

The invention concerns a method for an optical scanning device for reading a magneto-optical recording medium, on which data are stored above each other in a magnetic layer and in the form of pits, in which a light source directs light onto the recording medium and in which the light reflected from the recording medium is directed in dependence upon its direction of polarisation to a first photodetector or to a second photodetector.

A known optical recording medium is, for example, the CD-disc in which a light-reflecting aluminium layer succeeds the transparent layer. The light-reflecting aluminium layer has indentations, so-called pits, which represent the data stored on the CD-disc. The data can be read from the CD-disc by means of an optical scanning device because the reflective behaviour of the light-reflecting aluminium layer depends on the pattern formed by the indentations on the disc. Less light is reflected from an indentation, frequently also called a groove, than from a hump, often designated by a land.

Therefore, from the intensity of the light reflected from the CD-disc, the optical scanning device recognises whether the bit scanned is, for example, a logical one or a logical zero.

Another such optical recording medium, known under the designation magneto-optical disc, is described in the paper "Magneto-optische Versuche dauern an" (Magneto-optical trials continue) in Funkschau 13, June 20, 1986, pp.37-41.

In contrast to a conventional CD-disc, a magneto-optical disc has no pits. Behind the transparent layer there is a magnetic layer in which data can be recorded and from which data can be read. Firstly, it will be explained how data are written onto a magneto-optical disc.

The magnetic layer is heated up beyond the Curie temperature by means of a laser beam focussed onto the disc. However, it is usually sufficient to heat up the magnetic layer to the compensation temperature lying just below the Curie temperature. An electromagnet is arranged behind the focal point on the disc and this magnetises the region heated by the laser beam in the one or the other direction of magnetization. As the heated point cools down again to below the Curie temperature after the laser beam has been switched off, the direction of magnetisation determined by the electromagnet remains; it freezes so to speak. In this way the individual bits are stored in domains with differing directions of magnetisation. For example, in this case one direction of magnetisation corresponds to a domain for a logical one, while the opposing direction of magnetisation represents a logical zero.

In order to read the data, use is made of the Kerr effect.

The plane of polarisation of a linearly polarised light beam is rotated by a measurable angle upon reflection in a magnetised mirror. The plane of polarisation of the reflected light beam is rotated to the right or the left according to in which direction the mirror is magnetised. However, as the individual domains on the disc act like magnetised mirrors, the plane of polarisation of a scanning light beam rotates through a measurable angle to the right or the left according to the direction of magnetisation of the domain just scanned.

The optical scanning device recognises which bit is present, a logical one or a logical zero, from the rotation of the plane of polarisation of the light beam reflected from the disc. In contrast to a CD-disc with pits, a magneto-optical disc can be erased and rewritten on almost indefinitely.

From U.S. 4858218 there is known an optical scanning device for reading a magneto-optical disc, on which there are provided 2 adjacent data tracks. Data are recorded magnetically on the first data track, while they are stored on the second data track optically in the form of pits. In a development of this magneto-optical plate the magnetic track and the track with the pits lie above one another. The light beam reflected from the disc is reflected in dependence upon its direction of polarisation either to a first or to a second photodetector. The outputs of the two photodetectors are connected to the inputs of a differential amplifier and an adding amplifier. At the output of the adding amplifier, the data signal recorded by means of the pits may be derived, while the output of the differential amplifier delivers the data signal stored in the magnetic layer.

A disc-type recording medium is known from DE-OS 3732875 which represents a combination of an optical and magneto-optical disc. On this recording medium data are stored not only by means of pits but also in the magnetic layer of the disc. As the pits and the magnetic domains lie on top of each other, data are stored both in the form of pits and also in the magnetic layer at one and the same point. Therefore, the storage capacity of this disk is double the size of a normal optical disk or a magneto-optical disc.

An optical scanning device is explained in DE-OS 3732874 which is suitable for the three types of disc listed above because this optical scanning device can read data from an optical disc, for example, a compact disc, a magneto-optical disc and also a disc which is known from DE OS 3732875.

With this optical scanning device, the light of a laser is focussed onto the disc and reflected from there to a polarisation beam splitter which reflects the light, depending on its direction of polarisation, to either a first or a second photodetector. The data signal stored in the magnetic domains of the disc is obtained from the difference between the

photoelectric voltages of the first and second photodetectors. That data signal which reproduces the data stored on the disk by means of the pits is generated from the sum of the photoelectric voltages of the first and second photodetectors. In the case of a disc like the one specified in DE OS 3732875, the optical scanning device described in DE-OS 3732874 can simultaneously read data stored by means of the pits and also data stored in the magnetic domains.

However, as the pits also cause an albeit very small rotation of the direction of polarisation of the light radiated by the laser, crosstalk between the data signal obtained by scanning the pits and the data signal read from the magnetic domains by means of the Kerr effect cannot be completely avoided. In order to sufficiently attenuate this crosstalk, minimum distances between the individual data tracks must be maintained as well as a minimum length and a minimum width for the pits. However, these minimum sizes restrict the storage capacity of the recording medium.

It is, therefore, the object of the invention to suppress the undesired crosstalk as completely as is possible.

The invention solves this task in that a leading light beam which is polarised in a first plane of polarisation and a trailing light beam, which is polarised in a second plane of polarisation oriented perpendicularly to the first plane of polarisation, are so directed onto the recording medium that the leading light beam is incident upon the recording medium at a predetermined spacing from the trailing light beam, that the oscillating component in the first plane of polarisation of the leading light beam reflected from the recording medium is deflected onto a first photodetector and the oscillating component in the second plane of polarisation of the trailing light beam reflected from the recording medium is deflected onto a second photodetector, that the oscillating component in the first plane of polarisation of the trailing light beam reflected from the recording medium is deflected onto a four-quadrant detector consisting of four photodiodes and the oscillating component in the second plane of polarisation of the trailing light beam reflected from the recording medium is deflected onto a third photodetector, that from the output signals of the four-quadrant photodetector there are produced a focus error signal for a focus control circuit and a tracking error signal for a track control circuit and that by addition of the output signals of the first photodetector and the second photodetector the data signal is obtained which reproduces the data stored in the pits, while by addition and subtraction of the output signals of the first, second and third photodetectors and by delaying the output signals of the first and second photodetectors, by an amount which exactly compensates the spacing between the leading and trailing light beam, the data signal is obtained which reproduces the data stored in the magnetic layer.

Figure 1 shows an embodiment of the invention;
 Figure 2 shows the position of the light beams on the recording medium;
 Figure 3 shows a double refractive crystal for generating two light beams;
 Figure 4 shows two lasers for generating two light beams;
 Figure 5 shows an electrical circuit arrangement for generating the control and data signals;
 Figure 6 shows the data signal which reproduces the data stored in the magnetic layer.

The invention will now be described and explained with reference to the embodiment shown in Figure 1.

In Figure 1 the light generated by a laser L passes through a collimator lens KL onto a double refractive crystal K, which splits the light of the laser L into a leading light beam VL and a trailing light beam HL, the directions of polarisation of which are perpendicular to each other. The leading light beam VL and the trailing light beam HL pass from the double refractive crystal K through a prismatic beam splitter PM and an objective lens O which focuses the two light beams VL onto the recording medium AT by means of a focusing control circuit. The two light beams VL and HL are reflected from the recording medium AT, pass through the objective lens O and return to the prismatic beam splitter PM which directs them to a $\lambda/2$ plate PL and a polarisation beam splitter PO disposed subsequent thereto. The polarisation beam splitter PO directs the leading light beam VL, depending on its direction of polarisation, either onto a photodetector E or a photodetector G. The polarisation beam splitter PO directs the trailing light beam HL, depending on its direction of polarisation, either onto a four-quadrant photodetector VP, comprising four photodiodes A, B, C and D, or onto a photodetector F.

A part of the surface of the recording medium AT is illustrated in Figure 2. The pits PT are arranged along the data tracks T. The direction of magnetisation of the magnetic layer is indicated by the different hatching. The leading light beam VL and the trailing light beam HL are focussed onto the recording medium AT by means of the focussing control circuit and guided along the data tracks T by means of the tracking control circuit. The leading light beam VL shines onto the recording medium AT at a predetermined spacing X ahead of the trailing light beam HL. As indicated by the double-headed arrows, the direction of polarisation of the leading light beam VL is parallel to the direction of the track, while the direction of polarisation of the trailing light beam HL is perpendicular to the track direction.

The laser L and the double refractive crystal K are illustrated in Figure 3. The double refractive crystal K generates the leading light beam VL and the trailing light beam HL, with the

directions of polarisation and the separation X on the recording medium AT as shown in Figure 2, from the light beam generated by the laser L, the direction of polarisation of which is at angle of 45° to the horizontal.

Instead of a laser and a double refractive crystal, two lasers L1 and L2 can be provided adjacent each other in order to generate the leading light beam VL and the trailing light beam HL, as is shown in Figure 4. The directions of polarisation of the two laser beams VL and HL are perpendicular to each other.

The circuit arrangement illustrated in Figure 5 will now be described; subsequent to this it will be explained how the control signals for the focussing and tracking control circuits and the data signals are generated from the output signals of the photodetectors.

In Figure 5 the outputs of the two photodiodes A and C, which are located diagonally opposite each other in the four-quadrant photodetector VP, are connected to the inputs of an adder A1. The outputs of the other two photodiodes B and D, also located diagonally opposite each other in the four-quadrant photodetector VP, are connected to the inputs of an adder A2. The output of adder A1 is connected to the addition input of a differential amplifier D1 whereas the output of adder A2 is connected to the subtraction input thereof. The differential amplifier D1 forms the focussing error signal $FE = (AS + CS) - (BS + DS)$, the control signal for the focussing regulation circuit, from the output signals AS, BS, CS and DS of the photodiodes A, B, C and D of the four-quadrant photodetector VP. The focussing error signal is generated according to the so-called astigmatism method.

The output signals BS and CS from one pair of mutually-adjacent photodiodes B and C of the four-quadrant photodetector VP are added in an adder A3, the output of which is connected to the addition input of a differential amplifier D2. The output signals AS and DS from the other pair of mutually adjacent photodiodes A and D of the four-quadrant photodetector VP are added in an adder A4, the output of which is connected to the subtraction input of a differential amplifier D2. The tracking error signal $TE = (AS + DS) - (BS + CS)$, the control signal for the tracking control circuit generated according to the push-pull method, can be picked up at the output of the differential amplifier D2.

The output signals ES and GS of the photodetector E and the photodetector G are added in an adder A6, the output signal PS of which represents the data signal obtained from the pits.

The output signals AS, BS, CS and DS of the photodiodes A, B, C and D of the four-quadrant photodetector VP are added in an adder A5, the output of which is connected to the addition input of a differential amplifier D4. The output signal FS of

the photodetector F is fed to the subtraction input of the differential amplifier D4. The output signal ES of the photodetector E is fed via a delay line VZ1 to the addition input of a differential amplifier D3, while the output signal GS of the photodetector G passes via a delay line VZ2 to the subtraction input of the differential amplifier D3. The output of differential amplifier D3 is connected to the subtraction input of a differential amplifier D5, the addition input of which is connected to the output of differential amplifier D4. Therefore, the data signal $MS = (AS - BS + CS + DS - FS) - (ES - GS)$ generated from the data stored in the magnetic layer of the recording medium AT, can be picked up at the output of the differential amplifier D5.

The two delay lines VZ1 and VZ2 are necessary because the data signal MS, which reproduces the data recorded in the magnetic layer, is not generated only from the leading light beam VL, like the data signal PS which reproduces the data stored by means of the pits, but rather, generated from both the leading and the trailing light beam which are located on the recording medium at a spacing X from each other. The two delay lines VZ1 and VZ2 compensate for the temporal displacement between the output signals ES and GS from photodetectors E and G on the one hand, and the output signals AS, BS, CS, DS and FS from the photodetectors VP and F on the other.

As the leading light beam VL and the trailing light beam HL are of equal cross-section, it is advisable to select all photodetectors VP, E, F and G to be the same size. Therefore, the photodetectors are drawn as equally sized squares in the Figures 1 and 5.

The measure of scanning the recording medium with two light beams, which strike the recording medium at a predetermined spacing, instead of one light beam as proposed in DE-OS 3732874, considerably suppresses the crosstalk.

The data signal MS, the frequency of which might be for example, 10 kHz, obtained from the data stored in the magnetic layer of the recording medium is shown in Figure 6. However, the data signal MS is superimposed by an oscillation with, for example, 100 kHz, which is caused by the data signal which is obtained from the data stored by means of the pits. The amplitudes of the superimposed oscillation of 100 kHz can, however, be considerably reduced if, as shown in Figure 4, two lasers are provided in order to generate the leading and trailing light beams.

The invention is suitable for an optical recording and/or reproduction device which can read not only optical and magneto-optical recording media but also a combination of the two. The invention can be used advantageously in data processing because data can be read and recorded at the same time. However, in CD players and video disc players too, the

invention also offers the advantage, for example, that sound and vision can be recorded at the same time as reproduction.



CLAIMS

1. A method for an optical scanning device for reading a magneto-optical recording medium, on which data are stored above one another in a magnetic layer and in the form of pits, in which a light source shines light on the recording medium and in which the light reflected from the recording medium is directed in dependence on its direction of polarisation onto a first photodetector or onto a second photodetector, characterised in that a leading light beam (VL) which is polarised in a first plane of polarisation, and a trailing light beam (HL), which is polarised in a second plane of polarisation oriented perpendicular to the first plane of polarisation, are so directed onto the recording medium (AT) that the leading light beam (VL) is incident upon the recording medium (AT) at a predetermined spacing (X) in front of the trailing light beam (HL), that the component of the leading light beam reflected from the recording medium (AT) oscillating in the first plane of polarisation is directed onto a first photodetector (E) and the component of the leading light beam (VL) reflected from the recording medium (AT) oscillating in the second plane of polarisation is directed onto a second photodetector (G), that the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the first plane of polarisation is directed onto a four-quadrant photodetector (VP) consisting of four photodiodes (A,B,C,D) and the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the second plane of polarisation is directed onto a third photodetector (F), that a focussing error signal (FE) for a focussing control circuit and a tracking error signal (TE) for a tracking control circuit are produced from the output signals of the four-quadrant photodetector (VP) and that by addition of the output signals of the first photodetector (E) and the second photodetector (G) the data signal (PS) is obtained, which reproduces the data stored in the pits, while by addition and subtraction of the output signals of the first, second and third photodetectors (E,G,F) and by delaying the output signals (ES, GS) of the first and second photodetectors (E,G) to exactly compensate for the spacing (X) between the leading and trailing light beams (VL, HL), the data signal (MS) is obtained which reproduces the data stored in the magnetic layer.

2. A method according to claim 1, characterised in that the light of a laser (L) is deflected through a first collimator lens (KL) to a double refractive crystal (K), which produces the leading and trailing light beams (VL, HL), that the leading and trailing light beams (VL, HL) pass through a prismatic beam splitter (PM) and an objective lens (O) and are incident upon the recording medium (AT) which reflects them back to the prismatic beam splitter (PM), that the prismatic beam splitter (PM) deflects the light beam (VL, HL) reflected from the recording medium (AT) to a $\lambda/2$ -plate, subsequent to which there is arranged a polarisation beam splitter (PO), that the polarisation beam splitter (PO) directs the component of



the leading light beam (VL) reflected from the recording medium (AT) oscillating in the first plane of polarisation to pass through a first convex lens (L1) and a first cylindrical lens (Z1) to the first photodetector (E) and the component of the leading light beam (VL) reflected from the recording medium (AT) oscillating in the second plane of polarisation to pass through a second convex lens (L2) and a second cylindrical lens (Z2) onto the second photodetector (G), that the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the first plane of polarisation is directed by the polarisation beam splitter (PO) to pass through the first convex lens (L1) and the first cylindrical lens (Z1) onto the four-quadrant photodetector (VP) and that the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the second plane of polarisation is directed to pass through the second convex lens (L2) and the second cylindrical lens (Z2) onto the third photodetector (F).

3. A method according to claim 1, characterised in that a first light source (L1) produces the leading light beam (VL), that a second light source (L2) produces the trailing light beam (HL), that the two light beams (VL, HL) pass through a collimator lens (KL), a prismatic beam splitter (PM) and an objective lens (O) and are incident upon the recording medium (AT), which reflects them back to the prismatic beam splitter (PM), that the prismatic beam splitter (PM) deflects the light beams (VL, HL) reflected from the recording medium (AT) to a $\lambda/2$ plate (PL), subsequent to which there is arranged a polarisation beam splitter (PO), that the polarisation beam splitter (PO) directs the component of the leading light beam (VL) reflected from the recording medium (AT) oscillating in the first plane of polarisation to pass through a first convex lens (L1) and a first cylindrical lens (Z1) onto the first photodetector (E) and the component of the leading light beam (VL) reflected from the recording medium (AT) oscillating in the second plane of polarisation to pass through a second convex lens (L2) and a second cylindrical lens (Z2) onto the second photodetector (G), that the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the first plane of polarisation is directed by the polarisation beam splitter (PO) to pass through the first convex lens (L1) and the first cylindrical lens (Z1) onto the four-quadrant photodetector (VP) and that the component of the trailing light beam (HL) reflected from the recording medium (AT) oscillating in the second plane of polarisation is directed to pass through the second convex lens (L2) and the second cylindrical lens (Z2) onto the third photodetector (F).

4. A method according to claim 1, 2 or 3, characterised in that the direction of polarisation of the leading light beam (VL) extends parallel to the direction of the currently scanned data track (T) of the recording medium (AT).



5. A method according to claim 1, 2, 3 or 4, characterised in that the four-quadrant photodetector (VP) and the first photodetector (E) are located on a common carrier (T1).

6. A method according to claim 1, 2, 3, 4 or 5, characterised in that the second and third photodetectors (F,G) are located on a common carrier (T2).

7. A method according to claim 1, 2, 3, 4, 5 or 6, characterised in that in a first adder (A1) there are added the output signals (AS, CS) of one pair of mutually diagonally photodiodes (A,C) of the four-quadrant detector (VP), that in a second adder (A2) there are added the output signals (BS, DS) of the other pair of mutually diagonally located photodiodes (B,D) of the four-quadrant photodetector (VP), that the output of the first and the second adders (A1, A2) are connected to the inputs of a first differential amplifier (D1), at the output of which may be picked up the focussing error signal (FE) for the focussing control circuit, that the output signals (BS, CS) of a first pair of adjacent photodiodes (B ,C) of the four-quadrant photodetector (VP) are added in a third adder (A3) that the output signals (AS, DS) of the other pair of mutually adjacent photodiodes (A,D) of the four-quadrant photodetector (VP) are added in a fourth adder (A4) that the outputs of the third and fourth adders (A3, A4) are connected to the inputs of a second differential amplifier (D2), at the output of which the tracking error signal (TE) for the tracking control circuit can be picked up, that in a fifth adder (A5) there is formed the sum of the output signals (AS, BS, CS, DS) of the four photodiodes (A,B,C,D) of the four-quadrant photodetector (VP), that in a sixth adder (A6) there are added the output signal (ES) of the first photodetector (E) and the output signal (GS) of the second photodetector (G), that at the output of the sixth adder (A6) there can be a picked up the data signal (PS) obtained from the pits, that the output signal (ES) of the first photodetector (E) arrives at the adding input of a third differential amplifier (D3) via a first delay line (VZ1), that the output signal (GS) of the second photodetector (G) arrives at the subtraction input of the third differential amplifier (D3) via a second delay line (VZ2), that the output of the fifth adder (A5) is connected to the adding input of a fourth differential amplifier (D4), that the output signal (FS) of the third photodetector (F) is applied to the subtraction input of the fourth differential amplifier (D4), that the output of the third differential amplifier (D3) is connected to the adding input and the output of the fourth differential amplifier (D4) is connected to the subtraction input of a fifth differential amplifier (D5), at the output of which there can be picked up the data signal (MS) obtained from the magnetic layer.

8. A method according to claim 1,2,3,4,5,6,or 7, characterised in that all photodetectors (VP, E, F, G) are selected to be the same size.