

"BEAM-SPLITTING PRISM FOR AN OPTICAL READ/WRITE
UNIT".

The invention relates to a beam-splitting prism comprising an entrance surface for a radiation beam, a beam-splitting surface, and an exit surface for a radiation beam which has been deviated inside the prism, which entrance surface and exit surface form part of
5 prismatic glass elements, a roof-edge prism having a refractive edge being arranged on the exit surface.

A read unit comprising such a prism is described in the article: "PCM-Schallplatte fur die 80er Jahre" in "Radio Mentor" 45 (1979), pages 138-140. This read unit comprises a radiation source in the
10 form of a solid-state laser. The radiation beam emitted by said laser is focussed by means of an objective system onto a reflective information structure formed on a disc-shaped record carrier. The read beam reflected by the information structure, traverses the objective system for a second time, and then passes through a splitting prism
15 arranged between the radiation source and the objective system. Said prism deviates the modulated read beam out of the path of the radiation beam emitted by the source, so that the modulated beam can impinge on a radiation-sensitive detection system which supplies an electric signal related to the modulation of the last-mentioned beam.

20 For reading an information structure with minute information details, for example of the order of magnitude of $1\mu\text{m}$ or smaller, an objective having a large numerical aperture is required. The depth of focus of such an objective system is small. Since the distance between the information structure and the objective system may be
25 subject to variations in excess of said depth of focus, steps must be taken to enable said variations to be detected and the focussing to be corrected in response thereto. For this purpose, a roof-edge prism may be arranged on the exit surface of the splitting prism, as described in said article. Said prism splits the beam into two
30 sub-beams which impinge on separate elements of the radiation-sensitive

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detection system. Said system comprises four radiation-sensitive elements arranged on a line transverse to the refractive edge of the roof-edge prism. By subtracting the sum of the signals supplied by the two inner detection elements from the sum of the signals supplied by the two outer detection elements a signal is obtained which is proportional to the focussing error.

Until now the roof-edge prism was manufactured as a separate element from high-grade optical glass and was subsequently mounted on the splitting prism. The roof-edge prism has relatively small dimensions and is very vulnerable. It must have a large apex angle, for example between 170° and 180° , and is difficult to manufacture with the required accuracy and without burrs, which may affect the radiation distribution over the detection elements and hence the output signals of these elements. Apart from manufacturing and handling problems, problems arise as regards the accuracy required in the alignment of the roof-edge prism relative to the splitting prism.

It is an object of the present invention to eliminate said problems and to provide a splitting prism provided with a roof-edge prism which can be manufactured simply and has a low price.

The invention provides a beam-splitting prism comprising an entrance surface for a radiation beam, a beam-splitting surface and an exit surface for a radiation beam which has been deviated inside the prism, which entrance surface and exit surface form part of prismatic glass elements, and a roof-edge prism having a refractive edge arranged on the exit surface, said roof-edge prism comprising a cured transparent synthetic material, and being formed in situ on the exit surface.

The invention utilizes the fact that the roof-edge prism is a thin element, so that the material of this prism need not comply with the very stringent requirements imposed on the material of the splitting prism, which is traversed by the incident read beam forming the very small read spot on the record carrier.

Various transparent plastics or lacquers may be used as materials for the roof-edge prism, provided that they can be applied to the splitting prism in a satisfactorily liquid condition and can

subsequently cure, for example, thermally or under the influence of radiation. In a preferred embodiment of the splitting prism the roof-edge prism is made of a synthetic material which cures under the influence of ultraviolet radiation.

5 The invention also provides a method of manufacturing a splitting prism provided with a roof-edge prism comprising the steps of applying a drop of a liquid synthetic material the exit surface of the beam-splitting prism, pressing a die having a die surface comprising two die surface portions which enclose an obtuse angle into the drop of
10 synthetic material, curing the material, and removing the die.

By means of an adjustment tool the die can be positioned and aligned with the required accuracy. This enables the direction and the position of the refractive edge of the roof-edge prism relative to the prism support and hence relative to the optical axis of the
15 system to which the splitting prism belongs to be defined correctly and independently of the orientation of the exit surface of the splitting prism. This is because the entire space between said exit surface and the die is filled with transparent synthetic material.

If the synthetic material is an ultraviolet-curing substance
20 use is preferably made of a transparent die, so that the substance can be exposed through said die.

To facilitate separation of the die from the cured substance the die is preferably provided with an anti-adhesion coating.

The invention will now be described in more detail with
25 reference to the drawings, in which:

Figure 1 shows a longitudinal section of an optical read unit equipped with a beam-splitting prism and associated roof-edge prism to which the invention may be applied,

Figure 2 is a plan view of a beam-splitting prism and the
30 associated radiation-sensitive detection system suitable for use with the read unit of Figure 1,

Figure 3 is a perspective view of a part of the splitting prism provided with a beam-splitting roof-edge prism in accordance with the invention, and

35 Figure 4 illustrates how the roof-edge prism of Figure 3 is manufactured.

Figure 1 shows a small part of a round disc-shaped record carrier 1 in radial cross-section. The radiation-reflecting information structure is disposed on the upper side of the record carrier and comprises a multitude of information areas arranged in information tracks 2. The information structure is scanned by means of a radiation source 3, for example a solid-state laser, which produces a read beam b. A lens 4 forms the divergent beam into a parallel beam of such a cross-section that the pupil of an objective system 5 is properly filled. Said objective system then forms a radiation spot V of minimal dimensions on the information structure.

The read beam is reflected by the information structure and, as the record carrier moves relative to the read beam, the reflected beam is modulated in time in conformity with the information stored in the record carrier. In order to separate the modulated beam from the beam emitted by the radiation source a beam-splitting prism 6 is arranged between the radiation source and the objective system. Said prism may comprise two prismatic elements 7 and 8 between which a beam-splitting layer 9 is disposed. The prism 6 has an entrance surface 10 and an exit surface 11. The layer 9 may be a semitransparent mirror. In order to minimise the radiation loss in the read unit the use of a polarization-sensitive splitting layer is preferred. Between the objective system and the prism 6 a $\lambda/4$ plate 12 is then arranged, λ being the wavelength of the read beam b. Said prism is traversed two times by the read beam and rotates the plane of polarization of said beam through 90° in total. The beam emitted by the radiation source is then almost fully transmitted by the prism, whereas the modulated beam is almost fully reflected towards a radiation-sensitive detection system. This system supplies a signal which is modulated in accordance with the information stored in the record carrier.

In order to generate a focussing-error signal which provides an indication of the magnitude and direction of a deviation between the plane of focussing of the objective system and the plane of the information structure a roof-edge prism 14 is arranged on the exit surface 11 of the beam-splitting prism 6 and the radiation-sensitive system 13 is formed by four radiation-sensitive elements. These

elements are designated 16, 17, 18 and 19 in Figure 2, which illustrates the principle of focussing-error detection. Said Figure is a plan view of the beam-splitting prism with the roof-edge prism. The refractive edge 15 of the prism 14, as is shown in Figure 2, may be parallel to the optical axis, 00' in Figure 1, of the read unit. However, it is alternatively possible, as is shown in Figure 1, to rotate the roof-edge prism and the array of detection elements through 90° , so that the refractive edge 15 is disposed transversely of the optical axis 00'. The refractive edge may also be in an intermediate position between the positions parallel and transverse to the optical axis 00'.

The roof-edge prism splits the beam b into two sub-beams b_1 and b_2 which co-operate with the detection elements 16, 17 and the elements 18, 19 respectively.

After having passed through the beam-splitting prism the two beam halves of the read beam b may have different intensities, that is to say, in the embodiments shown in Figures 1 and 2 the upper half of the beam reflected by the splitting surface 9 may have a lower intensity than the lower half. In order to prevent different intensities of the sub-beams b_1 and b_2 as a result of said effect, the refractive edge of the roof-edge prism is preferably disposed parallel to the optical axis 00'.

Figures 1 and 2 represent the situation in which the read beam is focussed exactly on the plane of the information structure. The read unit may be adapted so that the focus F of the reflected beam is situated exactly on the refractive edge 15 of the roof-edge prism 14. At correct focussing the sub-beams b_1 and b_2 are symmetrically incident on their associated detection elements 16, 17 and 18, 19 respectively. In the case of a focussing error the energy distribution within the respective sub-beams b_1 or b_2 relative to the associated detection elements changes, which may also be regarded as a displacement of the sub-beams relative to the detection elements. If the focus of the beam emitted by the radiation source is situated above the plane of the information structure, the focus F of the reflected beam will

be situated to the right of the edge 15 in Figure 2. This would correspond to an inward displacement of the beams b_1 and b_2 , so that the detection elements 16 and 19 would receive less radiation energy than the detection elements 17 and 18. If the focus of the read beam emitted by the radiation source is situated below the plane of the information structure, the situation would be reversed and the detection elements 17 and 18 would receive less radiation energy than the detection elements 16 and 19. By applying, as is shown in Figure 2, the signals from the detection elements 17 and 18 to a first adder 20 and those from the elements 16 and 19 to a second adder 21 and applying the output signals of these adders to a differential amplifier 22, a focussing-error signal S_f is obtained. The information signal S_i can be recovered by means of a third adder 23 whose inputs are connected to the adders 20 and 21.

Alternatively, the read unit may be constructed so that at correct focussing the focus F of the reflected beam is disposed in the plane of the detection elements. If the focus of the beam emitted by the radiation source is then situated too high, the focus F will have shifted to the right but the detection elements 16 and 19 will receive more radiation energy than the detection elements 17 and 18.

Instead of four radiation-sensitive elements the detection system may comprise three such elements, for example only the elements 16, 17 and 18 of Figure 2. The focussing-error signal is then obtained by subtracting the output signals of the detection elements 16 and 17 from each other and the information signal is obtained by adding the output signals of the three elements 16, 17 and 18 to each other.

Either the base or the refractive edge 15 of the roof-edge prism 14 may be disposed against the exit surface 11 of the beam-splitting prism, as is shown in Figure 1 and Figure 2 respectively. When a high value is selected for the apex angle α of the roof-edge prism, for example approximately 170° , the prism 14 will have substantially the same effect in both cases. The apex angle α is selected as large as possible in order to enable the detection elements to be arranged as close as possible to each other and to be constructed as one integrated detector.

In accordance with the invention the roof-edge prism is made of a cured synthetic material. Figure 3 is an exaggerated perspective view of a prism half 7 of the beam-splitting prism on which a roof-edge prism 14 is arranged. In a practical embodiment the prism
 5 had a base area of $4 \times 4 \text{ mm}^2$, a maximum height h of the order of $200 \mu\text{m}$ and an apex angle α of approximately 170° .

Figure 4 schematically represents how the roof-edge prism can be manufactured. A drop of, for example, a transparent substance which cures upon exposure to ultraviolet light is applied to the
 10 exit surface 11 of the prism element 7, which is shown in plan view. A die 25 of a tool, not shown, is positioned with the desired high accuracy, so that the line of intersection of the two die surface portions 25A and 25B is situated at the correct distance from the central axis of the beam-splitting prism support, not shown, and
 15 said axis is oriented correctly relative to the optical axis $00'$, i.e. is parallel or transverse to said optical axis. Subsequently, the drop of synthetic material is exposed to ultra-violet radiation 28, exposure through the die being possible when a transparent die is used. After the material has cured the die is withdrawn. The die
 20 may be provided with an anti-adhesion coating in order to facilitate its separation from the cured material.

In the case of exposure through the die the die material need only be sufficiently transparent to ultraviolet radiation. Exposure is also possible via the beam-splitting prism. Then the prism
 25 material needs to be satisfactorily transparent to both ultraviolet and read-beam radiation. In the case of exposure through the beam-splitting prism the area exposed is larger than in the case of exposure via the die, so that excess synthetic material outside the die surface can also be cured.

30 Instead of ultraviolet-curing substances it is possible to employ other synthetic materials which can be applied in a more or less liquid condition and which upon application of the die cure under the influence of heat or in cold condition, such as epoxy-resins, or under the influence of radiation other than ultraviolet
 35 radiation.

Preferably, use is made of a die as shown in Figure 4, having a projecting die surface and by means of which a roof-edge prism as shown in Figure 3 can be obtained. The risk of air bubbles in the roof-edge prism thus manufactured is then minimised and if the synthetic material shrinks during curing it may be replenished with additional material from outside the die surface.

The beam-splitting prism 6 comprises two elements 7 and 8, one of which carries the splitting surface 9. The two elements may be secured to each other by means of an ultraviolet-curing cement. Assembly of the beam-splitting prism and formation of the roof-edge prism can be effected simultaneously using one fixture.

The invention has been described in connection with its use in an optical read unit, but may also be used in a write unit or in a combined write-read unit. The write unit is constructed in a similar way to the read unit described in the foregoing. For recording information, for example by melting pits into a metallic layer, more energy is needed than for reading and, in addition, the write beam should be modulated in time in accordance with the information to be written. The radiation source for the write unit may be a gas laser, such as a HeNe-laser, a modulator, such as an electro-optical or acousto-optical modulator, being arranged in the path of the write beam. It is alternatively possible to use a diode laser, the write beam being modulated by varying the electric current through the diode laser, so that no separate modulator is needed.

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CLAIMS:

1. A beam-splitting prism comprising an entrance surface for a radiation beam, a beam-splitting surface and an exit surface for a radiation beam which has been deviated inside the prism, which entrance
5 surface and exit surface form part of prismatic glass elements, and a roof-edge prism having a refractive edge arranged on the exit surface, said roof-edge prism comprising a cured transparent synthetic material, and being formed in situ on the exit surface.

2. A beam-splitting prism as claimed in Claim 1, wherein the
10 synthetic material cures under the influence of ultraviolet radiation.

3. A method of manufacturing a beam-splitting prism provided with a roof-edge prism, as claimed in Claims 1 or 2, comprising the steps of applying a drop of a liquid synthetic material to the
15 exit surface of the beam-splitting prism, pressing a die having a die surface comprising two die-surface portions which enclose an obtuse angle into the drop of synthetic material, curing the material and removing the die.

4. A method as claimed in Claim 3, in which the synthetic
20 material is an ultraviolet-curing substance, cured by exposure to ultra-violet radiation via a transparent die.

5. A method as claimed in Claim 3 or 4, wherein the die is provided with an anti-adhesion coating.

6. An optical read and/or write unit for reading and/or
25 recording information areas in a radiation-reflecting information surface, which unit comprises a radiation source, an objective system for focussing a beam emitted by the radiation source so that a radiation spot is formed on the information surface, and a beam splitting prism provided with a roof-edge prism arranged between the
30 radiation source and the objective system, for diverting the beam



which has been reflected by the information surface out of the radiation path of the beam emitted by the source and towards a radiation-sensitive detection system, which beam-splitting prism is a prism as claimed in Claim 1 or 2.

5 7. A beam-splitting prism substantially as described with reference to Figure 3 of the accompanying drawings.

8. A method of manufacturing a beam splitting prism substantially as described with reference to Figure 4 of the accompanying drawings.

10 9. An optical read and/or write unit substantially as described with reference to Figures 1, 2 and 3 of the accompanying drawings.

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