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(19)

(54) METHOD FOR THE OPTICAL READING OF AN INFORMATION SUPPORT AND OPTICAL READING DEVICE EMPLOYING SAID READING METHOD

(71) We, THOMSON-BRANDT, a French Body Corporate, of 173, Boulevard Haussmann—75008 Paris—France— do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to the optical reading of information which has been previously recorded on a support in the form of a track comprising a succession of diffracting elements having a substantially constant width and whose length and spacing are non-uniform the deformations constituting the track being derived from a rectangular waveform encoding the information to be read.

In a known embodiment, the support is in the form of a disc on the surface of which the information is encoded in the form of a spiral track. Along this track the diffracting elements are characterized by hollows or projections having a substantially constant width, of the order of a semi-micron. In order to read such a track, it is known to project onto the track a luminous spot by means of a circular microscope objective.

When employing conventional objectives having a numerical aperture of the order of 0.45 with a track having a pitch less than 1.6 μm the radiation diffracted by the track sections in the neighbourhood of the track section to be read are inevitably illuminated, at the same time as the track to be read, by the central spot (or by the first bright ring of the diffraction pattern thereof), the light diffracted thereby being superimposed on the radiation diffracted by the central section. Such a phenomenon will hereinafter be referred to as "diaphoty".

An object of the invention is to provide a reading method in which a reading spot is projected by optical projection means on the track to be read, the optical projection means being so arranged that this reading spot is laterally bonded by diffraction fringes, said fringes being spaced apart a distance which is twice the pitch of the track to be read inscribed on the support so that only a very small part of the diffracted radiation comes from the track sections next adjacent the section being read.

According to the invention there is provided a method of reducing diaphoty (as hereinbefore defined) when optically reading information recorded on a support in the front of a succession of diffracting elements of constant width and variable length and spacing along a track or tracks having a constant pitch as measured transverse to the track being read, wherein a spot of light is projected so as to be centered on the track section to be read, the optical projection means being so arranged that said central spot is bounded in the direction orthogonal to the direction of travel of the track by diffraction fringes which extend parallel to the track being read, and wherein the illumination minima of said fringes coincide with the middles of the track sections next adjacent the track section being read.

For a better understanding of the invention and to show how the same may be carried into effect, reference will be made to the following description and the attached drawings among which:

Fig. 1 represents two diagrams which are representative of distribution of the illumination and the intensity function obtained when light from a circular aperture is focussed to a spot;

Fig. 2 represents two diagrams which are representative of the illumination distribution and of the intensity function obtained when light from a slit is focussed to a line;

Fig. 3 represents an embodiment of a device when reading a suitable information support according to the invention;

Fig. 4 represents a second embodiment of such a reading device.

Shown in Fig. 1a) is the appearance (much magnified) of the spot of light produced when a beam of light is focussed to a point by an objective lens having a circular pupil. This pattern comprises a central spot and alternately dark and bright concentric diffraction rings. The distribution of intensity measured with respect to the intensity at the centre against the distance from the center (reckoned in units of

$$f\frac{\lambda}{a}$$

wherein *a* is the radius of the pupil of the objective, *f* is the focal length of the objective and λ the wavelength of the light, is represented in Fig. 1*b*. The maximum illumination in the first bright ring is very distinctly less than the illumination at the center (in the order of 1.75% of the latter).

When it is desired to read an information support by means of a reading spot of this type, the reading objective must be adapted to the track to be read in such manner that diffracted light from the diffracting elements of adjacent track sections on either side of the track to be read does not intrude in an excessive manner, upon the radiation diffracted by the element being read. Alternatively, only supports on which there are engraved tracks having a sufficiently large pitch should be read. If it is assumed, which is usually the case, that the diaphoty is rather low when the illumination received by the neighbouring sections is lower than 1% of the illumination received by the section being read, the track pitch is determined as a function of the numerical aperture of the reading objective. Thus a reading objective having a numerical aperture equal to 0.45 results, when the reading radiation has a wavelength of 0.63 μm, in a satisfactory reading provided that the pitch of the track is not less than 1.6 μm. That is to say that the track sections in the neighbourhood of the track section to be read are located outside the first bright ring of the diffraction pattern. Neighbouring track sections are shown in Fig. 1a, the pitch of the track being equal to 1.6 μm. Such a positioning causes the exterior sections to receive no more than 1% of the illumination received by the section being read, which is satisfactory.

Fig. 2 represents diagrams similar to Fig. 1 in respect of an objective with a pupil in the form of a slit, the distance *x* from a point of the network to the center being, as before, reckoned in units of

$$f\frac{\lambda}{a}$$

wherein *f* is the focal length of the projection objective, *a* is half the width of the slit and λ the reading wavelength. The maximum intensity at the center of the first bright fringe is markedly higher than the intensity at the center of the first bright ring for a circular pupil. However, as the fringes are rectilinear, and therefore the whole of the neighbouring track section adjacent the section being read may be placed in minima of illumination, the illumination in the first bright fringe is therefore unlikely to notably intrude upon diffraction, the radiation diffracted by the element illuminated by the central fringe. The width of the slit must therefore be adapted to the pitch of the track to be read. The even spacing of the fringes causes the next adjacent track sections to also coincide with the dark fringes.

If it is considered that the slit is obtained by a partial masking off of a circular microscope objective having an aperture of 0.45 similar to that employed in the above example, the semi-width a_s of the slit being equal to

$$\frac{a}{\sqrt{2}}$$

where a is the radius of the pupil of the unmasked objective, the width of the bright fringe is substantially equal to two microns and consequently the pitch of the track may be chosen to be equal to one micron so that the middle of the track sections next adjacent the section being read coincide with the first illumination minima. Although the illumination rapidly increases on each side of these minima, such a disposition, when the track has a width of 0.4 μ, does not result in an illumination of the neighbouring sections exceeding 1% of the illumination received by the central section.

Note that, even if the decentering of the disc with respect to the diffraction pattern reaches an amplitude of 0.1 μ, the diaphoty remains low.

In practice, the diffraction pattern of the circular objective thus masked off is closely similar to the diffraction pattern obtained by means of a rectangular pupil.

Such a diffraction area is constituted by two superimposed orthogonal fringe networks which produce a kind of cross pattern with a central rectangular bright spot. Along each of the two orthogonal axes of the spot, the intensity distribution is as shown in Figure 2b. Each of the spots produced other than the central spot and axial spots has one dimension which is either

$$\frac{f\lambda}{a''} \text{ or } \frac{f\lambda}{b''}$$

where a″ and b″ are the two sides of the rectangle. The central spot itself has dimensions

$$\frac{2f\lambda}{a''} \text{ by } \frac{2f\lambda}{b''}$$

and those spots lying on the abscissae have one dimension

$$\frac{2f\lambda}{b''}$$

while those spots lying on the ordinates have one dimension

$$\frac{2f\lambda}{a''}$$

The reading method according to the invention comprises projecting on the support to be read, this support being readable by means of a concentrated radiation (by transmission or by reflection), a diffraction pattern comprising a spot of light centered on the track to be read which spot is bounded in the direction orthogonal to that direction of travel of the track in the reading plane by diffraction fringes which extend parallel to the track being read the pitch of the track being such that the track section next adjacent the track being read coincides with the illumination minima of the fringes.

This reading method may be carried out with an optical device for reading an information support comprising a projection objective adapted to concentrate the radiation it receives on the support to be read, this objective being partly shut off so as to form a pupil having a substantially rectangular shape having edges parallel to the direction of travel of the track and a width which is a function of the pitch of the track to be read.

Figure 3 represents an optical device reading an optically encoded information support by means of an objective having a pupil laterally limited by two edges parallel to the track as described hereinbefore.

This optical reading device, only partly represented, comprises a monochromatic radiation source S located on the optical axis OZ of a projection system which comprises an objective 2 forming at 0 the image of the source S and a stop 1 covering the pupil of the objective. This opaque stop is provided with a rectangular window 3 limiting the radiation beam transmitted towards the support 10. On the drawing only a fraction of the information support has been shown. By way of a non-limitative example, it has been supposed that the track containing the information is inscribed in a spiral on the surface of the support 10 which has the shape of a disc. The center of this disc is located in the direction OY which represents the radial direction, the axis OX representing the direction of travel. The track therefore appears on the drawing in the form of equidistant spiral sections 6, 7, 8 (their pitch being, by way of example, equal to 1 μm whereas their width is equal to 0.4 μm). The hollows, such as 9, constitute the diffracting elements (projecting elements would produce a similar diffracting action on the reading beam).

It is also possible to suppose that the information support to be read is in the form of a tape carrying tracks which are parallel to the direction OX of travel.

As the support is assumed to be readable by transmission, the radiation diffracted by the track being read is received by photodetector cells 11 and 12, located in a detection plane parallel to the plane of the support, respectively on each side of a plane defined by the axes OY, OZ.

The output signals of these two cells are applied to the inputs of a differential amplifier 13 whose output signal V(t) is characteristic of the recorded information.

As described above with reference to Fig. 2, the radiation from the pupil 3 is projected onto the support and produces a pattern comprising a substantially rectangular central spot surrounded by two substantially orthogonal networks of diffraction fringes. The pitch of the track sections in conjunction with the width *e* of the pupil 3 is so chosen that the first dark fringes coincide with the track sections next adjacent the central section. The distribution of the illumination along the axis OY is represented diagrammatically along O′Y′. The rectangular spot represented around O corresponds to the projection of a truncated pyramidal cone within which the intensity of the radiation remains higher than a predetermined fraction of the intensity at the center of the spot. The length l of the pupil determines the length of the reading spot. It is such that this length is adapted to the spatial frequency recorded on the support, that is to say, at least equal to the minimum length of the diffracting elements such as 9.

In Fig. 3 only the reading device proper has been shown. It is of course necessary to add thereto devices for radially controlling the reading device with respect to the track to be read, for correcting radial error (correction of the decentering) and for correcting vertical error to form a complete system for reading recorded information supports. Such devices are described in publications related to this field and form no specific part of the invention.

Fig. 4 shows another embodiment of a device for reading an optically encoded information support according to the invention supposed to be. By way of example, this embodiment is also adapted to read supports by transmission.

In this figure, the same elements as in Fig. 3 are designated by the same references. The source of radiation (not shown) delivers a parallel beam. The projection objective 22 has a pupil of rectangular section. To adapt the input beam to this pupil, the projection device comprises an anamorphic device comprising, by way of example, a divergent cylindrical lens 20 and a convergent cylindrical lens 21. The projection objective 22 is a spherical lens which projects onto the support a diffraction pattern similar to that previously described, the pupil being rectangular.

As before, the dimensions of the pitch of the adjacent tracks in conjunction with *e* and *l* of the pupil are such that the projected spot is laterally bounded by diffraction fringes whose minima coincide with the middles of the track sections next adjacent the section to be read, the central spot having a length adapted to the recorded spatial frequency.

Such devices are adapted to the reading of discs on which the items of information have been recorded along a spiral track having a small pitch (of the order of a micrometre).

The amount of information capable of being stored therefore considerably increases. By way of example, a support disc on which has been formed the impression of a track having a pitch of 1 μm corresponds to a program duration of 48 minutes whereas a similar disc corresponds to only 30 minutes of program when the pitch is equal to 1.6 μm.

It is also possible to record the same amount of information as on discs having a pitch of 1.6 μm on the same area. The benefit will then be in respect of the reduction of the speed of rotation of the disc, which permits the utilization of slower, and therefore cheaper, position control devices.

Another possibility of benefit would be to reduce the engraved area by recording the same quantity of items of information as on conventional support but on a ring of the disc of larger inside radius. There is then a benefit in the larger spatial frequencies which can thus be recorded (there would no longer be, in the case of a video-disc, one image per track revolution but more than one image, which would prevent the stoppage on an image, but for applications of the video-disc for the general public, this stoppage on an image is not essential).

The invention is not limited to what has been previously described and illustrated. In particular, similar reading devices may be employed for reading supports which are readable by reflection.

WHAT WE CLAIM IS:—

1. A method of reducing diaphoty (as hereinbefore defined) when optically reading information recorded on a support in the form of a succession of diffracting elements of constant width and variable length and spacing along a track or tracks having a constant pitch as measured transverse to the track being read; wherein a spot of light is projected so as to be centered on the track section to be read, the optical projection means being so arranged that said central spot is bounded in the direction orthogonal to the direction of travel of the track by diffraction fringes which extend parallel to the track being read, and wherein the illumination minima of said fringes coincide with the middles of the track sections next adjacent the track section being read.

2. A method for reducing diaphoty as claimed in claim 1, wherein light is projected from a point source of radiation through a circular objective masked off by a pupil which is centered on the optical axis, said pupil having two edges parallel to the direction of travel of the track, the distance between said two edges being determined as a function of the pitch of the track, of the wavelength of the radiation, and of the numerical aperture of the objective.

3. A method for reducing diaphoty as claimed in claim 2, wherein the pupil has a rectangular shape, the diffraction pattern comprising two orthogonal networks of parallel fringes surrounding the bright central spot.

4. A method of reducing diaphoty as claimed in claim 1, wherein light is projected through an objective having a rectangular pupil, the diffraction pattern

comprising two orthogonal network of parallel fringes surrounding the central spot.

5. A method for reducing diaphoty as claimed in claim 4, wherein the dimension of the rectangular pupil in the direction of travel of the track, which determines the pitch of the network of fringes in the direction orthogonal to the direction of travel, is determined with respect to the value of the highest spatial frequency of the diffracting elements recorded on said support.

6. A method of reducing diaphoty (as hereinbefore defined) substantially as hereinbefore described with reference to the accompanying drawings.

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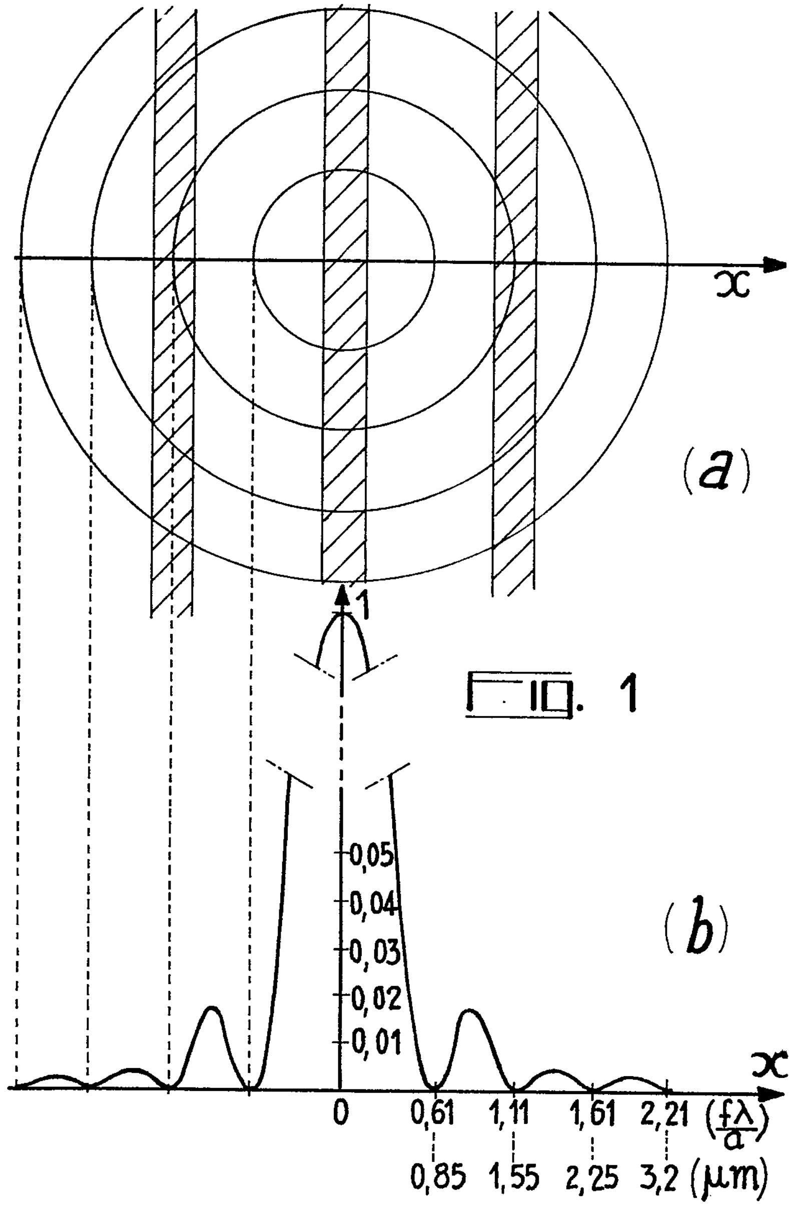

Fig. 1

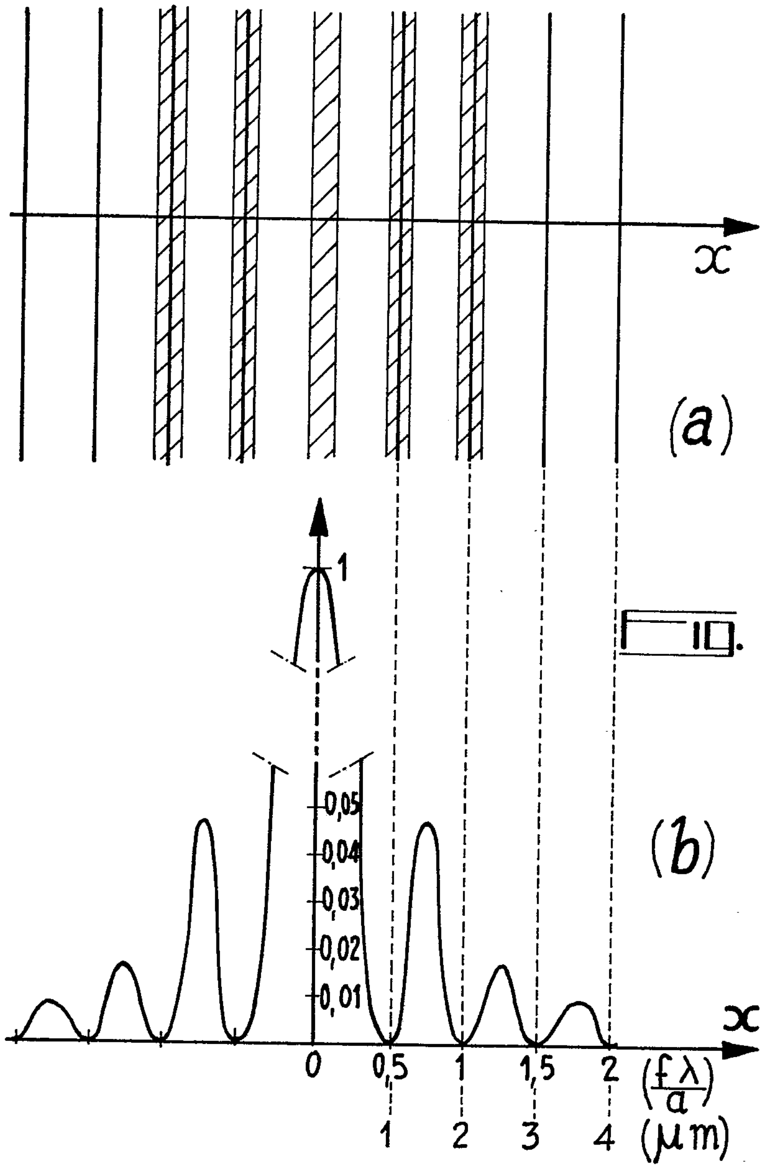

Fig. 2

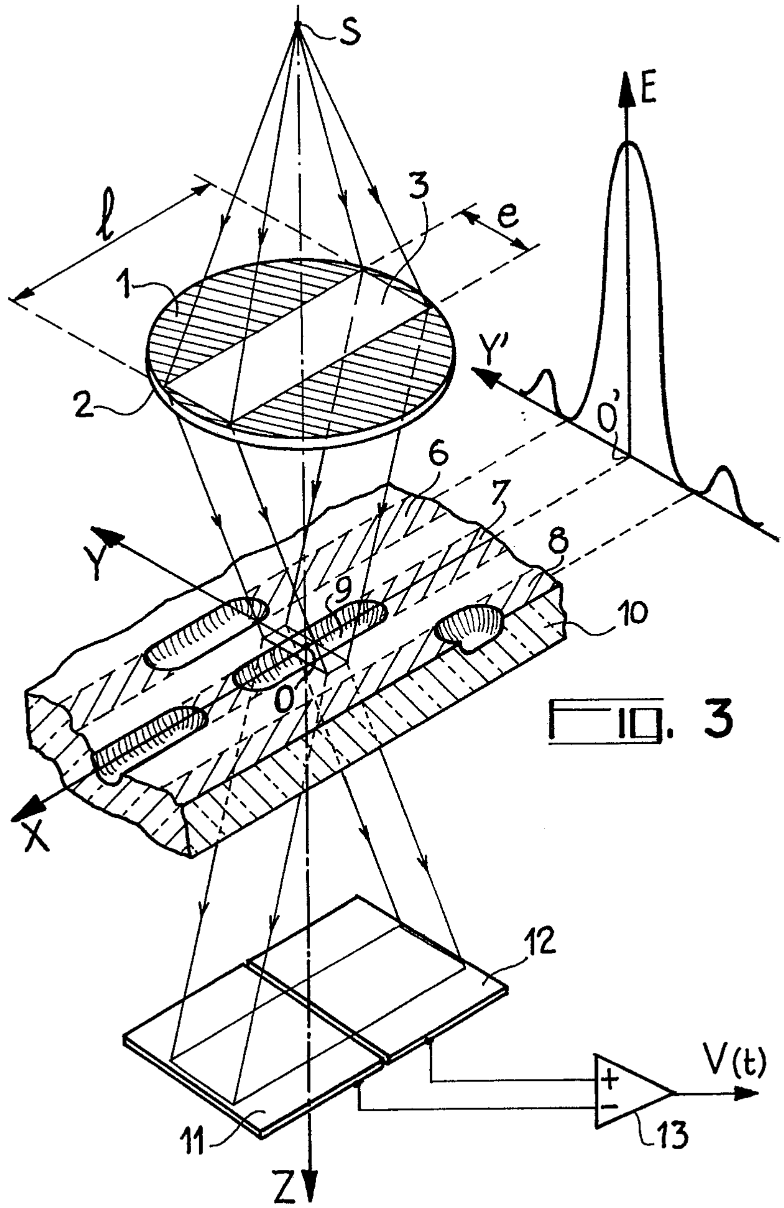

FIG. 3

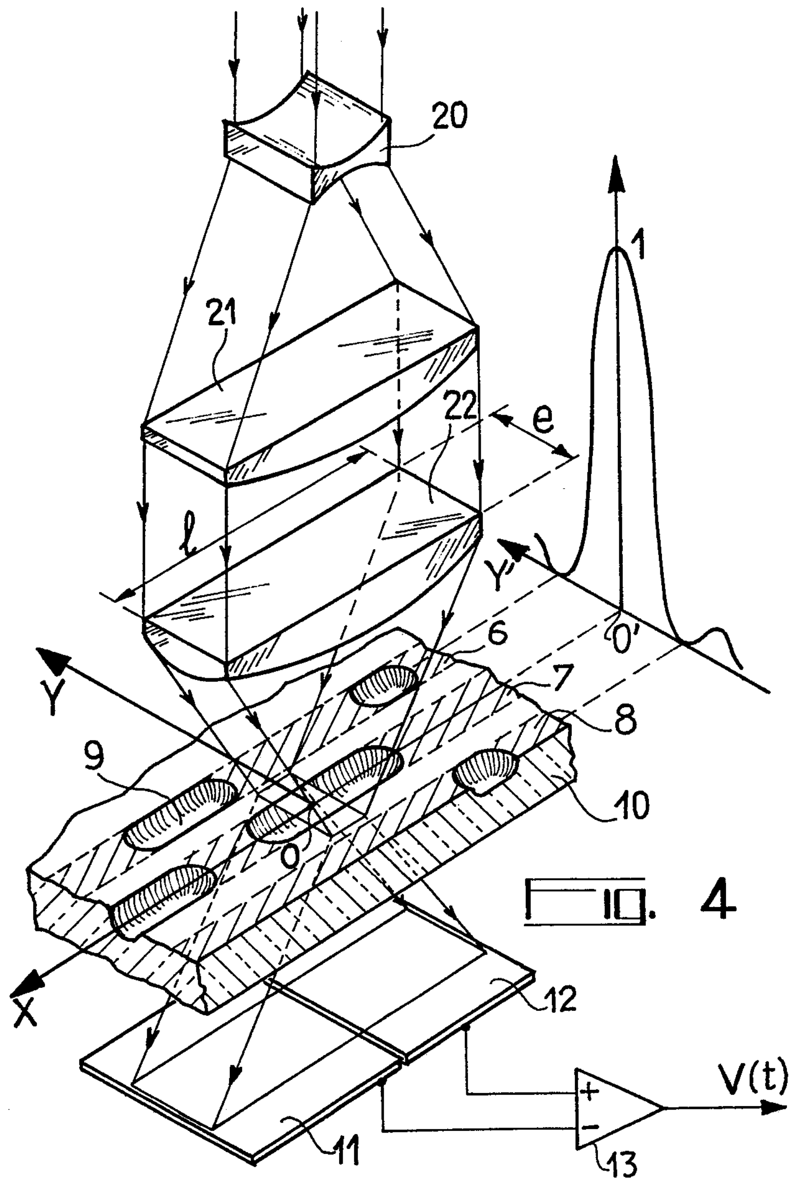

FIG. 4