The present invention relates to a method for calibrating the optical power of a write-in light radiation beam applied to an optical disc used for the recording of data, in particular an automatic method of calibration for the recording of digital data. The present invention further relates to a device for implementing this method.

The digital optical discs of the prior art are, in general, discs on the surface of which there has been deposited a layer sensitive to light radiations, on which layer it is possible to write in, by means of a source of light radiations (whether or not within the visible spectrum), data of binary type. This writing-in is most frequently obtained by the action of the heat released by the light radiations of a focussed beam, upon contact with the sensitive layer. Depending upon the particular case concerned, the writing-in obtained is constituted either by a perforation of this layer or by a deformation in the form of microcavities or microreliefs, or by any other modification of the layer. It is easy to find, under these conditions, that the geometry of the writing-in obtained is closely linked to the luminous power applied to the sensitive layer and thus that this power must be capable of being controlled and regulated with precision.

The luminous power to be applied to the sensitive layer, in order to obtain a correct writing-in, is a function of a plurality of parameters including principally:

. the quality of the optical elements between the sensitive layer and the source of light radiations (lens, prisms...), this being a quality which, moreover, may become impaired in the course of time by variation of the surface condition due to ageing and to the contamination of the elements by dust;

. the angle of incidence of the write-in light beam in relation to the layer, this angle being a function of the tolerances of the disc and of the associated mechanical system;

. the sensitivity of the material making up the layer itself, which may vary slightly from one disc to another;

. the system employed for the slaving of the focussing of the beam which exhibits limited performance levels; there necessarily subsists therefore a slight error of focussing of the light spot on the sensitive layer;

. variations of the parameters of the source of light radiations itself (most frequently, the source concerned is a semiconductor laser) which are capable of variation within significant proportions from one source to another and likewise of being affected by ageing;

. the limited precision of the electronic system for controlling and regulating the power emitted by the source of light radiations.

European Patent Application A 44072 discloses a focussing control system in an apparatus for recording data on an optical disc. The object of the invention is to provide an end-of-focussing error signal. In this patent, a description is given of a system for calibrating the laser power. However, this calibration takes place only when the beams are focussed.

In fact, the calibration devices known at the present time permit the control of only a proportion of these parameters: for example, the optical power emitted by the source may be controlled by means of an appropriate system for measuring the optical power, this system may take into account a proportion of the parameters of the optical system (contamination by dust), but it is adversely affected by the error due to the measurement system itself, which may furthermore vary over time. The parameters associated with the disc and with the error of the servo mechanisms as well as with the deformations of the light spot are not taken into account by such a system.

In the Patent US-A-4,297,730, a description has also been given of a method permitting the automatic regulation of certain parameters which are critical for

the purpose of obtaining an optimum recording, but within the field of magnetic recording.

The object set for the invention is to provide a method for calibrating which alleviates the disadvantages which have just been set forth.

The method for calibrating according to the invention utilises a means for testing all the parameters set forth hereinabove and which is capable of influencing the geometry of the writing-in obtained.

The subject of the invention is a method for calibrating the optical power of a focussed light radiation beam emitted by a source, said beam being applied to an optical substrate intended to record data and comprising at least one layer of a material having optical characteristics which may be modified under the influence of said radiations, this method being used in a data recording device comprising means for focussing an optical write-in beam in the surface of said optical substrate, said beam being able to be electrically modulated by an incident electric signal representing said data, means ensuring the scanning of said surface by said write-in beam, opto-electric read-out means whose interaction with the modifications of optical characteristics of said surface produces an electric read-out signal, and control means allowing adjustment of the power of the write-in beam in such a way that the read-out signal conveniently reproduces the time distribution of the pulses constituting said incident electric signal, characterised in that the control means perform the following steps:

a) in a first step, at least one message comprising a predetermined number of binary test words constituted by a succession of binary elements having a first logic level ("1") and a second logic level ("0") is recorded in zones distinct from the data zones, the binary words being recorded with a plurality of stepped optical write-in power levels of the radiation beam applied to said layer of sensitive material,

b) then, during a second step,

- the binary test words which have previously been recorded are read out,
- for each test word, the duration of the binary elements having the first logic level and the duration of the binary elements having the second logic level are measured,
- the ratio between said durations is determined,
- the optimum optical write-in power is determined from this ratio, and
- an optimum control value for the power emitted by the source is elaborated on the basis of this determination, and this value is stored in memory.

The invention will be better understood, and further features and advantages will become more clearly evident, upon reading the description which follows with reference to the accompanying figures, in which:

- Figure 1 diagrammatically represents an optical disc recorder in which the invention may be implemented,
- Figure 2 represents a particular circuit employed within the scope of the invention for the measurement and the control of the optical power emitted by a source,
- Figures 3 to 5 are diagrams illustrating a plurality of situations which arise within the scope of the writing-in of data by optical means,
- Figure 6 represents an illustrative embodiment of a test circuit employed within the scope of the invention,
- Figure 7 represents an illustrative embodiment of a circuit for generating synchronisation signals,
- Figure 8 diagrammatically illustrates a particular structure of an optical disc on which test words have been recorded.

The calibration device according to the invention will first of all be described in terms of its principal arrangements.

According to the invention, there are reserved, for example at the start and at the end of the useful recording zone of an optical disc, a few tracks on which,

during a first stage, a message of particular binary configuration is written in, this message being supplied by an appropriate recording system and comprising successive recordings of one and the same binary word which are made with differing stepped luminous powers on either side of the power level which is assumed to be good in order to obtain a correct writing-in.

During a second step, re-reading takes place of the binary message recorded previously and processing takes place of the signal emanating from this reading by means of appropriate electronic means, in such a manner as to determine what optical write-in power has given the best results. It is, moreover, probable that, having regard to the power response of the sensitive layers, a plurality of power levels have given suitable results. In this case, of course, it is the mean value of these various levels which is selected for the future writing-ins.

The correct optical power level, once determined, is stored in memory electronically and will be used for the purpose of making all the recordings which will follow, until such time as it is judged to be expedient to initiate a new test. The periodicity of these tests may be either determined by the operator or, preferably, initiated automatically in accordance with a program determined in advance. This may be, for example, upon each loading of a new disc into the write-read apparatus and at regular time intervals (every 24 or 48 h) if the same disc remains permanently in the apparatus.

The benefit of having test tracks at the start and at the end of the disc is that of being able at the same time to place in memory the law for the correction of write-in power as a function of the radius. In fact, the law of variation of the write-in power as a function of the radius being determined by an interpolation between the levels obtained for the powers required for writing in within the central zone and within the peripheral zone of the disc, it is possible to obtain the power required for any other value of the radius.

Preferably, the method of calibration according to the invention utilises the same read and write means and the same recording substrate as those used for the recording of the useful binary messages, and an error of calibration of the power accordingly becomes very improbable.

The invention will now be described in a more detailed manner with reference to Figures 1 to 6.

Figure 1 is a general diagram of a write-read apparatus for optical discs including means for calibrating the write-in power for the implementation of the invention.

This apparatus comprises means common to those in general use in the prior art, and only the means required for the comprehension of the present invention have been shown.

This apparatus is intended to inscribe on a disc 1 binary data arranged in accordance with a predetermined geometric configuration. For the recording of digital data, use is generally made of a configuration of concentric circular tracks 10, whether or not comprising a prerecorded guide data item, for example prerecorded continuous smooth tracks or "flags" distributed along the virtual tracks and between which the useful data item is recorded.

It is possible to use such a disc either to inscribe data at a determined point of one of the tracks or to read data inscribed at any point of this track. The disc, for example having a diameter of approximately 30 cm, is given a rotational movement by convention, about an axis parallel to one of the axes, Z, of an orthonormed trihedron XYZ. This movement is transmitted by a drive motor M integral with the frame of the optical record-read system. In the illustrative embodiment illustrated in Figure 1, the device for access to a predetermined track 10 of the disc 1 comprises a fixed part comprising a source of light energy and a movable part constituted by the record-read head. As is known, the latter comprises an objective lens of the microscope

type O_b, integral with an electromagnetic coil B which moves within the magnetic field of a permanent magnet (not shown) ensuring the vertical slaving and a galvanometer mirror m ensuring the radial slaving. As is likewise known, the sources of light energy comprise laser sources, for example helium-neon (He Ne) gas or semiconductor lasers. The gas lasers deliver a polarised parallel beam, the cross-section of which is very small. The laser beam must be expanded in such a manner as to cover the entrance pupil of the objective lens, this being so irrespective of the position of the objective lens along the optical axis. The semiconductor laser sources emit a divergent beam inscribed within a cone of elliptical cross-section. It is then necessary to use an anamorphic component and optical elements (lens etc...) which make the emitted beam cylindrical. These arrangements depart from the scope of the invention and are well known to a person skilled in the art. In the part of the text which follows, it will be assumed that the beam emitted by the source S is a beam of parallel rays. It will likewise be assumed, without this being a limitation, that the beam emitted by the source S is linearly polarised and that the reading and the detection of the inscribed data are undertaken by reflection. A separating optical element 2 disposed in the path of the beam of parallel rays F permits the discrimination of the incident beam, emitted by the source S, from the reflected beam, which is retransmitted to optoelectronic detecting means 3 associated with a focussing element, which is represented in the form of a converging lens L.

The separating optical element 2 is, in the example illustrated in Figure 1, constituted by a polarising separator cube. This cube is, in general, associated with an element for the bidirectional conversion of the linear polarisation into a circular polarisation, this element being disposed on the exit face of the cube 2, that is to say the face opposite to the face which faces the source S. Such arrangements are described, among others which depart from the scope of the

invention, and by way of example, in the published French Patent Application FR-A-2,483,664.

It is likewise possible to use, in place of a separator cube, other likewise conventional means such as a partially reflecting mirror.

The light beam F which is focussed on the disc is partially reflected by the latter and deflected by means of the prism 2 and of the lens L onto read cells coupled to an amplifier and included within the optoelectronic detecting means 3, the output of which is coupled to the calibration device of the invention 4 and to servomechanisms 5 and 6.

During the reading, as is known, signals are likewise derived from the output signals of the optoelectronic detecting means, these signals representing the recorded data.

The correct focussing is ensured by the slaving device 6 acting on the objective lens O_b via the coil B, and the following of the track is ensured by the slaving device 5 and the movable mirror m.

The calibration device 4 according to the invention, in the specific illustrative embodiment shown in Figure 1, comprises a test circuit 40 receiving on one input e_1 the output signals of the optoelectronic detecting means 3, a synchronisation circuit 41 receiving likewise the output signals of the optoelectronic detecting means 3 and elaborating synchronisation signals. The test circuit 40, after processing and matching of the signals received, retransmits them to a circuit for logic processing of signals 42 (input e_2). Preferably, this circuit 42 is constituted by a microprocessor, but may be constituted by any similar circuit such as a wired logic circuit or programmable logic array (known by the English-language abbreviation: "PLA").

These circuits 42 control the optical power emitted by the source S (input e_c) via a control circuit 8 which receives in feedback (input e_{CR}) signals representing this emitted power.

The circuit 41 supplies synchronisation signals

to the circuits 40 (input e_{S1}) and 42 (input e_{S2}).

The various components of the device according to the invention will now be more specifically described.

There is no need to describe in detail the optoelectronic detecting means 3, which may be common to the prior art. They comprise photodetector elements, for example a four-quadrant cell of the type described in the published French Patent Application FR-A-2,483,664.

This cell is followed by amplifier stages which elaborate at the output signals representing the write-in state of the optical disc 1, that is to say the state of reading of the data inscribed on the tracks 10.

From these same signals there may be extracted synchronisation signals, for example in the manner described in the French patent application filed under No. 82/04,218 on 12th March 1982 in the name of the Applicant. These synchronisation signals serve to sample the transmission of the read signals from the test circuits 40 to the logic processing circuits 42 and then to the control circuits 8.

Where a microprocessor is involved, these logic processing circuits, according to an advantageous aspect of the invention, may have a multiple function. In fact, besides the specific function which they perform within the scope of the invention, they may likewise be used for the other tasks of management of the operation of the read-write apparatus for the optical disc.

In reality, in a preferred variant, the device of the invention uses, in shared time, the data processing means, generally a microprocessor, with which this type of apparatus is equipped. It is sufficient to provide a set of instructions specific to the implementation of the method of the invention, stored in memory in any suitable form, which are generally recorded within a control ROM in the form of a resident program. In the text which follows, for the sake of simplification, it will be considered that the control circuits 42 are constituted by a microprocessor.

In a particular illustrative embodiment, this

microprocessor 42 for controlling the apparatus passes to the system 8 for controlling the luminous power emitted by the source S a write instruction, at previously programmed power levels, of eight binary messages, which may be, in the selected example, eight times one sequence of 64 bits, and stepped according to a linear law on either side of an assumed level which is a priori indicated in order to obtain a correct writing-in.

This a priori determination may be obtained by experiment, by statistical tests, or by computation.

It is assumed that the cyclic ratio of the inscription control binary signals is equal to unity.

Figure 2 represents a particular construction of the control device 8 for the luminous power emitted by the source S.

The microprocessor 42 for controlling the apparatus passes the power control data by means of four transmission lines to a digital-analogue converter 80 disposed as input stage in the power control circuits 8. It is thus possible to obtain at the output of the converter 80 sixteen current levels which are different and regularly stepped. Among these sixteen levels, eight are selected by the microprocessor. A differential amplifier 81 amplifies the output current of the converter 80 and controls, via a transistor power amplifier stage 82, the current passing through a laser diode included within the source S (input e_c). A photoelectric cell D is coupled to the rear emission face of this laser diode S and the current of this cell D (output e_{CR}) is passed in feedback to the differential amplifier 81 (inversion input) in such a manner as to obtain an emission of light which is well controlled and stable in relation to the temperature variations.

There is moreover provided a set of resistors and of potentiometers R_1 to R_8 to polarise and to regulate the neutral points of the various elements which are activated. In particular, the feedback level may be regulated by means of the potentiometer R5 disposed between the anode of the photodiode D and a reference potential

selected by convention as being that of ground. The direct (+) input of the differential amplifier 81 is likewise connected, via a resistor R_4, to ground. The neutral point of the (-) inversion input of this amplifier is regulated by means of a potentiometer disposed between a source of voltage, equal to +5V in the example selected moreover at the cathode of the photodiode D, and ground. The slide of this potentiometer is connected via a resistor R_2 to the inversion input of the amplifier 81, the latter input being moreover connected to the output of the digital-analogue converter 80 via a resistor R_3. Finally, the transistor 82 of the power amplifier stage being of the NPN type in the example illustrated in Figure 2, the emitter thereof is connected, via a resistor R_6, to a source of negative voltage, -5V.

Naturally, all these elements are described only by way of simple illustration of a specific illustrative embodiment of the devices of the invention and are capable of numerous other technological choices within the range of a person skilled in the art in order to accomplish the functions of the means for controlling the emission power of the source S.

Once inscribed on the optical disc 1, in zones reserved for this purpose, the binary words will be reread and the effect of the level of power emitted on the characteristic parameters of the writing-in will be evaluated and, from this evaluation, a determination will be made of the optical emission power required in order to obtain an optimum writing-in.

Figure 3 shows a diagram illustrating the form of the signals, for example of the voltage signals, emanating from the optoelectronic conversion of the beam of light radiations reflected by the inscribed surface of the optical disc 1 (Figure 1) by the optoelectronic component 3. The upper curve illustrates the progression, as a function of time, of the signals V_D present at the output of photoelectric cells included in the optoelectronic component 3, and the lower curve the progression of signals V_S emanating from the shaping of

the signals V_D, for example by means of conventional threshold circuits operating in all or nothing mode. These signals exhibit two logic levels "0" and "1" which are each associated with a logic level read, likewise corresponding to a "0" or "1" bit inscribed on the disc.

Figure 3 shows a read signal V_D (and a shaped signal V_S) corresponding to an optimum write-in power. It follows that the amplitude of the read signals V_D find their amplitude varying symmetrically about a mean value $V_{threshold}$, which is used as threshold value. It likewise follows that the cyclic ratio of the shaped signals V_S is equal to unity or at least very close to this value. This cyclic ratio is the ratio (T_1/T_0) representing the respective durations of the signal V_S in the condition "1" (T_1) and at "0" (T_0), that is to say likewise the length of the writing-ins representing the inscriptions of a "1" bit and of a "0" bit, since there is a one-to-one correspondence between durations of the read signal and inscription lengths, having regard to the speed of rotation of the disc 1.

Figure 4 shows signals corresponding to a write-in power which is too low. Moreover, in order to provide a better illustration of the phenomenon, it has been assumed that the write-in power decreased as a function of time (from left to right in Figure 4).

If it is assumed that the threshold value $V_{threshold}$ is constant, it is found that the variations of amplitude of the read signals V'_D become progressively more asymmetric in relation to this threshold value. It follows that the cyclic ratio (T1/T0) of the shaped signals likewise departs progressively further from the optimum value, that is to say unity. In the present case, the duration of the signals corresponding to a writing-in of a "1" bit diminishes; this is readily appreciated, the layer of material sensitive to the radiations generally presenting a sensitivity threshold and the distribution of energy of a laser beam being capable of being approximated to a gaussian distribution, the length of a disturbance of the layer of this material corresponding

to the effective exposure to the radiations diminishes in correlation with the optical power carried by the radiations.

It must be well understood that a writing-in corresponds to one bit at the logic level "1" only by convention. The opposite convention could of course be adopted.

The diagram of Figure 5 illustrates the opposite effect, that is to say where the power emitted by the laser source S is too high. The cyclic ratio (T1/T0) of the signals V_S, after shaping of the read signals V_D, is then greater than unity, and increases in correlation with the increase in the optical power received by the sensitive layer in the course of the writing-in.

It is an easy matter, using appropriate circuits, to measure the durations T_1 and T_0 and to determine in this manner what is the power which gave a correct writing-in, that is to say that for which the cyclic ratio is the closest to unity.

Figure 6 represents a practical illustrative embodiment of test circuits 40 intended to measure the durations T_1 and T_0.

A clock signal H supplied by the synchronisation circuit (Figure 1: 41) which will be described in detail in the text which follows and which is of frequency equal to eight times that of the sequence of bits for the recording in this illustrative embodiment, is transmitted by the input e_{S11} to a first input of an "AND" logic gate: 400. This logic gate 400 transmits the clock pulses during a window F of a duration equal to 64 bits, corresponding to the sequences of 64 bits previously written in. This window F is likewise supplied by the synchronisation circuit (input e_{S12}) and transmitted to a second input of the logic gate 400. The clock pulses are switched on the one hand to a counter 404 via a first input of an "AND" logic gate: 401 when the condition of a signal V_S originating from the reading is at the level "1" (input e_{S13}), this signal being transmitted to a second input of the logic gate 401 and, on the other

hand, to a counter 405 via an "AND" logic gate: 403 when the condition of the signal V_S originating from the reading is at the zero level; this signal is transmitted to the "AND" gate: 403 by an inverter 402.

In the example illustrated, the counters 404 and 405 are binary counters provided with parallel outputs SC_1 and SC_2. The outputs of the "AND" logic gates: 401 and 403 are connected to incrementing inputs e_{H1} and e_{H2}, respectively, of the counters 404 and 405.

The counters 404 and 405 are reset to zero by a signal RAZ before the start of the window F transmitted to reset-to-zero inputs e_{RAZ1} and e_{RAZ2}. Thus, at the end of the window F of duration equal to 64 bits, there is available the sum of the clock pulses which have occurred during the thirty-two successive conditions at "1" of the signal V_S on the output of the counter 404 and the sum of the clock pulses which have occurred during the thirty-two successive conditions at zero of the signal V_S on the output of the counter 405. The parallel outputs SC_1 and SC_2 of the counters 404 and 405 are connected to the microprocessor 42 for controlling the apparatus, which may thus undertake the comparison between the logic levels carried by the outputs SC_1 and SC_2 and thus determine the ratio T_1/T_0 (Figures 3 to 5), this being undertaken with respect to a mean implemented over 64 bits for greater accuracy.

If a recording has been made of a plurality of successive sequences of 64 bits or more, using stepped power levels as has been described with reference to Figures 3 to 5, it is possible for the microprocessor 42 to determine which one of these write-in power levels has given the ratio T_1/T_0 which is closest to unity, and to store in memory this power level in order to perform the subsequent writing-ins.

Figure 7 illustrates a specific illustrative embodiment of the synchronisation circuit 41 (Figure 1).

To this circuit there are assigned the tasks, on the one hand, of recognition of the start of a test word and, on the other hand, of generation of a signal F

representing a time window, of duration equal to the total duration of the number of bits of the test word (sixty-four in the selected example) and of a clock signal H in phase with respect to the read signals.

It is necessary first of all to recognise, among all the data inscribed on the disc, the specific data representing the test words. Numerous methods are known. Preferably, although this is not a limitation, use will be made, within the scope of the invention, of the teaching of the French Patent Application No. 82/04,219 filed on 12th March 1982 in the name of the Applicant.

According to this patent application, the useful data recorded are associated with specific data or "flags" serving to resynchronise the read means employed. Preferably, the useful data and the specific data are encoded in accordance with the "N.R.Z." code; the specific data being associated with durations of pulses which are unused in the "N.R.Z." code. If T is the period which represents the duration of an elemental binary signal or bit and which corresponds to a cycle frequency F = 1/T, a duration equal to one and a half times the period T is chosen, for example, for the specific data.

Accordingly, the synchronisation circuit 41 comprises a first component 410 which will be referred to as the "flag detector" receiving the read signals V_s supplied by the optoelectronic detection circuits 3 and intended to discriminate, among the recorded data, the specific data or flags. These data are recorded at the start of the test word in a known time relationship with the useful data, that is to say the alternating sequence of logic "1" and "0" making up the binary test word (sixty-four bits in the selected example).

The synchronisation circuit 41 further comprises an oscillator 420, for example a quartz oscillator delivering a signal H having a frequency which is a multiple of the bit frequency. It is necessary that this frequency should be sufficiently high to ensure a precise operation, for example eight times the bit frequency F as has been stated in relation to the description of

Figure 6. It is likewise necessary that these signals should be maintained in phase with the signals V_S emanating from the reading and received from the output of the optoelectronic detection circuits 3. To this end, there is provided a phase restoration component 430 receiving a signal V_a supplied by the flag detector component 410 and indicating the start of the test word, which is used as operation authorisation signal, a phase restoration component which generates in return, from the clock signals H', clock signals H which are likewise transmitted to a generator 440 of the time window signal F. The clock signals H are synchronised with respect to one of the transitions of the signals V_S, for example the rising front of the pulses representing a logic "1".

If necessary, the time window F may be used to generate the reset-to-zero signal RAZ for the counters 404 and 405 of the test circuit 40 (Figure 6).

The various components which have just been described may be constructed in accordance with the teachings of the aforementioned French patent application.

By way of example, the discriminating component 400 may be constructed on the basis of two monostable elements triggered, for example, by the rising front of the pulses emanating from the reading and generating pulses of duration slightly greater and slightly less than one and a half times the bit period T. The logic intersection of these two pulses may be used to determine whether the pulse emanating from the reading is associated with a flag (duration 1.5 T).

The phase restoration circuits 430 may be constructed with the aid of an oscillator of the voltage-controlled type ("VCO" in accordance with the English-language terminology) equipped with a phase-locked loop ("PLL") comprising a phase comparator, receiving the signals supplied by the flag detector 410 and the oscillator 420. This oscillator is restored in phase at each flag detection.

The generator 440 of the time window signal F may

be constituted on the basis of a binary counter incremented by the clock signals H. It is furthermore reset to zero at the start of counting by a signal RAZ' derived from the enabling signal V_a supplied by the flag detector 410 and sets the signal F at a first logic condition, for example at the "1" logic condition. At the end of counting, that is to say at maximum capacity which must be an integral multiple of the number of bits of the test word, it sets the signal F at the second logic condition, "0" in the selected example. As has been described, these synchronisation signals are used by the test 40 and data processing 42 circuits.

As has been indicated, the elements of the circuits may be selected from among those which are currently available commercially. By way of example, it is possible to use integrated circuits of the type 74 F191, HA 5195, a microprocessor of the type 6809 and a laser diode emitting radiations of optical power 15 mW of wavelength centred on 820 nm.

The test carried out as has just been described may be repeated, of course, on a plurality of occasions over the periphery of the disc, both within a zone close to the rotation axis and at the periphery in order to eliminate a possible local defect of the sensitive layer which might lead to an erroneous interpretation of the result.

The device according to the invention requires the provision of zones reserved for the inscription of test words, that is to say zones which cannot be used for the recording of useful data. However, this does not constitute a real constraint. In fact, if 250 tracks are provided at the periphery of the disc and the same quantity within a central zone close to the axis of the disc in order to carry out the calibration tests, the space occupied on the disc is typically less than 0.5 millimetre of total width for each group of 250 tracks; this is very small on a disc having a diameter of 30 centimetres. Furthermore these tracks, in view of a smaller requirement with regard to error rate than for

the useful writing-in, may be placed outside the zone which is generally used for the writing-in of the useful digital data, just before the start and just after the end of this zone. Such an arrangement is illustrated in Figure 8.

Within the scope of the applications envisaged for the recording of data of digital type, it is customary to use discs, the diameter of which is generally 30 cm, as has been stated, and generally comprising approximately 40,000 tracks 10 distributed over a ring 11 of width 8 cm or useful zone. Most frequently, the recordings are distributed within zones, delimited in advance or angular sectors 110. Typically, this number of sectors is of the order of 10 to 25.

Within this configuration, it is thus possible to reserve two annular zones 12 and 13 contiguous with the useful recording zone 11 and respectively at the periphery (zone 12) and close (zone 13) to the centre O of the disc 1. Preferably, the test words are distributed regularly within these sectors.

It is possible to proceed from the hypothesis that it is possible to inscribe 3200 blocks of 64 bits per track, i.e. for 250 tracks: 800,000 blocks. It is thus possible, if each test involves the inscription of four groups of eight blocks distributed over one turn of the disc, to carry out 25,000 tests both within a peripheral zone 12 and within the inner zone 13.

In the event of an intensive use of the disc and at the rate of one test every 24 hours, this represents approximately 70 years of possible use of the disc, 24 hours out of 24.

Accordingly, with respect to this specific illustrative embodiment, it is found that the implementation of the method for calibrating the power emitted by the source does not give rise to any substantial degradation either of the recording capacity of the disc or of its service life, while still permitting the integration, in the power measurement carried out, of a large number of parameters which were not taken into account in the

methods of the prior art.

It is possible to summarise the steps of the calibration method according to the invention as follows:

a/ recording of a predetermined number of binary test words, each binary word being recorded with a distinct optical power level: each binary word being constituted by a sequence of bits in accordance with a regular succession to the "0" and "1" logic conditions,

b/ read-out of these binary test words,

c/ analysis of each binary word. This analysis being preferably carried out by forming the mean over the number of bits of the binary words,

d/ determination, from this analysis, of the optical power to be used,

e/ and elaboration, from this determination, of an optimum control quantity for the power emitted by the source and the storage of this quantity.

In preferred variants, the method further comprises supplementary steps of inscription of a plurality of groups of binary words distributed regularly, on the one through (sic), according to angular sectors and, on the other hand, within two zones, one close to the periphery, the other close to the central zone of the disc.

As has been stated, the first supplementary measure permits the formation of means which set aside the risks of errors due to dispersions and aberrations in the characteristics of sensitivity of the layer of material sensitive to the radiations and the second measure permits the performance of an interpolation, and from this interpolation is deduced the value of the optimum optical power required for the inscription, along a radial axis, taking account of a predetermined variation law.

In order to set the concepts, a mean value of optimum power of writing-in of the inner radius of the annular recording zone (Fig. 8:11) is typically 8 mW. Tests will be carried out on either side of this value, with increments of, for example, 0.5 mW.

As regards the interpolation, it is found that a typical mean value of optimum power of writing in is 11 mW at the outer radius. It is possible to divide the annular zone, for example, into four annular sub-zones, for which the values 8, 9, 10 and 11 mW will be adopted in the case where the extreme values are 8 and 11 mW.

CLAIMS

1. Method for calibrating the optical power of a focussed light radiation beam emitted by a source (S), said beam being applied to an optical substrate (1) intended to record data and comprising at least one layer of a material having optical characteristics which may be modified under the influence of said radiations, this method being used in a data recording device comprising means (B) for focussing an optical write-in beam (F) in the surface of said optical substrate, said beam being able to be electrically modulated by an incident electric signal representing said data, means (5, 6) ensuring the scanning of said surface by said write-in beam, opto-electric read-out means (2, 3) whose interaction with the modifications of optical characteristics of said surface produces an electric read-out signal (V_s), and control means (4) allowing adjustment of the power of the write-in beam (F) in such a way that the read-out signal conveniently reproduces the time distribution of the pulses constituting said incident electric signal, characterised in that the control means perform the following steps:

a) in a first step, at least one message comprising a predetermined number of binary test words constituted by a succession of binary elements having a first logic level ("1") and a second logic level ("0") is recorded in zones (12, 13) distinct from the data zones, the binary words being recorded with a plurality of stepped optical write-in power levels of the radiation beam applied to said layer of sensitive material,

b) then, during a second step,

- the binary test words which have previously been recorded are read out,
- for each test word, the duration (T_1) of the binary elements having the first logic level and the duration (T_0) of the binary elements having the second logic level are measured,
- the ratio between said durations (T_1/T_0) is determined,
- the optimum optical write-in power is determined from

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this ratio, and

- an optimum control value for the power emitted by the source is elaborated on the basis of this determination, and this value is stored in memory.

2. Method according to Claim 1, characterised in that the binary test words are recorded in the form of monotonic sequences of binary elements showing alternately a first logic level ("1") and a second logic level ("0") of identical durations.

3. Method according to Claim 2, characterised in that the optical power level is determined by obtaining a ratio (T_1/T_0) between the durations which is closest to unity.

4. Method according to any one of Claims 1 to 3, characterised in that, the substrate being constituted by a disc (1) which is organised in sectors (110), the recording step comprises the recording of a plurality of messages of binary words which are regularly distributed in these sectors.

5. Method according to any one of Claims 1 to 4, characterised in that, the substrate being constituted by a disc comprising an annular zone (11) with determined inner and outer radii, this zone being intended for data recording, the recording step comprises the recording of at least two messages of binary test words, one in an area (13) of the rotation axis (O) situated at a distance less than or equal to the inner radius, and the other in an area (12) situated at a distance from the rotation axis greater than or equal to the outer radius, and in that the method comprises an additional step in which the law of variation of the optimum control value for the power emitted along an axis intersecting the rotation axis is determined by interpolating between the values determined for each one of said binary test words, and in which this law is stored in memory.

6. Method according to any one of Claims 1 to 5, characterised in that each binary test word comprises a determined number of pairs of binary elements of alternate logic levels, and in that the ratio (T_1/T_0) between

the duration of the first logic level and that of the second logic level is determined by establishing the mean of said determined number.

7. Method according to any one of Claims 1 to 6, characterised in that the step of recording binary test words is performed automatically at predetermined time intervals.

8. Device for implementing the method according to any one of Claims 1 to 7 in a data write-in and read-out apparatus, in a predetermined area (11) of an optical substrate (1) having at least one layer of material which is sensitive to light radiations, comprising a source (S) of a beam (F) of these light radiations, means (0_b, m) for access to said area (11) and focussing this beam (F) onto the layer of sensitive material for the data recording, optoelectronic read-out means (3) for reading these data, control means (4) allowing the write-in beam power to be adjusted, characterised in that the control means comprise means (8) for controlling the optical power of the radiations emitted by the source (S) such that at least one message comprising a predetermined number of binary test words associated with a plurality of stepped write-in power levels is written-in into said sensitive material layer, each test word being constituted by binary elements having alternately a first logic level ("1") and a second logic level ("0"), optoelectronic read-out means (3) for reading these recorded binary words and for converting them into a binary electric signal, means (40) for evaluating the duration (T_1) of the binary elements having the first logic level ("1") and the duration (T_0) of the binary elements having the second logic level ("0") means (42) for determining and storing a control signal for the optical power emitted by the source, these means determining the ratio (T_1/T_0) between the duration of the binary elements at the first logic level ("1") and the duration of the binary elements at the second logic level ("0"), and elaborating a signal for controlling the power emitted by the source (S) giving the optimum power, means (41) for synchronising

the operation of the evaluation means (40) and the means (42) for determining and storing and the means (41) (sic) for controlling the optical power emitted by the source.

9. Device according to Claim 8, characterised in that the means (40) for evaluating the durations of the binary signals comprise a first binary counter (403) receiving clock signals (H) on a first input (e_{H1}) during first time intervals (T_1) during which the read-out binary signals present a first logic level ("1") and incremented by these clock signals (H), a second binary counter (404) receiving the clock signals (H) on a second input (e_{H2}) during second time intervals (T_0) during which the read-out binary signals present a second logic level ("0") and incremented by these signals, logic means (401, 402) switching the clock signals (H) towards the first binary counter (403) during the second (sic) time intervals and towards the second binary counter (404) during the second time intervals, logic enabling means (400) allowing the clock signals to be transmitted during a total time interval corresponding to the time of reading out and converting the binary test words, and means (RAZ) for resetting both binary counters (403, 404); and in that both binary counters are counters provided with parallel outputs (SC_1, SC_2) supplying on these outputs respectively a first binary word representing the total duration of the binary signals at the first logic level ("1") and a second binary word representing the total duration of the binary signals at the second logic level ("0").

10. Device according to Claim 9, characterised in that the means (42) for determining and storing a signal for controlling the optical power emitted by the source (S) are constituted by data processing means comprising a memory for storing these data, these means receiving said first and second binary words supplied by the first and second binary counters (403, 404), elaborating the ratio (T_1/T_0) between these two binary words and storing in the data memory a binary control word corresponding to the optical power level emitted by the source for which said ratio (T_1/T_0) is closest to unity.

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11. Device according to Claim 10, characterised in that, the recording of binary test words comprising the recording of at least two binary test words, the processing means (42) interpolate according to a predetermined law between the control words corresponding to those optical power levels emitted by the source associated with each binary test word for which said ratio (T_1/T_0) is closest to unity.

12. Device according to either of Claims 10 and 11, characterised in that the data processing means (42) are constituted by a microprocessor.

13. Device according to any one of Claims 8 to 12, characterised in that, the source (S) for emitting a light radiation beam (F) being a laser diode (L_a), the means (8) for controlling this source comprise a digital-analogue converter (80) receiving from the data processing means (42) the said control words and converting them into electric signals, the amplitudes of which are representative of the binary value of these control words, and means (81, 82) for amplifying these electric signals, generating at the output a current for controlling the laser diode in such a manner as to generate one optical power level in bi-uniform correspondence with the amplitude of said electric signals.