Description

The invention relates to a method of recording information on a record carrier having a magneto-optical recording layer, a pattern of magnetic domains having a first and a second direction of magnetisation being formed in the recording layer by scanning the recording layer with a radiation beam in order to temporarily heat the recording layer locally, the heated portions of the recording layer being exposed to a magnetic field which is directed substantially perpendicularly to the recording layer and which is generated by means of a coil, the coil being energised with an energising current which is modulated in conformity with an information signal, during which modulation the energizing current has a first polarity during first time intervals and a second polarity during second time intervals.

The invention further relates to a magneto-optical recording apparatus for recording information on a record carrier having a recording layer of a magneto-optical material, which recording apparatus comprises an optical system for scanning the recording layer by means of a radiation beam so as to locally heat the scanned portion of the recording layer, a coil for generating a magnetic field in the scanned portion of the recording layer, which field is directed substantially perpendicularly to the recording layer, an energising circuit for generating an energising current in the coil,which current is modulated in conformity with an information signal, such that during first time intervals the current has a first polarity and during second time intervals the current has a second polarity.

Such a method and apparatus are known from European Patent Specification EP-A 0,230,325. In the known method a constant intensity laser beam is aimed at a rotating magneto-optical disc by means of an optical system to image a radiation spot on the magneto-optical disc. The portion of the magneto-optical disc which is scanned by the radiation spot is heated to substantially the Curie temperature. The heated portion is magnetised by means of a coil which has a core of a soft magnetic material and is arranged opposite the optical system, at the other side of the rotating magneto-optical disc. The coil is energised with an alternating current modulated in conformity with the information signal, in such a way that the heated portion is magnetised in a direction which depends on the instantaneous polarity of the alternating current. The magnetisation is preserved after cooling. In this way a pattern of magnetic domains representative of the information signal is formed in the recording layer.

This recording method has the advantage that a previously formed pattern of magnetic domains can be overwritten. In order to achieve an adequate recording velocity a small low inductance coil is used, which is energised with a comparatively large energising current. A problem which then occurs is the substantial heat dissipation in the coil, the coil core and the electronic drive circuitry. This heat dissipation is therefore a restrictive factor in raising the recording velocity and/or increasing the magnetic field strength, for example in order to increase the distance from the coil to the recording layer.

It is an object of the invention to provide a method as defined in the opening paragraph, which enables the heat dissipation in the coil and/or the electronic drive circuitry to be reduced.

It is another object of the invention to provide an apparatus as defined in the second paragraph, for carrying out the method.

With respect to the method this object is achieved in that the radiation beam is pulse modulated, in that the first and second time intervals are separated by third time intervals in which no energizing currents are generated, the phase relation between the time intervals in which radiation pulses are generated and the first or second time intervals is maintained such that cooling of the heated portions of the recording layer takes place substantially inside the first or second time intervals.

With respect to the apparatus said object is achieved in that the recording apparatus comprises means for the pulse-modulation of the radiation beam, in that the energizing circuit is adapted to interrupt the generation of the energizing current during third time intervals, which separate the first and second time intervals from one another, and in that the recording apparatus further comprises a synchronizing circuit for maintaining a predetermined phase relationship between the time intervals in which the radiation pulses of the radiation beam are generated and the first or second time intervals, such that the cooling of the heated portions of the recording layer takes place substantially in the first or second time interval.

The invention is based inter alia on the recognition of the fact that if radiation energy is applied in the form of pulses, the temperature throughout the recording layer has decreased to substantially the ambient temperature in the time intervals between the radiation pulses, so that the magnetic field need be generated only during the short time in which the portion heated by the radiation pulse cools. Therefore, the coil has to be energised only briefly, which results in a reduced heat dissipation.

Another advantage of the recording method in accordance with the invention is that during heating of the recording layer the temperature gradient in the boundary region of the magnetic domain to be formed is very high, so that the accuracy with which the boundaries of the magnetic domain are formed is high. When the pattern of magnetic domains is subsequently read, this results in an improved signal-to-noise ratio.

Another advantage of the pulsed supply of the radiation energy is that the laser load is reduced, which leads to a longer service life of the laser.

Further advantage of the pulsed supply of the radiation energy is that the thermal load of the recording layer and hence the rate of ageing of the record carrier, is reduced in comparison with a radiation beam of constant intensity.

A preferred embodiment of the method is characterized in that the time intervals in which the radiation pulses and the energising-current pulses are generated partly overlap one another.

This embodiment has the advantage that the magnetic field is always present at the end of the radiation pulse, at which instant the temperature in the recording layer is maximal, so that the size of the portion heated above the write temperature is also maximal.

Another embodiment of the method is characterized in that the coil is of a type having a core of a non-magnetic material.

If in this embodiment a magnetic field of the same strength is generated the heat dissipation as a result of the resistive losses in the coil turns will be larger than in the case of a coil having a core of a magnetic material, but this is offset by the fact that no heat is dissipated in the core material. When the frequency of the energising current is increased the dissipation in the magnetic material of a coil having a magnetic core will increases at substantially faster rate than the heat dissipation in the coil turns. Indeed, above a specific frequency the heat dissipation in the magnetic material will be very dominant. Therefore, the last-mentioned embodiment of the method is very suitable for high recording velocities owing to the absence of a core of a magnetic material.

An embodiment of a recording apparatus which is very suitable for recording binary information signals having a specific bit rate is characterized in that the synchronising means are adapted to synchronise the generation of the radiation pulses and of the energising-current pulses with the bit rate of the information signals and in that the means for modulating the energising current are adapted to generate energising-current pulses of a polarity dictated by the logic value of the information signal.

An embodiment of the recording apparatus which is very suitable for recording FM modulated signals is characterized in that the synchronising means comprise an oscillator for generating an FM-modulated periodic signal, means for generating radiation pulses in synchronism with the periodic signal, and means for generating energising-current pulses in synchronism with the periodic signal, in such a way that a number of energising current pulses of a first polarity always alternates with an equal number of energising current pulses of opposite polarity.

Another embodiment of the recording apparatus is characterized in that the optical system comprises focusing means for focusing the radiation beam, the recording apparatus comprising means for maintaining a predetermined distance between the focusing means and the recording layer in order to focus the radiation beam on the recording layer, and in that the core of the coil is radiation-transmitting and is mechanically coupled to the focusing means, the coil being arranged in such a way that the radiation beam is projected onto the recording layer via the core of the coil.

This embodiment advantageously utilizes the absence of a coil core of a magnetic material. The mechanical coupling between the focusing means and the magnet coil ensures that the distance between the magnet coil and the recording layer is maintained constant during recording. This has the advantage that the conditions under which the heated portion of the recording layer is magnetised are maintained constant in a very simple manner, which is beneficial for the recording quality.

Further embodiments and the advantages thereof will now be described in more detail hereinafter with reference to Figs. 1 to 13, of which

Fig. 1 shows an embodiment of a recording apparatus in accordance with the invention,

Figs. 2, 9 and 11 show the intensity of the radiation beam, the energising current for generating the magnetic field and the resulting magnetic-domain patterns for different embodiments of the invention,

Fig. 3 represents a radiation pulse, the resulting temperature change in the recording layer, and an energising-current pulse as a function of time,

Figs. 4 and 5 illustrate the effect of the phase difference between the radiation pulses and the energising pulses on the signal-to-noise ratio,

Figs. 6 and 7 illustrate the temperature variation in the recording layer when this layer is heated with a pulsating radiation beam and with a constant-intensity beam respectively,

Figs. 8 and 10 show different synchronising circuits for use in the recording apparatus,

Fig. 12 shows a further embodiment of the recording apparatus in accordance with the invention, and

Fig. 13 shows an example of the coil for use in the recording apparatus.

Fig. 1 shows an embodiment of an apparatus in accordance with the invention for recording information on a disc-shaped record carrier 1. The record carrier comprises a transparent substrate 3 provided with a magneto-optical recording layer 2 of a customary type, for example as described in "PHILIPS Technical Review", Vol. 42, no. 2, pp. 38-47. The recording layer 2 is covered with a protective coating 4. The apparatus comprises a turntable 5 and a drive motor 6 for rotating the record carrier 1 about its axis. An optical system in the form of a customary optical head 7

is arranged opposite the rotating record carrier 1. The optical head 7 comprises a radiation source in the form of a semiconductor laser 8 for generating a radiation beam which is concentrated to form a tiny radiation spot on the recording layer 2 by means of a system of lenses 10 and 11. At the other side of the record carrier 1, opposite the optical head 7, a coil 12 is arranged which, when energised, produces a magnetic field which is directed substantially perpendicularly to the portion of the recording layer 2 scanned by the radiation beam 9.

A laser modulation circuit 13 of a customary type produces control pulses for the semiconductor laser 8, so that the laser 8 generates radiation pulses having a length of for example 80 ns. An energising circuit 14 generates energising current pulses of a first and a second polarity, which energising current pulses are applied to the coil 12. A synchronising circuit 15 derives from an information signal Vi control signals of equal frequency for the laser modulation circuit 13 and the energising circuit 14, a fixed relationship being maintained between the control signal, in such a way that the energising-current pulses are generated with a specific time delay relative to the radiation pulses. The delay time is selected in such a way that the radiation pulses and the energising-current pulses partly overlap one another. The radiation pulses and energising pulses thus generated are shown as a function of time in Fig. 2, the radiation pulses bearing the reference numerals 20a, ..., 20g and the energising-current pulses bearing the reference numerals 21a, ..., 21g.

How the control signals for the laser modulation circuit 13 and the energising circuit 14 are derived from the information signal Vi will be described in detail hereinafter. However, first the write process will be described with reference to Figs. 2 and 3.

Fig. 3 shows the radiation pulse 20a and the energising pulse 21a to a highly enlarged time scale. The reference numeral 30 in Fig. 3 indicates the temperature variation as a function of time for the area 22a (see Fig. 2) of the recording layer 2 which is irradiated by the radiation pulse 20a. As a result of the applied radiation energy the temperature in the area 22a rapidly rises above the write temperature Ts, which is the temperature above which the direction of magnetisation of the recording layer can be changed by the generated magnetic field. The write temperature Ts is generally situated in the proximity of the Curie temperature of the material of the recording layer.

At the end of the radiation pulse 20a the material cools very rapidly to approximately the ambient temperature as a result of the heat transfer in the recording layer 2.

The delay and the length of the energising-current pulses 21a have been selected in such a way that cooling of the recording layer takes place during the generation of energising pulse 21a, so that the area 22a is permanently magnetised in a direction of magnetisation defined by the polarity of the energising current pulse 21a. After the area 22a of the recording layer has cooled sufficiently, the generation of the magnetic field is discontinued by termination of the energising pulse 21a until during the next radiation pulse 20b the area 22b is heated above the write temperature Ts and the area 22b is magnetised as a result of the coil 12 being energised with the energising-current pulse 21b. In the train of energising-current pulses 21 shown in Fig. 2 the energising-current pulse 21b has a polarity opposite to the polarity of the energising-current pulse 21a, so that the direction of magnetisation in the area 22b is also opposed to the direction of magnetisation in the area 22a. The area 22b partly overlaps the area 22a, so that the direction of magnetisation in the overlapping portion of 22a is reversed. After the magnetisation of the area 22b the areas 22c, ..., 22g are magnetised by means of the radiation pulses 20c, ..., 20g and the energising-current pulses 21c, ..., 21g, yielding a pattern of magnetic domains 23 having a first direction of magnetisation and domains 24 having a second direction of magnetisation as is shown in Fig. 2.

It is to be noted that the direction of magnetisation outside the domains 23 and 24 is not indicated in Fig. 2. In reality the recording layer outside said domains is magnetised in one of the two possible directions.

The method of recording information described in the foregoing has the advantage that the coil 12 has to be energised only during the very short cooling period of the areas 20, enabling the heat dissipation as a result of the ohmic losses in the coil turns to be limited. Moreover, this also enables the heat dissipation in the energising circuit 14 to be limited.

Although the method is also advantageous in the case of coils having cores of a magnetic material, the use of a coil without a core of a magnetic material is to be preferred at high write velocities. When the core of a magnetic material is dispensed with a larger energising current will be required for a magnetic field of the same strength resulting in an increase of the resistive losses in the coil, but at very high frequencies this increase is outweighed by the very strong increase of the heat dissipation in the magnetic material occurring when the frequency is increased. Indeed, the heat dissipation in the magnetic material is far more frequency-dependent than the increase of the ohmic losses at increasing frequency.

Figs. 4 and 5 illustrate the effect of the size of the overlap of the radiation pulses 20 and the energising-current pulses 21 on the signal-to-noise ratio when the pattern of magnetic domains thus formed is read.

In Fig. 4 the end of the radiation pulse 20 is indicated by t0 and the beginning of the energising-current pulse is indicated by t1. The time interval t1-t0 is designated by T. Fig. 5 gives the signal-to-noise ratio as a function of the time interval T. A measurement

conducted for a pulse width of 50 ns has shown that the signal-to-noise ratio is optimum if the beginning of the energising current pulse is situated approximately 12 ns before the end of the radiation pulse.

Fig. 6 illustrates the temperature variation in the scanning direction (x) in the case that the duration of the radiation pulses is 80 ns, the scanning velocity is 1.2 m/s and the frequency of the radiation pulses is 4.32 MHz. These values for the frequency and scanning velocity correspond to the customary bit rate and scanning velocity when digital signals are recorded in conformity with the CD standard. The reference numerals 60, 61, 62, 63, 64 and 65 indicate the temperature variation at the beginning of the radiation pulse and 20 ns, 40 ns, 60 ns, 80 ns and 100 ns after the beginning of the radiation pulse. As is apparent from Fig. 6 the temperature rises above the write temperature Ts during the generation of the radiation pulse, until the maximum temperature is reached at the end of the radiation pulse (after 80 ns). After this the temperature decreases very rapidly below the write temperature Ts. For the positional accuracy of the boundaries of the magnetic domain to be formed it is important that the temperature gradient at the location of the domain boundaries is high. The domain boundaries are situated at location where the temperature of the recording layer intersects the write temperature. In Fig. 6 these locations bear the reference numerals 66 and 67.

It will be appreciated that the influence of fluctuations in ambient temperature, variations in write sensitivity and the magnetic field strength on the positional accuracy of the boundary of the magnetic domain being formed, decreases as the temperature gradient in the boundary region increases.

It is to be noted that the temperature gradient increases as the required energy is applied to the recording layer within a shorter time. Therefore, it is advantageous to select radiation pulses of a small length relative to the pulse repetition time.

By way of illustration Fig. 7 shows the temperature variation in the recording layer in the case that the recording layer is scanned with a constant-intensity radiation beam. As will be apparent from a comparison of the temperature variations in Figs. 6 and 7, the temperature gradient in the case of scanning with a constant-intensity radiation beam is substantially lower than in the case of scanning with a pulsed radiation beam.

Fig. 8 shows a first example of a synchronising circuit 15 suitable for controlling the recording process of a digital information signal Vi of a specific bit rate, for example an NRZ modulated signal as shown in Fig. 9. The synchronising circuit shown in Fig. 8 comprises a circuit for recovering a channel clock signal Vcl of a frequency equal to the bit rate of the information signal Vi. Such a circuit may comprise a phase detector 80 of a customary type which at every zero crossing of the information signal Vi determines the phase difference between this zero crossing and the clock signal Vcl. The phase detector 80 supplies a signal which is indicative of the detected phase difference to a voltage controlled oscillator 81 via a loop filter 82. The oscillator generates a periodic signal of a frequency which is an integral multiple of the channel-clock signal Vcl, from which periodic signal the channel-clock Vcl is derived by frequency division by means of a counter 83. The phase detector 80, the loop filter 82, the voltage-controlled oscillator 81 and the counter 83 constitute a phase-locked loop circuit of a customary type.

The count of the counter 83 is applied to the decode circuit 85 via a bus 84, which decoder circuit generates three logic "1" signals 86a, 86b and 86c when three consecutive counts are reached. The signals 86a and 86b are applied to the inputs of a two-input AND gate 87. The output signal of the AND gate 87 is applied to the laser modulation circuit 13, which is responsive to every pulse of the output signal of the AND gate 87 to generate a pulse shaped control signal for the laser 8. The signals 86b and 86c are applied to a two-input AND gate 88. The output signal of the AND gate 88 serves as the control signal for an electronic switch 89. The information signal Vi is applied to a first input of the switch 89, a second input of the switch 89 being connected to earth potential. Depending on the logic value of the control signal received from the AND gate 88 the electronic switch 89 connects the output of the switch 89 to the first or to the second input of the switch 89. The resulting signal 90 on the output of the switch 89 comprises a pulse train of a frequency equal to the bit rate of the signal Vi, the polarity of the pulses being dependent upon the instantaneous polarity of the information signal Vi. The signal 90 is applied to the energising circuit 14. The energising circuit 14 may comprise, for example, a high power voltage amplifier 91 which generates a voltage proportional to the input voltage of the amplifier 91. The output of the amplifier 91 is connected to the coil 12 via a resistor 92, the resistor 92 serving to limit the energising current. The resistance value of the resistor 92 and the inductance of the coil 12 are adapted to one another in such a way that the time constant of the RL circuit thus formed is small relative to the pulse width of the energising-current pulse.

In addition to the information signal Vi and the channel clock signal Vcl Fig. 9 shows the radiation pulses 20 and the energising current pulses 21 generated by the circuit of Fig.8 and the resulting. pattern of magnetic domains 23 and 24. In the pattern thus formed the portions of the signal Vi having a high signal level are represented by the domains 24 and the portions of the signal Vi having a low signal level are represented by the domains 23.

Fig. 10 shows a second example of a synchronising circuit 15 suitable for recording FM modulated

signals. The circuit comprises a voltage controlled oscillator 100 for generating a periodic pulse shaped signal Vcl' whose frequency is modulated in conformity with the input signal Vi'. The signal Vi' and the FM modulated signal Vcl' are shown in Fig. 11. It is to be noted that Fig. 11 shows only three different signal levels for the signal Vi'. However, it will be appreciated that the signal level for the signal Vi' can assume any arbitrary value between a minimum and a maximum level. The control signal for the laser modulation circuit 13 is derived directly from the FM modulated signal Vcl' by means of a delay circuit 101, which delays the signal Vcl' by a specific time. The control signal for the energising circuit 14 is also derived from the FM modulated signal. For this purpose the synchronising circuit 15 comprises a frequency divider 102, which derives from the signal Vcl' an NRZ signal 103 having a frequency which is a submultiple of the frequency of the signal Vcl'(for example a quarter) . The signal Vi', the signal Vcl' and the output signal 103 of the frequency divider 102 are shown in Fig. 11. The signal 103 is applied to a first input of an electronic switch 104. A second input of the electronic switch 104 is connected to earth potential. The control signal for the electronic switch 104 is derived directly from the signal Vcl' by means of a delay circuit 105. The delay times of the delay circuit 105 and the delay circuit 101 are selected in such a way that the output signal of the circuit 105 lags the output signal of the circuit 101 to such an extent that the beginning of a pulse on the output of the circuit 105 appears before the end of the associated pulse on the output of the circuit 101. Fig. 11 also shows the radiation pulses 20, the energising pulses 21 and the associated pattern of magnetic domains 23 and 24 obtained by means of the circuit shown in Fig. 10.

The embodiment of the invention shown in Figs. 10 and 11 advantageously utilises the fact that successive areas 22 overlap one another so that the length of the domains can be changed within specific limits by varying the frequency with which the radiation pulses 20 and the energising-current pulses are generated. A contiguous domain is always obtained if the spacing between two consecutive pulses is so small that the areas 22 overlap one another.

Fig. 12 shows another embodiment of the recording apparatus in accordance with the invention. In Fig. 12 components corresponding to the components in Fig. 1 bear the same reference numerals. The recording apparatus shown in Fig. 12 comprises a focus control system of a customary type comprising the lens 11, a semi-transparent mirror 120, a roof prism 121, a system of radiation sensitive detectors 122, a subtractor circuit 123, a control circuit 124, and an actuator 125. The beam reflected from the recording layer 2 is passed to the roof prism 121 by means of the semi-transparent mirror 120. The roof prism 121 splits the radiation beam into two sub-beams 9a and 9b which are aimed at the system of radiation sensitive detector 122. With this generally known method the difference in intensity between the sub-beams 9a and 9b is a measure of the focusing error. The subtractor circuit 123 devices a signal which is indicative of said intensity difference from the measurement signals supplied by the detector 122. Said signal is applied to the control circuit 124, which generates such a control signal for the actuator 125 that the actuator 125 keeps the radiation beam in focus on the recording layer 2 by moving the lens 11, which means that the distance between the lens 11 and the recording layer 2 is maintained constant.

If the coil 12 is a coil having a transparent core, for example an air-core coil, the coil 12 may be secured to the underside of the lens 11 in such a way that the radiation beam 9 is aimed at the recording layer via the transparent core of the coil 12. Such a construction has the advantage that the distance between the coil 12 and the recording layer is maintained constant during recording, which means that the conditions under which the area of the recording layer 2 heated by the beam 9 is magnetised always remain constant, which is beneficial for the recording quality.

Fig. 13 shows an example of the air-core coil 12, its shape being chosen in such a way that the heat dissipation in the coil is minimized for a given diameter D and a distance L from the record carrier 1.

This optimum coil shape can be determined as follows. The position of the first turn 130a of the coil 12 is dictated by the choice of L and D. Subsequently, the position of the next turn is selected in such a way that the ratio between the dissipation in this turn and the magnetic field produced in the record carrier 1 by this turn is minimal. The position of the following turn is determined in a similar way. This procedure of adding turns is continued until the magnetic field produced by all the turns is adequate.

Claims

1. A method of recording information on a record carrier (1) having a magneto-optical recording layer (2), a pattern of magnetic domains (23,24) having a first and a second direction of magnetisation being formed in the recording layer by scanning the recording layer (2) with a radiation beam (9) in order to temporarily heat the recording layer (2) locally, the heated portions of the recording layer being exposed to a magnetic field which is directed substantially perpendicularly to the recording layer and which is generated by means of a coil (12), the coil being energized with an energising current which is modulated in conformity with an information signal, during which modulation the energizing current has a first po-

signals. The circuit comprises a voltage controlled oscillator 100 for generating a periodic pulse shaped signal Vcl' whose frequency is modulated in conformity with the input signal Vi'. The signal Vi' and the FM modulated signal Vcl' are shown in Fig. 11. It is to be noted that Fig. 11 shows only three different signal levels for the signal Vi'. However, it will be appreciated that the signal level for the signal Vi' can assume any arbitrary value between a minimum and a maximum level. The control signal for the laser modulation circuit 13 is derived directly from the FM modulated signal Vcl' by means of a delay circuit 101, which delays the signal Vcl' by a specific time. The control signal for the energising circuit 14 is also derived from the FM modulated signal. For this purpose the synchronising circuit 15 comprises a frequency divider 102, which derives from the signal Vcl' an NRZ signal 103 having a frequency which is a submultiple of the frequency of the signal Vcl'(for example a quarter) . The signal Vi', the signal Vcl' and the output signal 103 of the frequency divider 102 are shown in Fig. 11. The signal 103 is applied to a first input of an electronic switch 104. A second input of the electronic switch 104 is connected to earth potential. The control signal for the electronic switch 104 is derived directly from the signal Vcl' by means of a delay circuit 105. The delay times of the delay circuit 105 and the delay circuit 101 are selected in such a way that the output signal of the circuit 105 lags the output signal of the circuit 101 to such an extent that the beginning of a pulse on the output of the circuit 105 appears before the end of the associated pulse on the output of the circuit 101. Fig. 11 also shows the radiation pulses 20, the energising pulses 21 and the associated pattern of magnetic domains 23 and 24 obtained by means of the circuit shown in Fig. 10.

The embodiment of the invention shown in Figs. 10 and 11 advantageously utilises the fact that successive areas 22 overlap one another so that the length of the domains can be changed within specific limits by varying the frequency with which the radiation pulses 20 and the energising-current pulses are generated. A contiguous domain is always obtained if the spacing between two consecutive pulses is so small that the areas 22 overlap one another.

Fig. 12 shows another embodiment of the recording apparatus in accordance with the invention. In Fig. 12 components corresponding to the components in Fig. 1 bear the same reference numerals. The recording apparatus shown in Fig. 12 comprises a focus control system of a customary type comprising the lens 11, a semi-transparent mirror 120, a roof prism 121, a system of radiation sensitive detectors 122, a subtractor circuit 123, a control circuit 124, and an actuator 125. The beam reflected from the recording layer 2 is passed to the roof prism 121 by means of the semi-transparent mirror 120. The roof prism 121 splits the radiation beam into two sub-beams 9a and 9b which are aimed at the system of radiation sensitive detector 122. With this generally known method the difference in intensity between the sub-beams 9a and 9b is a measure of the focusing error. The subtractor circuit 123 devices a signal which is indicative of said intensity difference from the measurement signals supplied by the detector 122. Said signal is applied to the control circuit 124, which generates such a control signal for the actuator 125 that the actuator 125 keeps the radiation beam in focus on the recording layer 2 by moving the lens 11, which means that the distance between the lens 11 and the recording layer 2 is maintained constant.

If the coil 12 is a coil having a transparent core, for example an air-core coil, the coil 12 may be secured to the underside of the lens 11 in such a way that the radiation beam 9 is aimed at the recording layer via the transparent core of the coil 12. Such a construction has the advantage that the distance between the coil 12 and the recording layer is maintained constant during recording, which means that the conditions under which the area of the recording layer 2 heated by the beam 9 is magnetised always remain constant, which is beneficial for the recording quality.

Fig. 13 shows an example of the air-core coil 12, its shape being chosen in such a way that the heat dissipation in the coil is minimized for a given diameter D and a distance L from the record carrier 1.

This optimum coil shape can be determined as follows. The position of the first turn 130a of the coil 12 is dictated by the choice of L and D. Subsequently, the position of the next turn is selected in such a way that the ratio between the dissipation in this turn and the magnetic field produced in the record carrier 1 by this turn is minimal. The position of the following turn is determined in a similar way. This procedure of adding turns is continued until the magnetic field produced by all the turns is adequate.

Claims

1. A method of recording information on a record carrier (1) having a magneto-optical recording layer (2), a pattern of magnetic domains (23,24) having a first and a second direction of magnetisation being formed in the recording layer by scanning the recording layer (2) with a radiation beam (9) in order to temporarily heat the recording layer (2) locally, the heated portions of the recording layer being exposed to a magnetic field which is directed substantially perpendicularly to the recording layer and which is generated by means of a coil (12), the coil being energized with an energising current which is modulated in conformity with an information signal, during which modulation the energizing current has a first po-



larity during first time intervals and a second polarity during second time intervals, characterized in that the radiation beam is pulse modulated, in that the first and second time intervals are separated by third time intervals in which no energizing currents are generated, the phase relation between the time intervals in which radiation pulses are generated and the first or second time intervals is maintained such that cooling of the heated portions of the recording layer takes place substantially inside the first or second time intervals.

2. A method as claimed in Claim 1, characterized in that the first and second time intervals partly overlap the time intervals in which the radiation pulses are generated.

3. A method as claimed in Claim 1 or 2, characterized in that the coil (12) is of a type having a core of a non-magnetic material.

4. A magneto-optical recording apparatus for recording information on the record carrier (1) having a recording layer (2) of a magneto-optical material, which recording apparatus comprises an optical system (7) for scanning the recording layer (2) by means of a radiation beam (9) so as to locally heat the scanned portion of the recording layer, a coil (12) for generating a magnetic field in the scanned portion of the recording layer (2), which field is directed substantially perpendicularly to the recording layer (2), an energizing circuit (14) for generating an energizing current in the coil, which current is modulated in conformity with an information signal, such that during first time intervals the current has a first polarity and during second time intervals the current has a second polarity, characterized in that the recording apparatus comprises means (13) for the pulse-modulation of the radiation beam, in that the energizing circuit (14) is adapted to interrupt the generation of the energizing current during third time intervals, which separate the first and second time intervals from one another, and in that the recording apparatus further comprises a synchronizing circuit (15) for maintaining a predetermined phase relationship between the time intervals in which the radiation pulses (20) of the radiation beam are generated and the first or second time intervals, such that the cooling of the heated portions of the recording layer takes place substantially in the first or second time interval.

5. A recording apparatus as claimed in Claim 4, characterized in that the predetermined phase relationship is selected in such a way that the first or second time intervals lag the time intervals in which radiation pulses are generated to such an extent that the first or second time intervals and the time intervals in which radiation pulses (20) are generated partly overlap each other.

6. A recording apparatus as claimed in Claim 4 or 5, for recording a binary information signals having a specific bit rate, characterized in that the synchronizing circuit (15) is adapted to synchronize the time intervals in which the radiation pulses (20) are generated and the first or second time intervals with the bit sequence generation of the information signal, and in that the means (14) for modulating the energizing current are adapted to generate the energizing current in the first and second time intervals with a polarity dictated by the logic value of the information signal.

7. A recording apparatus as claimed in Claim 6, characterized in that the recording apparatus comprises an oscillator (81) for generating a periodic signal, in that the synchronizing circuit (15) is adapted to derive the generation instants for the radiation pulses (20) and the first or second time intervals from the periodic signal, and in that the synchronizing circuit (15) further comprises means for maintaining a fixed phase relationship between the information signal and the periodic signal.

8. A recording apparatus as claimed in Claim 7, characterized in that the apparatus comprises phase-comparison means (80 for determining the phase difference between the periodic signal and the information signal and means (82) for synchronizing the information signal with the periodic signal depending on the detected phase difference.

9. A recording apparatus as claimed in Claim 7, for recording an FM modulated signal, characterized in that the synchronizing circuit (15) comprise an oscillator (100) for generating an FM-modulated periodic signal, means for generating radiation pulses (20) in synchronism with the periodic signal, and means for generating the energizing current in the first and second intervals in synchronism with the periodic signal, in such a way that a number of first time intervals always alternates with an equal number of second time intervals.

10. A recording apparatus as claimed in any one of the Claims 4 to 8, characterized in that the coil (12) is of a type having a core of a non-magnetic material.

11. A recording apparatus as claimed in Claim 10, characterized in that the optical system comprises focusing means (11) for focusing the radiation

beam, the recording apparatus comprising means (122, 123, 124, 125) for maintaining a predetermined distance between the focusing means (11) and the recording layer (2) in order to focus the radiation beam (9) on the recording layer (2), and in that the core of the coil (12) is radiation-transmitting and is mechanically coupled to the focusing means, the coil (12) being arranged in such a way that the radiation beam (9) is projected onto the recording layer (2) via the core of the coil (12).

Patentansprüche

1. Verfahren zur Aufzeichnung von Information auf einem Aufzeichnungsträger (1) mit einer magnetooptischen Aufzeichnungsschicht (2), wobei durch Abtasten der Aufzeichnungsschicht (2) mit einem Strahlungsbündel (9) zur vorübergehenden lokalen Erwärmung der Aufzeichnungsschicht (2) in der Aufzeichnungsschicht ein Muster magnetischer Domänen (23, 24) mit einer ersten und einer zweiten Magnetisierungsrichtung gebildet wird, wobei die erwärmten Teile der Aufzeichnungsschicht einem Magnetfeld ausgesetzt werden, das nahezu senkrecht auf die Aufzeichnungsschicht gerichtet wird und mit Hilfe einer Spule (12) erzeugt wird, wobei die Spule mit einem Erregerstrom erregt wird, der einem Informationssignal entsprechend moduliert ist, wobei während dieser Modulation der Erregerstrom während erster Zeitintervalle eine erste Polarität und während zweiter Zeitintervalle eine zweite Polarität hat, dadurch gekennzeichnet, daß das Strahlungsbündel pulsmoduliert ist, daß die ersten und zweiten Zeitintervalle durch dritte Zeitintervalle getrennt werden, in denen keine Erregerströme erzeugt werden, die Phasenbeziehung zwischen den Zeitintervallen, in denen Strahlungsimpulse erzeugt werden, und den ersten und zweiten Zeitintervallen aufrechterhalten wird, so daß Kühlung der erwärmten Teile der Aufzeichnungsschicht im wesentlichen innerhalb der ersten oder der zweiten Zeitintervalle erfolgt.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die ersten und zweiten Zeitintervalle die Zeitintervalle, bei denen die Strahlungsimpulse erzeugt werden, teilweise überlappen.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Spule (12) von einer Art ist, die einen Kern aus nicht-magnetischem Material hat.

4. Magnetooptische Aufzeichnungseinrichtung zur Aufzeichnung von Information auf dem Aufzeichnungsträger (1) mit einer Aufzeichnungsschicht (2) aus magnetooptischem Material, wobei die Aufzeichnungseinrichtung ein optisches System (7) zum Abtasten der Aufzeichnungsschicht (2) mit Hilfe eines Strahlungsbündels (9) umfaßt, um so den abgetasteten Teil der Aufzeichnungsschicht lokal zu erwärmen, sowie eine Spule (12) zur Erzeugung eines Magnetfeldes im abgetasteten Teil der Aufzeichnungsschicht (2), wobei dieses Feld nahezu senkrecht auf die Aufzeichnungsschicht (2) gerichtet ist, und eine Erregerschaltung (14) zur Erzeugung eines Erregerstroms in der Spule, wobei der Strom einem Informationssignal entsprechend moduliert ist, so daß der Strom während erster Zeitintervalle eine erste Polarität und während zweiter Zeitintervalle eine zweite Polarität hat, dadurch gekennzeichnet, daß die Aufzeichnungseinrichtung Mittel (13) zur Pulsmodulation des Strahlungsbündels umfaßt, daß die Erregerschaltung (14) zur Unterbrechung der Erzeugung des Erregerstroms während dritter Zeitintervalle, die die ersten und zweiten Zeitintervalle voneinander trennen, eingerichtet ist, und daß die Aufzeichnungseinrichtung weiterhin eine Synchronisationsschaltung (15) umfaßt, um eine zuvor bestimmte Phasenbeziehung zwischen den Zeitintervallen, in denen die Strahlungsimpulse (20) des Strahlungsbündels erzeugt werden, und den ersten oder zweiten Zeitintervallen aufrecht zu erhalten, so daß das Abkühlen der erwärmten Teile der Aufzeichnungsschicht im wesentlichen in dem ersten oder zweiten Zeitintervall erfolgt.

5. Aufzeichnungseinrichtung nach Anspruch 4, dadurch gekennzeichnet, daß die zuvor bestimmte Phasenbeziehung so gewählt wird, daß die ersten oder zweiten Zeitintervalle den Zeitintervallen, in denen Strahlungsimpulse erzeugt werden, in einem solchen Ausmaß nacheilen, daß die ersten oder zweiten Zeitintervalle und die Zeitintervalle, in denen Strahlungsimpulse (20) erzeugt werden, einander teilweise überlappen.

6. Aufzeichnungseinrichtung nach Anspruch 4 oder 5, zum Aufzeichnen binärer Informationssignale mit einer bestimmten Bitrate, dadurch gekennzeichnet, daß die Synchronisationsschaltung (15) zum Synchronisieren der Zeitintervalle, in denen die Strahlungsimpulse (20) erzeugt werden, und der ersten oder zweiten Zeitintervalle mit der Bitfolgenerzeugung des Informationssignals eingerichtet ist, und daß die Mittel (14) zum Modulieren des Erregerstroms eingerichtet sind, um den Erregerstrom in den ersten und zweiten Zeitintervallen mit einer durch den Logikwert des Informationssignals bestimmten Polarität zu er-

* C L M S *

zeugen.

7. Aufzeichnungseinrichtung nach Anspruch 6, dadurch gekennzeichnet, daß die Aufzeichnungseinrichtung einen Oszillator (81) zur Erzeugung eines periodischen Signals umfaßt, daß die Synchronisationsschaltung (15) eingerichtet ist, um die Erzeugungszeitpunkte für die Strahlungsimpulse (20) und die ersten oder zweiten Zeitintervalle aus dem periodischen Signal abzuleiten, und daß die Synchronisationsschaltung (15) außerdem Mittel zum Aufrechterhalten einer festen Phasenbeziehung zwischen dem Informationssignal und dem periodischen Signal umfaßt.

8. Aufzeichnungseinrichtung nach Anspruch 7, dadurch gekennzeichnet, daß die Einrichtung Phasenvergleichsmittel (80) zur Bestimmung der Phasendifferenz zwischen dem periodischen Signal und dem Informationssignal umfaßt sowie Mittel (82) zur Synchronisation des Informationssignals mit dem periodischen Signal in Abhängigkeit von der detektierten Phasendifferenz.

9. Aufzeichnungseinrichtung nach Anspruch 7 zum Aufzeichnen eines FM-modulierten Signals, dadurch gekennzeichnet, daß die Synchronisationsschaltung (15) einen Oszillator (100) zur Erzeugung eines FM-modulierten periodischen Signals umfaßt, Mittel zur Erzeugung von Strahlungsimpulsen (20) synchron zum periodischen Signal und Mittel zur Erzeugung des Erregerstroms in den ersten oder zweiten Zeitintervallen synchron zum periodischen Signal, so daß eine Anzahl erster Zeitintervalle immer mit einer gleichen Anzahl zweiter Zeitintervalle abwechselt.

10. Aufzeichnungseinrichtung nach einem der Ansprüche 4 bis 8, dadurch gekennzeichnet, daß die Spule (12) von einer Art ist, die einen Kern aus nicht-magnetischem Material hat.

11. Aufzeichnungseinrichtung nach Anspruch 10, dadurch gekennzeichnet, daß das optische System Fokussierungsmittel (11) zur Fokussierung des Strahlungsbündels hat, wobei die Aufzeichnungseinrichtung Mittel (122, 123, 124, 125) zum Aufrechterhalten eines zuvor bestimmten Abstandes zwischen den Fokussierungsmitteln (11) und der Aufzeichnungsschicht (2) umfaßt, um das Strahlungsbündel (9) auf die Aufzeichnungsschicht (2) zu fokussieren, und daß der Kern der Spule (12) strahlungsdurchlässig und mechanisch mit den Fokussierungsmitteln gekoppelt ist, wobei die Spule (12) so angeordnet ist, daß das Strahlungsbündel (9) über den Kern der Spule (12) auf die Aufzeichnungsschicht (2) projiziert wird.

Revendications

1. Procédé d'enregistrement d'information sur un support d'enregistrement (1) présentant une couche d'enregistrement magnéto-optique (2), une configuration de domaines magnétiques (23, 24) présentant une première et une deuxième direction de magnétisation étant formée dans la couche d'enregistrement par exploration de la couche d'enregistrement (2) avec un faisceau de rayonnement (9) pour chauffer temporairement et localement la couche d'enregistrement (2), les parties chauffées de la couche d'enregistrement étant exposées à un champ magnétique qui est orienté de façon sensiblement perpendiculaire à la couche d'enregistrement et qui est engendré au moyen d'une bobine (12), la bobine étant excitée avec un courant d'excitation en conformité avec un signal d'information, pendant ladite modulation le courant d'excitation présente une première polarité pendant de premiers intervalles de temps et une deuxième polarité pendant de deuxièmes intervalles de temps, caractérisé en ce que le faisceau de rayonnement est modulé par impulsions, en ce que les premiers et les deuxièmes intervalles de temps sont séparés par de troisièmes intervalles de temps dans lesquels aucun courant d'excitation n'est engendré, en ce que la relation de phase entre les intervalles de temps dans lesquels des impulsions de rayonnement sont engendrées et les premiers ou les deuxièmes intervalles de temps est maintenue de façon que le refroidissement des parties chauffées de la couche d'enregistrement se déroule sensiblement en les premiers ou les deuxièmes intervalles de temps.

2. Procédé selon la revendication 1, caractérisé en ce que les premiers et les deuxièmes intervalles de temps recouvrent partiellement les intervalles de temps dans lesquels sont engendrées les impulsions de rayonnement.

3. Procédé selon la revendication 1 ou 2, caractérisé en ce que la bobine (12) est d'un type présentant un noyau en matériau non magnétique.

4. Appareil d'enregistrement magnéto-optique pour l'enregistrement d'information sur le support d'information (1) présentant une couche d'enregistrement (2) en matériau magnéto-optique, ledit appareil d'enregistrement comportant un système optique (7) pour explorer la couche d'enregistrement (2) au moyen d'un faisceau de rayonnement (9) de manière à chauffer localement la partie explorée de la couche d'enregistrement, une bobine (12) pour engendrer un champ magnétique dans la partie explorée de la couche d'enre-

gistrement (2), ledit champ est orienté de façon sensiblement perpendiculaire à la couche d'enregistrement (2), un circuit d'excitation (14) pour engendrer dans la bobine un courant d'excitation modulé en conformité avec un signal d'information de façon que pendant de premiers intervalles de temps le courant présente une première polarité et que pendant de deuxièmes intervalles de temps le courant présente une seconde polarité, caractérisé en ce que l'appareil d'enregistrement comporte des moyens (13) pour la modulation par impulsions du faisceau de rayonnement, en ce que le circuit d'excitation (14) est conçu de manière à interrompre l'engendrement du courant d'excitation pendant de troisièmes intervalles de temps séparant les premiers et les deuxièmes intervalles les uns des autres, et en ce que l'appareil d'enregistrement comporte en outre un circuit de synchronisation (15) pour maintenir une relation de phase prédéterminée entre les intervalles de temps dans lesquels sont engendrés les impulsions de rayonnement (20) du faisceau de rayonnement et les premiers ou les deuxièmes intervalles de temps, de façon que le refroidissement des parties chauffées de la couche d'enregistrement se déroule sensiblement dans le premier ou le deuxième intervalle de temps.

5. Appareil d'enregistrement selon la revendication 4, caractérisé en ce que la relation de phase prédéterminée est choisie de façon que les premiers ou les deuxièmes intervalles de temps sont décalés par rapport aux intervalles de temps dans lesquels sont engendrées des impulsions de rayonnement de telle façon que les premiers et les deuxièmes intervalles de temps et les intervalles de temps dans lesquels sont engendrées des impulsions de rayonnement (20) se recouvrent partiellement.

6. Appareil d'enregistrement selon la revendication 4 ou 5 conçu pour enregistrer des signaux d'information binaires présentant une vitesse de bit spécifique, caractérisé en ce que le circuit de synchronisation (15) est conçu de manière à synchroniser les intervalles de temps dans lesquels sont engendrés les impulsions de rayonnement (20) et les premiers et les deuxièmes intervalles de temps avec l'engendrement de séquence de bit du signal d'information, et en ce que les moyens (14) pour moduler le courant d'excitation sont conçus pour engendrer le courant d'excitation dans les premiers et les deuxièmes intervalles de temps avec une polarité dictée par la valeur logique du signal d'information.

7. Appareil d'enregistrement selon la revendication 6, caractérisé en ce que l'appareil d'enregistrement comporte un oscillateur (81) pour engendrer un signal périodique, en ce que le circuit de synchronisation (15) est conçu pour dériver les instants d'engendrement des impulsions de rayonnement (20) et les premiers ou les deuxièmes intervalles de temps du signal périodique, et en ce que le circuit de synchronisation (15) comporte en outre des moyens pour maintenir une relation de phase fixe entre le signal d'information et le signal périodique.

8. Appareil d'enregistrement selon la revendication 7, caractérisé en ce que l'appareil comporte des moyens de comparaison de phase (80) pour déterminer la différence de phase entre le signal périodique et le signal d'information et des moyens (82) pour synchroniser le signal d'information avec le signal périodique en fonction de la différence de phase détectée.

9. Appareil d'enregistrement selon la revendication 7 pour enregistrer un signal FM modulé, caractérisé en ce que le circuit de synchronisation (15) comporte un oscillateur (100) pour engendrer un signal FM périodique modulé, des moyens pour engendrer des impulsions (20) en synchronisme avec le signal périodique, et des moyens pour engendrer le courant d'excitation dans les premiers et les deuxièmes intervalles de temps en synchronisme avec le signal périodique de façon qu'un certain nombre de premiers intervalles de temps alterne toujours avec un nombre équivalent de deuxièmes intervalles de temps.

10. Appareil d'enregistrement selon l'une quelconque des revendications 4 à 8, caractérisé en ce que la bobine (12) est d'un type présentant un noyau en matériau non magnétique.

11. Appareil d'enregistrement selon la revendication 10, caractérisé en ce que le système optique comporte des moyens de focalisation (11) pour focaliser le faisceau de rayonnement, l'appareil d'enregistrement comportant des moyens (122, 123, 124, 125) pour maintenir une distance prédéterminée entre les moyens de focalisation (11) et la couche d'enregistrement (2) pour focaliser le faisceau de rayonnement (9) sur la couche d'enregistrement (2) et en ce que le noyau de la bobine (12) transmet le rayonnement et qu'il est accouplé mécaniquement aux moyens de focalisation, la bobine (12) étant disposé de façon que le faisceau de rayonnement (9) est projeté sur la couche d'enregistrement (2) par l'intermédiaire du noyau de la bobine (12).