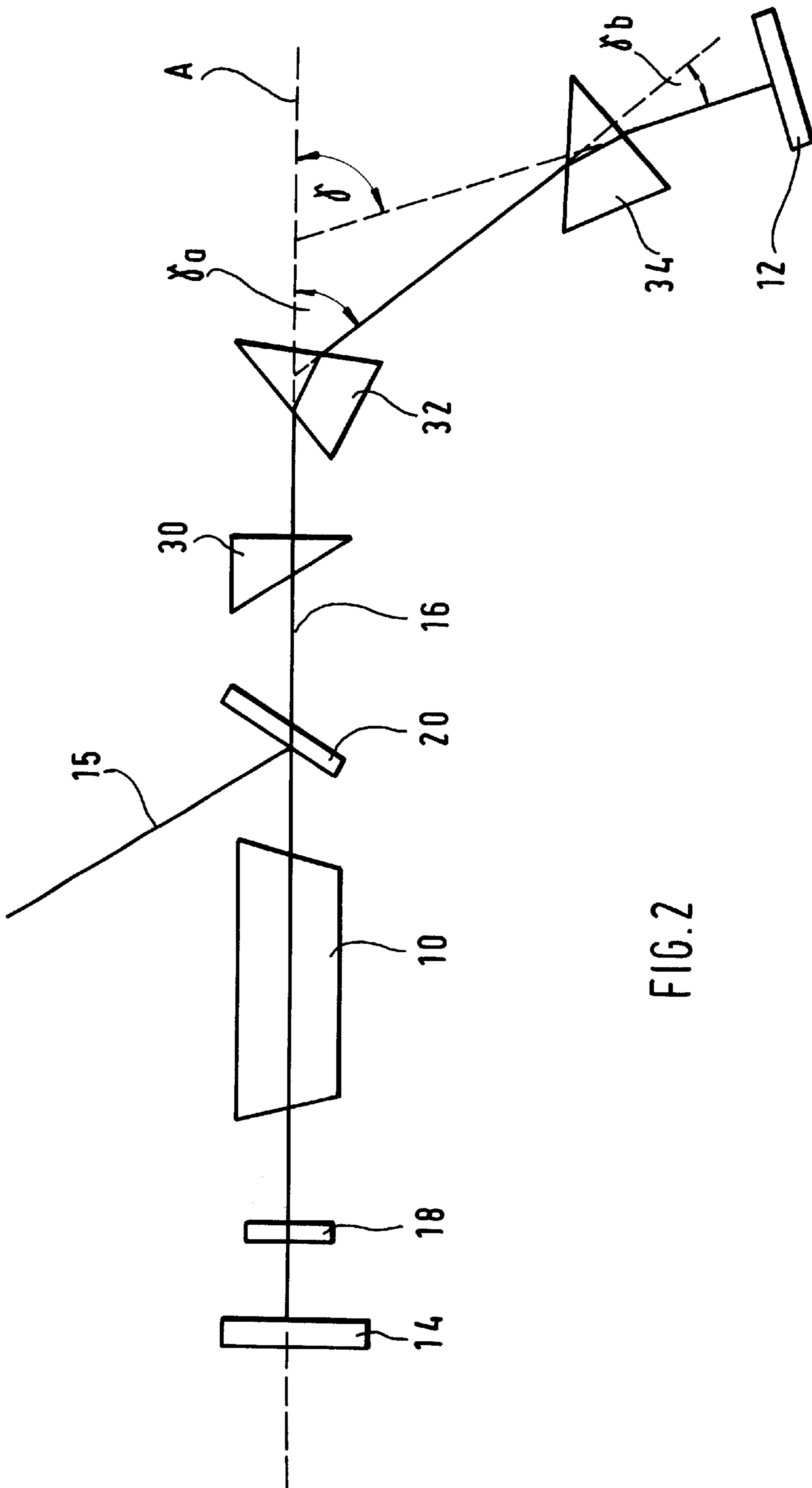


FIG. 2

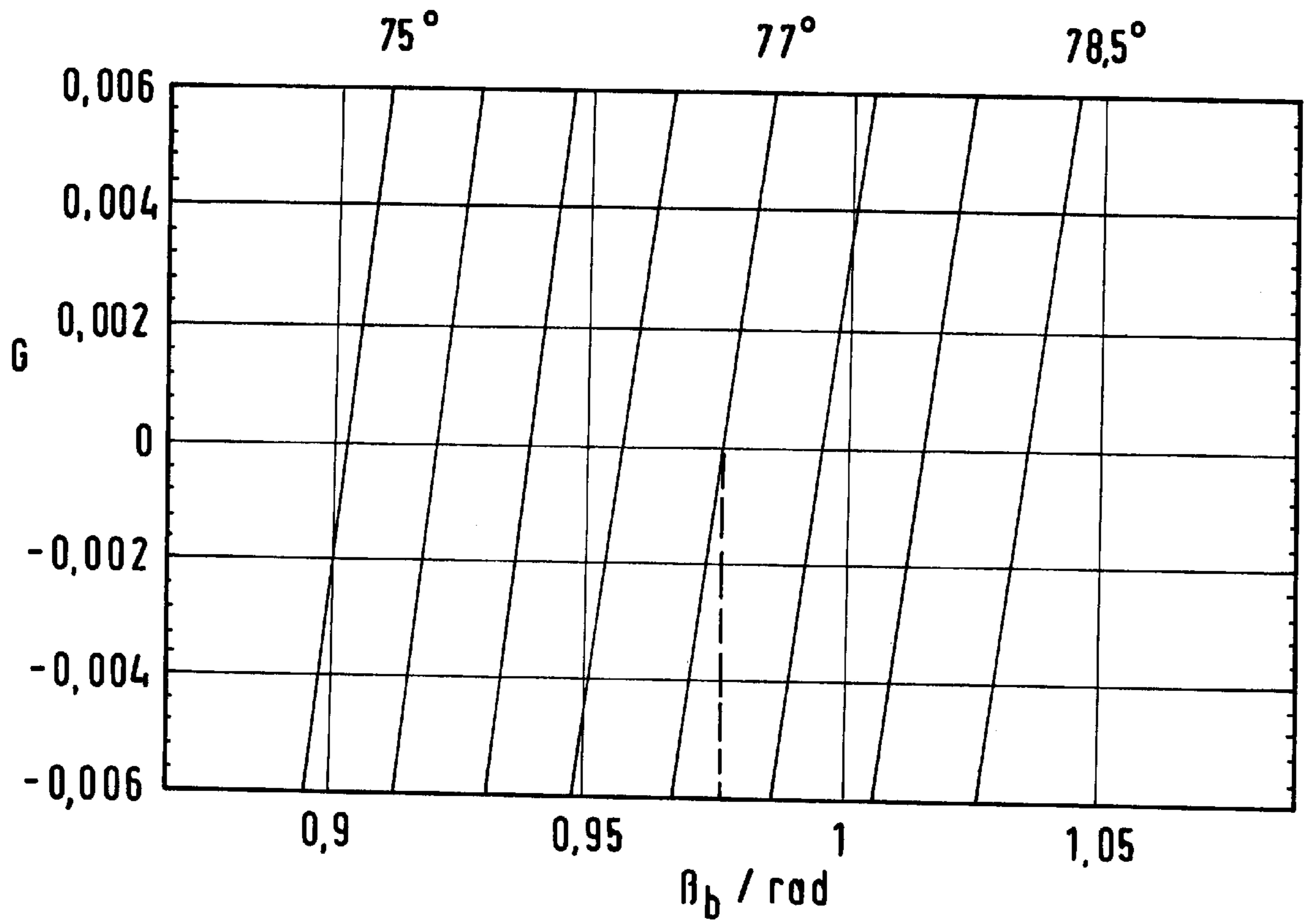


FIG. 4

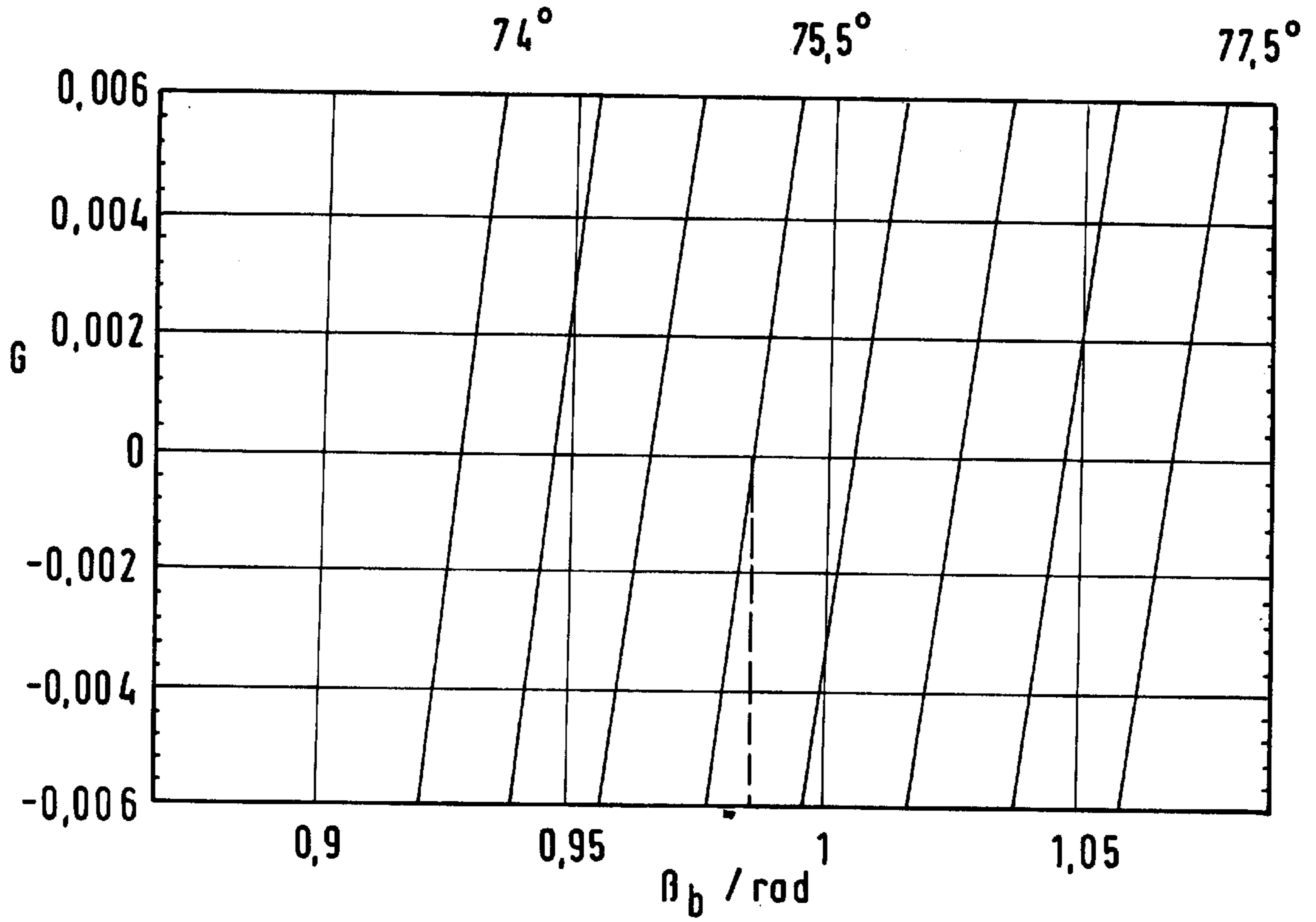


FIG.5

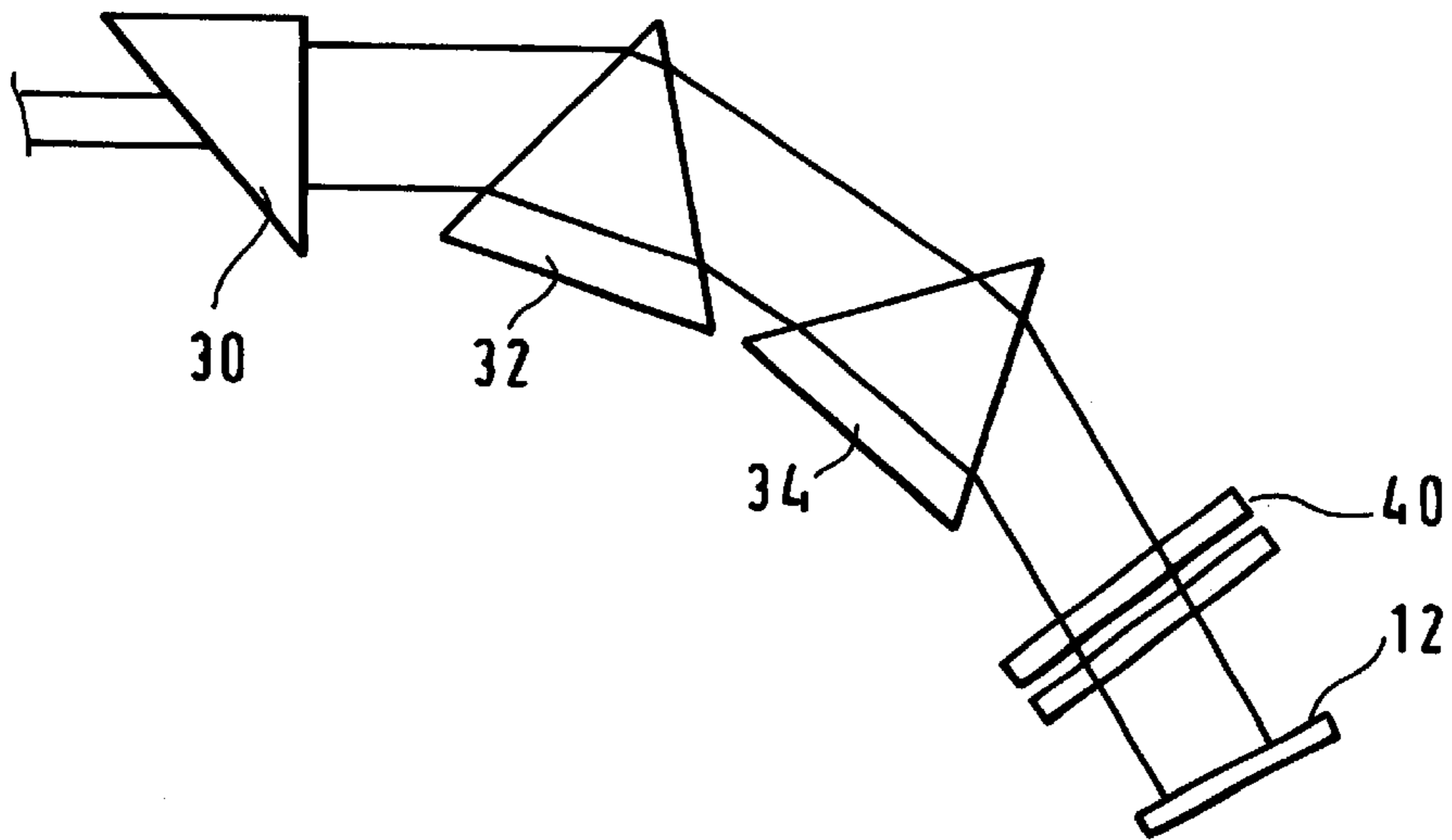


FIG.6

LASER FOR GENERATING NARROW-BAND RADIATION

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

FIELD OF THE INVENTION

The instant invention relates to a laser for generating narrow-band radiation, comprising

- a laser resonator which includes two reflecting elements and a laser active medium disposed between them,
- a group of several refractive, wavelength selective elements each deflecting incident light at an angle which is specific of the wavelength of the incident light.

BACKGROUND OF THE INVENTION

A laser of this kind is known from U.S. Pat. No. 5,150,370.

Lasers of the kind mentioned are applied particularly in the art of photographic lithography for the production of integrated circuits. Wavelengths below 200 nm are required for making structures in the dimension range of 0.18 μm by photographic lithography. Achromatic imaging optics for this wavelength range are difficult to produce. For this reason radiation of very narrow bandwidths is needed for the photolithographic production of structures of the above mentioned order of magnitude in order to keep errors caused by chromatic aberration in the structures obtained through photographic lithography within admissible tolerance limits. Acceptable bandwidths for refractive imaging optics lie in the range of 1 pm (refractive optics made of quartz alone: 0.3 pm, refractive optics of different materials: a few pm), the range extending from 10 pm to 100 pm for the catadioptrics which operate with a beam splitter and mirrors. In contrast thereto, an ArF excimer laser ($\lambda=193$ nm) has a bandwidth of 430 pm in the so-called free running operation so that optical elements must be provided inside the laser to limit the bandwidth if the above requirements are to be met.

It is known in the art to locate gratings providing beam expansion, prism assemblies, and/or Fabry-Perot etalons in the beam path of the resonator for narrowing the bandwidth.

As gratings and Fabry-Perot etalons are characterized by a high loss factor per round trip (transmission <70%) they are suited only conditionally for use in an ArF laser of which the resonator loss is much greater than in an XeCl or KrF laser, for instance. With Brewster prisms, on the other hand, and especially prisms with an antireflective coating the transmission is more than 95%.

Arrangements thus have been suggested with one or two dispersion prisms disposed in the resonator of the laser (1st International Symposium on 193 nm Lithography, Colorado Springs, Aug. 15-18, 1995). In this manner, bandwidths of approximately 10 pm can be achieved. The principle of such an arrangement is illustrated diagrammatically in FIG. 1 which depicts part of the beam path of the resonator. The incoming beam passes through an (optional) achromatic beam expander **1** and then is directed through a dispersion prism **2** to the highly reflective mirror **3** of the resonator which in turn reflects the incident light through the prism **2** and the beam expander **1** back to the second mirror of the resonator. The resonator mirror **3** is disposed at an angle with respect to the optical axis A of the laser, this angle corresponding to the deflection angle γ of the prism for the desired

wavelength, e.g. $\lambda=193$ nm so that essentially only light of this wavelength is reflected and circulated in the resonator.

However, in excimer lasers including such prism assemblies time variations of the emission wavelength of the laser occur during burst operation, whereby the usefulness of the laser is limited as far as photographic lithography is concerned.

SUMMARY OF THE INVENTION

It is the object of the invention to improve a laser of the kind specified initially such that variations in radiation in response to temperature and, therefore, dependent on time during burst operation, are reduced as best as possible.

According to the solution proposed by the invention, in a laser for generating narrow-band radiation, comprising a laser resonator which includes two reflecting elements and a laser active medium disposed between them, as well as a group of several refractive, wavelength selective elements each deflecting incident light at an angle (γ_a, γ_b) which is specific of the wavelength of the incident light, at least one of the refractive, wavelength selective elements has a refractive index which rises as the temperature rises ($dn/dT>0$) and at least one of these elements has a refractive index which drops as the temperature rises ($dn/dT<0$). The laser may be an excimer laser, especially an ArF excimer laser. The group or refractive, wavelength selective elements preferably are arranged in the beam path of the resonator.

It was found that the variations in time of the emission wavelength, as observed with arrangements according to the state of the art, are due to the fact that the refractive index of the prisms used is dependent upon temperature and, therefore, the deflection angle for the desired radiation, e.g. light of 193 nm wavelength, varies during burst operation because of the radiation absorption in correspondence with the heating and cooling of the prisms. In accordance with the invention, this variation of the deflection angle at least is reduced by use of a combination of no less than two refractive elements which differ in sign of dn/dT .

If the elements are designed and arranged appropriately the temperature responsive changing of the deflection angle can be eliminated altogether. In particular, the angles of incidence at the refractive dispersive elements can be selected such that the sum of the individual deflection angles of the respective elements at a predetermined wavelength of the incident light is independent of temperature variations during operation of the laser.

For the ultraviolet range of the spectrum, quartz glass is the preferred material for at least one refractive dispersive element, especially quartz glass known under the tradename of Suprasil ($dn/dT>0$), while CaF_2 ($dn/dT<0$) is the material for at least one refractive dispersive element.

A special embodiment of the invention comprises a beam splitter which is disposed between the laser active medium and one of the reflecting elements, the group of refractive, wavelength selective elements being arranged between the beam splitter and the reflecting element. In this way the assembly which confines the bandwidth is positioned in a part of the resonator which, in operation, has a relatively low light intensity as a consequence of which the service life of the assembly is prolonged.

The refractive, dispersive elements particularly may be dispersion prisms. At the same time, preferably at least one of these prisms is a Brewster prism. The surface of incidence of the other prisms may be given an antireflective coating.

The laser according to the invention especially may comprise a first dispersion prism and a second dispersion

prism, the change in response to temperature of the refractive index of the first prism having a different sign than the change of the refractive index of the second prism, and the apex angle of the second prism being selected such that upon incidence of light radiating through the first prism on the second prism at the Brewster angle, the overall deflection angle as determined by the first and second prisms is independent of temperature variations during operation of the laser. This eliminates the need for an antireflective coating on the surface of incidence of the second prism.

Advantageously, the surfaces of incidence of the prisms are illuminated as completely as possible. To accomplish that, a beam expander may be arranged ahead of the first prism.

In another embodiment of the invention a Fabry-Perot etalon may be included in the beam path of the laser in front of or behind the group of refractive dispersive elements. Bandwidths of less than 1 pm are obtainable with this embodiment.

BRIEF DESCRIPTION OF THE DRAWING

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 illustrates the principle of a prism assembly confining the bandwidth;

FIG. 2 diagrammatically shows a first embodiment of a laser arrangement according to the invention;

FIG. 3 shows the beam path through the two prisms confining the bandwidth in the laser arrangement shown in FIG. 2;

FIG. 4 presents the zero position function in dependence on the apex angle and the angle of incidence of the second prism for a first wavelength;

FIG. 5 presents the zero position function in dependence on the apex angle and the angle of incidence of the second prism for a second wavelength;

FIG. 6 depicts the assembly which confines the bandwidth in a second embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 is a diagrammatic presentation of the beam path of a first embodiment of the invention, an excimer laser being used as the example.

The laser resonator comprises two highly reflective mirrors **12**, **14** with a laser active medium between them which is brought about by gas discharge caused by electrodes in an appropriate compartment **10**. A polarizing beam splitter permitting approximately 98% of p-polarized light to pass while reflecting approximately 98% of s-p-polarized light is disposed between the laser active medium **10** and the mirror **12**. At the other side, i.e. between the laser active medium **10** and the mirror **14**, there is a rotary component **18** which rotates the polarization plane of the light, e.g. a $\lambda/4$ plate or a Faraday rotator. The polarizing beam splitter couples out essentially s-polarized light **15** from the resonator, while it passes essentially p-polarized light **16** which then is reflected by mirror **12** so as to run through another cycle in the resonator. Component **18** has the effect of coupling out a certain portion of the resonator radiation. The laser arrangement including the beam splitter **20** is advantageous in that only part of the radiation generated in the laser active medium is incident on optical elements which are arranged between the beam splitter **20** and the mirror **12**, whereby their service life is prolonged.

An assembly which narrows the bandwidth is arranged between the beam splitter **20** and the mirror **12**. It consists of an achromatic beam expander **30**, a Brewster prism **32** made of a quartz glass which is highly transparent to ultraviolet light, preferably Suprasil, and a prism **34** made of CaF_2 which is coated to render it antireflecting on its surface of incidence. The beam path through the prisms **32** and **34** is shown schematically in FIG. 3. The temperature coefficient of the refractive index, i.e. the derivation of the refractive index according to temperature is $18 \cdot 10^{-6} \text{ K}^{-1}$ for Suprasil and $-3 \cdot 10^{-6} \text{ K}^{-1}$ for CaF_2 at $\lambda=193 \text{ nm}$. The deflection angle Γ_a of prism **32** thus changes in opposite sense to the deflection angle γ_b of prism **34** when the temperature changes. Therefore, the variation of the total angle $\gamma = \gamma_a + \gamma_b$ upon temperature variation is kept small or even caused to disappear entirely.

The condition for disappearance of the variation of the total deflection angle γ following a temperature change ΔT_a at prism **32** and a temperature change ΔT_b at prism **34** may be expressed as follows:

$$\Delta\gamma = \frac{d\gamma_a}{dn_a} \cdot \frac{dn_a}{dT} \cdot \Delta T_a + \frac{d\gamma_b}{dn_b} \cdot \frac{dn_b}{dT} \cdot \Delta T_b = 0 \quad (1)$$

wherein index "a" designates values belonging to prism **32** and index "b" designates values belonging to prism **34**, n_a , n_b being the refractive indices of prisms **32** and **34**, respectively.

The table below lists the values used in the calculations made here:

	Suprasil		CaF ₂	
	248 nm	193 nm	248 nm	193 nm
refractive index n	1.508	1.561	1.467	1.501
dispersion $dn/d\lambda$ (μm^{-1})	-0.6	-1.6	-0.4	-1.0
temperature coefficient dn/dT (10^{-4} K^{-1})	14.9	18	-7.5	-3.0
absorption coefficient α (10^{-3} cm^{-1})	5.3	20 . . . 30	3.3	5.6
density (g/cm^3)g		2.2		3.18
specific heat c ($\text{J/g} \cdot \text{K}$)		0.772		0.85
heat conductivity ($\text{W/m} \cdot \text{K}$)		1.38		9.71

Data taken from: Journal of Non-Crystalline Solids 135 (1991 86; Kohlraush (1968), Herzeus, Quartzglas für Optik - Daten und Eigenschaften, 1994.

The derivations $d\gamma_a/dn_a$ and $d\gamma_b/dn_b$, in general, depend on the refractive index, the geometry of the refractive element, and the direction of the incident ray. For prisms in particular, they are determined by the respective refractive indices n_a , the apex angles ϵ_a , ϵ_b of the prisms, and the angles of incidence β_a and β_b , respectively, the relationship between the deflection angle γ , the angle of incidence β , the apex angle ϵ , and the refractive index n being well known.

Where effects of heat conduction are negligible, the following applies to the temperature change due to radiation absorption ΔT :

$$\Delta T = (F\alpha\gamma)/(gc)$$

wherein

α =absorption coefficient of the material of the prism

g =density of the material of the prism

c =specific heat of the material of the prism

F =total fluence of the laser radiation at the entry into the prism.

Due to the negligible absorption within prism **32**, the total fluence F_b at the entry into prism **34** is nearly the same as F_a (the total fluence into prism **32**). Thus $\Delta T_a/\Delta T_b$ is not time-dependent. The solution of equation (1), consequently, always is possible by proper choice of $d\gamma_a/dn_a$ and $d\gamma_b/dn_b$, respectively. If one applies any common numerical zero position search method equation (1) can be resolved readily according to any one of the determining values β_a , ϵ_a , β_b , and ϵ_b , for example according to angle of incidence β_b , with apex angle ϵ_b of prism **34**, apex angle ϵ , and the angle of incidence β_a or prism **32** being given. Also, the respective value e.g. an angle of incidence β_b which renders the whole deflection independent of temperature when the other values are given can be determined easily by experiment.

Solution of equation (1) for two different wavelengths are given below for purposes of illustration. To this end, it is convenient to define a zero position function G as follows:

$$G = F^2(n_a \epsilon_a, \beta_a; n_b, \epsilon_b, \beta_b) - \frac{(|dn_b/dT| \cdot \Delta T_b)^2}{(|dn_a/dT| \cdot \Delta T_a)^2} \text{ with}$$

$$F(n_a \epsilon_a, \beta_a; n_b, \epsilon_b, \beta_b) = \frac{d\gamma_a/dn_a}{d\gamma_b/dn_b}$$

The zero positions of G correspond to the solutions of equation (1).

In the first example, prism **32** is a Brewster prism made of Suprasil with symmetric beam passage and an apex angle $\epsilon_a=67.08^\circ$. The apex angle of CaF_2 prism **34** was given as $75^\circ, 75.5^\circ, 76^\circ \dots 78.5^\circ$, and equation (1) was resolved for $\lambda=248$ nm by determining the zero position of function G with β_b being the variable. In FIG. **4**, function G is plotted above the angle of incidence β_b for the various apex angles. It will be seen that for each apex angle ϵ_b an angle of incidence β_b may be found at which the thermally provoked changes of the deflection angles γ_a, γ_b are compensated, in other words $G=0$. Compensation occurs, for example, for $\epsilon_b=77^\circ$ and $\beta_b=55.86^\circ$ (0.975 rad). Compensation especially may be achieved at the Brewster's angle ($\beta_b=0.972$ rad) if the apex angle $\epsilon_b=76.9^\circ$. In this case it is not necessary to provide the entry surface of prism **34** with an antireflective coating.

In the second embodiment, prism **32** is a Brewster prism made of Suprasil with symmetric beam passage and an apex angle $\epsilon_a=65.3^\circ$. The apex angle of the CaF_2 prism was given as $74^\circ, 74.5^\circ, 75^\circ \dots 77.5^\circ$, and equation (1) was solved for $\lambda=193$ nm with β_b as the variable. In FIG. **5**, function G is plotted above the angle of incidence β_b for the various apex angles. Here, compensation at the Brewster's angle ($\beta_b=0.973$ rad) occurs at an apex angle $\epsilon_b=77.5^\circ$.

The principle described above may be applied readily also to assemblies which limit the bandwidth and contain more than two prisms. The corresponding generalization of equation (1) is as follows:

$$\Delta\gamma = \frac{d\gamma_a}{dn_a} \frac{dn_a}{dT} \Delta T_a + \frac{d\gamma_b}{dn_b} \frac{dn_b}{dT} \Delta T_b +$$

$$\frac{d\gamma_c}{dn_c} \frac{dn_c}{dT} \Delta T_c + \frac{d\gamma_d}{dn_d} \frac{dn_d}{dT} \Delta T_d + \dots = 0 \quad (2)$$

wherein indices c, d designate the respective values of the further prisms. Here, too, there always is a solution, provided at least one prism is made of a material having another sign of the temperature coefficient of the refractive index than that of the material of other prisms.

FIG. **6** illustrates an assembly narrowing the bandwidth in accordance with a second embodiment of the invention. This embodiment differs from the one shown in FIG. **1** in that the

assembly narrowing the bandwidth includes a Fabry-Perot etalon **40** between prism **34** and mirror **12** in addition to the two prisms **32** and **34**. Bandwidths of 1 pm and less are obtainable with this arrangement. Moreover, the apparatus according to the invention may comprise other elements to limit the bandwidth, such as a grating instead of mirror **14**.

In the embodiments described above the narrowing prism assembly was located in the area between the beam splitter **20** and the mirror **12**. This is advantageous in view of the fact that less radiation loading and less heating is suffered. In principle, a prism assembly with thermal compensation, as described above, may be positioned anywhere in the beam path of the laser. Thus the invention may be realized also with other laser configurations than the one illustrated in FIG. **1**, for instance, with those functioning without the polarizing beam splitter **20**.

What is claimed is:

1. A laser for generating narrow-band radiation, comprising:
 - a laser resonator which includes two reflecting elements between which there is disposed a laser active medium, and
 - a plurality of refractive, wavelength selective elements each deflecting incident light at an angle that depends upon the wavelength of the incident light, wherein at least one of the refractive, wavelength selective elements has a refractive index which increases as the temperature rises and at least another one of the refractive, wavelength selective elements has a refractive index which decreases as the temperature rises.
2. The laser as claimed in claim 1, wherein at least one of the refractive, wavelength selective elements is made of quartz glass and at least another one of the refractive wavelength selective elements is made of CaF_2 .
3. The laser as claimed in claim 1, further comprising:
 - a beam splitter arranged between the laser active medium and one of the reflecting elements, wherein the plurality of refractive, wavelength selective elements being located between the beam splitter and the one reflecting element.
4. The laser as claimed in claim 1, wherein the plurality of refractive, wavelength selective elements are dispersion prisms.
5. The laser as claimed in claim 4, wherein the plurality of refractive, wavelength selective elements includes at least one Brewster prism.
6. The laser as claimed in claim 4, wherein the surfaces of incidence of the prisms are lighted substantially completely.
7. The laser as claimed in claim 4, further comprising:
 - a beam expander disposed in the laser resonator adjacent to one of the prisms.
8. The laser as claimed in claim 4, wherein the prisms are disposed in the resonator such that radiation is incident onto one of the prisms at Brewster's angle.
9. The laser as claimed in claim 1, further comprising:
 - a Fabry-Perot etalon contained in the beam path of the laser ahead of or behind the plurality of refractive, wavelength selective elements.
10. A laser for generating narrow-band radiation, comprising:
 - a laser resonator which includes two reflecting elements between which there is disposed a laser active medium, and
 - a plurality of refractive, wavelength selective elements each deflecting incident light at an angle which is specific of the wavelength of the incident light, at least

one of the refractive, wavelength selective elements has a refractive index which increases as the temperature rises and at least another one of the refractive, wavelength selective elements has a refractive index which decreases as the temperature rises,

wherein the angles of incidence at the refractive, wavelength selective elements are selected such that the sum of the individual deflection angles of the respective elements at a predetermined wavelength of the incident light is independent of radiation induced temperature variations during operation of the laser.

11. A laser for generating narrow-band radiation, comprising:

a laser resonator which includes two reflecting elements between which there is disposed a laser active medium, and

a plurality of refractive, wavelength selective elements each deflecting incident light at an angle which is specific of the wavelength of the incident light, at least one of the refractive, wavelength selective elements has a refractive index which increases as the temperature rises and at least another one of the refractive, wavelength selective elements has a refractive index which decreases as the temperature rises,

wherein the plurality of refractive, wavelength selective elements contains first and second dispersion prisms, the variation in response to temperature of the refractive index of the first prism having a different sign than the variation in response to temperature of the refractive index of the second prism, and that the apex angle of the second prism is selected such that upon incidence at Brewster's angle on the second prism of the light having passed through the first prism the overall deflection angle determined by the first and second prisms is independent of radiation-induced temperature variations during operation of the laser.

12. A laser for generating narrow-band radiation, comprising:

a resonant laser cavity defined by at least two mirrors and having a laser active medium disposed therebetween for generating a laser beam; and

a first and a second refractive elements disposed in the laser cavity to select the wavelength of the laser beam, the first and second refractive elements each deflect incident light at an angle that depends upon the refractive index of that refractive element and the wavelength of the incident light, the first refractive element has a refractive index that increases as the temperature thereof increases, and the second refractive element has a refractive index that decreases as the temperature thereof increases:

wherein the first and second refractive elements are selected to deflect a predetermined wavelength of the laser beam at a total deflection angle such that variations in the total deflection angle for the predetermined wavelength, due to temperature variations of the first and second refractive elements, are minimized.

13. The laser as claimed in claim **12**, wherein the first and second refractive elements are dispersion prisms.

14. The laser as claimed in claim **13**, wherein the first refractive element is made of quartz glass and the second refractive element is made of CaF_2 .

15. The laser as claimed in claim **13**, wherein the prisms are disposed in the laser cavity such that the laser beam is incident onto one of the prisms at Brewster's angle.

16. The laser as claimed in claim **13**, wherein at least one of the first and second refractive elements is a Brewster prism.

17. The laser as claimed in claim **13**, further comprising: a beam expander disposed in the laser cavity such that the surfaces of the prisms are lighted substantially completely.

18. The laser as claimed in claim **13**, further comprising: a Fabry-Perot etalon disposed in the laser cavity adjacent to one of the first and second refractive elements.

19. A laser generating narrow-band UV radiation for use with a photolithography system, said photolithography system including an imaging system with refractive optics comprising a single material for making integrated circuit structures having sub-micron dimensions, comprising:

a laser resonator which includes two reflecting elements between which there is disposed a discharge chamber containing a laser active gas mixture;

a plurality of electrodes in the discharge chamber for providing a gas discharge and thereby energizing the gas mixture to produce an output laser beam; and

a plurality of optical elements in the beam path of the resonator for narrowing the bandwidth of the output laser beam of the laser to less than 1 pm, and wherein the plurality of optical elements includes a prism made of CaF_2 and a diffraction grating arranged to produce a narrow-band output laser beam.

20. A laser as in claim **19**, wherein the refractive index n of the prism for incident 248 nm radiation is around 1.467 and for incident 193 nm radiation is around 1.501.

21. A laser as in claim **20**, wherein the temperature coefficient dn/dT of the prism for incident 248 nm radiation is around $-7.3 \times 10^6 \text{ K}^{-1}$ and for incident 193 nm radiation is around $-3.0 \times 10^6 \text{ K}^{-1}$.

22. A laser as in claim **21**, wherein the absorption coefficient α of the prism for incident 248 nm radiation is around $3.3 \times 10^{-3} \text{ cm}^{-1}$ and for incident 193 nm radiation is around $5.6 \times 10^{-3} \text{ cm}^{-1}$.

23. A laser as in claim **22**, wherein the density of the prism is around 3.18 g/cm^3 .

24. A laser as in claim **23**, wherein the specific heat c of the prism is around $0.85 \text{ J/g}\cdot\text{K}$.

25. A laser as in claim **19**, wherein the laser active gas mixture includes fluorine and a buffer gas.

26. A laser as in claim **19**, wherein the plurality of optical elements disposed in the beam path of the resonator for narrowing the bandwidth of the output beam further includes a second prism arranged to produce a narrow-band output laser beam.

27. A laser as in claim **26**, wherein the plurality of optical elements disposed in the beam path of the resonator for narrowing the bandwidth of the output beam further includes a third prism arranged to produce a narrow-band output laser beam.

28. A laser as in claim **19**, wherein the laser active gas mixture includes fluorine, a buffer gas and a rare gas selected from the group of rare gases consisting of argon and krypton.

29. A laser as in claim **19**, wherein the laser active gas mixture includes fluorine, a buffer gas and argon.

30. A laser generating narrow-band UV radiation for use with a photolithography system, said photolithography system including an imaging system with refractive optics comprising a single material for making integrated circuit structures having sub-micron dimensions, comprising:

a laser resonator which includes two reflecting elements between which there is disposed a discharge chamber containing a laser active gas mixture;

a plurality of electrodes in the discharge chamber for providing a gas discharge and thereby energizing the gas mixture to produce an output laser beam; and

a plurality of optical elements in the beam path of the resonator for narrowing the bandwidth of the output laser beam of the laser to less than 1 pm, and wherein the plurality of optical elements includes a prism made of CaF_2 and a diffraction grating arranged to produce a narrow-band output laser beam, wherein the laser active gas mixture includes fluorine, a buffer gas and krypton.

31. A laser generating narrow-band UV radiation for use with a photolithography system, said photolithography system including an imaging system with refractive optics comprising a single material for making integrated circuit structures having sub-micron dimensions, comprising:

a laser resonator which includes two reflecting elements between which there is disposed a discharge chamber containing a laser active gas mixture;

a plurality of electrodes in the discharge chamber for providing a gas discharge and thereby energizing the gas mixture to produce an output laser beam; and

a plurality of optical elements in the beam path of the resonator for narrowing the bandwidth of the output laser beam of the laser to less than 1 pm, and wherein the plurality of optical elements includes a prism made of CaF_2 and a Fabry-Perot etalon arranged to produce a narrow-band output laser beam.

32. A laser as in claim 31, wherein the refractive index n of the prism for incident 248 nm radiation is around 1.467 and for incident 193 nm radiation is around 1.501.

33. A laser as in claim 32, wherein the temperature coefficient dn/dT of the prism for incident 248 nm radiation is around $-17.3 \times 10^6 \text{ K}^{-1}$ and for incident 193 nm radiation is around $-3.0 \times 10^6 \text{ K}^{-1}$.

34. A laser as in claim 33, wherein the absorption coefficient α of the prism for incident 248 nm radiation is around $3.3 \times 10^{-3} \text{ cm}^{-1}$ and for incident 193 nm radiation is around $5.6 \times 10^{-3} \text{ cm}^{-1}$.

35. A laser as in claim 34, wherein the density of the prism is around 3.18 g/cm^3 .

36. A laser as in claim 35, wherein the specific heat c of the prism is around $0.85 \text{ J/g}\cdot\text{K}$.

37. A laser as in claim 31, wherein the laser active gas mixture includes fluorine, a buffer gas and a rare gas selected from the group of rare gases consisting of argon and krypton.

38. A laser as in claim 31, wherein the laser active gas mixture includes fluorine, a buffer gas and argon.

39. A laser as in claim 31, wherein the laser active gas mixture includes fluorine, a buffer gas and krypton.

40. A laser as in claim 31, wherein the laser active gas mixture includes fluorine and a buffer gas.

41. A laser as in claim 31, wherein the plurality of optical elements disposed in the beam path of the resonator for narrowing the bandwidth of the output beam further includes a second prism arranged to produce a narrow-band output laser beam.

42. A laser generating narrow-band UV radiation for use with a photolithography system, said photolithography system including an imaging system with refractive optics comprising a single material for making integrated circuit structures having sub-micron dimensions, comprising:

an optical resonator;

a gas discharge compartment located within the resonator and having a laser active gas mixture selected to generate said UV radiation;

a plurality of wavelength selective elements located in the resonator for narrowing the output band of the laser to less than 1 pm, and wherein at least one of said wavelength selective elements is defined by a prism formed from calcium fluoride.

43. A laser as recited in claim 42, wherein said wavelength selective elements further include an etalon.

44. A laser as recited in claim 42, wherein said wavelength selective elements further include a grating.

45. A laser as recited in claim 42, wherein said wavelength selective elements further include a second prism.

46. A laser as recited in claim 45, wherein said second prism is located between the gas discharge compartment and the calcium fluoride prism.

47. A laser as in claim 42, wherein the laser active gas mixture includes fluorine, a buffer gas and argon.

48. A laser as in claim 42, wherein the laser active gas mixture includes fluorine, a buffer gas and krypton.

49. A laser as in claim 42, wherein the laser active gas mixture includes fluorine and a buffer gas.

50. A laser as recited in claim 42, wherein said wavelength selective elements further include a grating.

51. A laser as recited in claim 45, wherein said second prism is located between the gas discharge compartment and the calcium fluoride prism.

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