This invention relates to a process permitting radial following of a track of an optical information medium, particularly in disc form, by a beam of light energy and also focusing of this beam onto a given plane of the medium. The invention also relates to a device for implementing this process.

Many processes for radial following of tracks have been described in the known art. When it is a question of recording information in sequential form, for example video information, the tracks are generally not materialised in advance but rather created in real time at the moment of recording. The information is recorded along tracks having the form of a single spiral extending from the peripheral zone of the disc towards a central zone or vice versa, or else having the form of concentric circles centred on the axis of rotation of the disc.

In the simplest systems, reliance is placed on the accuracy of the components for advancing the recording head to create this track. During reading, data, recorded for example in the form of micro-reliefs, interfere with a reading beam focused in the plane of the recording face of the disc. The running of these micro-reliefs under the focusing spot modulates the beam and this modulation is detected by means of photoelectric cells converting the variations in luminous intensity into electrical signals. These electrical signals may also be used for a track-following purpose.

The process which has just been described necessitates the advance of the recording head to show a very high degree of mechanical stability, this in order to prevent two successive grooves from overlapping or at least from being poorly discernible during reading. With a view to improving the system which has just been described, a process was proposed in the French patent application published under the number 2,366,636, using the last track written or one of the tracks previously written as reference. To the system for mechanically advancing the recording head is added a system for optical deflection of the recording spot. The reading spot is caused to keep following an already written groove of the track by a conventional position control system. By means of the optical deflection system, the recording spot is maintained at a distance which is constant and equal to a whole multiple of the pitch of the track, from the reading spot.

However, when one wishes to record information in a random manner, for example in applications relating to data processing, it is no longer possible to use the processes which have just been described or similar processes. It is in general necessary to materialise beforehand the tracks with respect to which information may be recorded. To do this, it is customary to create a pre-engraving in whatever form it may be. In one constructional example described in the French patent application published under the number 2,365,854, during the manufacture of the medium, the tracks are materialised in the form of a smooth groove created in an auxiliary layer of this medium. These tracks may be detected even in the absence of any recording of information, this recording being performed in a subsequent phase in a photosensitive or thermosensitive layer in contact with the auxiliary layer.

In a preferred variant of the known art, the pre-engraved tracks may be merged with the regions in which the data are recorded. A system termed single-track is then obtained.

In other processes, the pre-engraved track or tracks are distinct from the tracks along which the data are recorded. Systems termed twin-track are then obtained. To distinguish these two types of track, it may be arranged for the pre-engraving to consist of a signal decomposable into a first spectrum of frequencies and the information decomposable into a second separate spectrum of frequencies. During the writing, the reading beam may be used to follow the pre-engraved track as in the above-mentioned second French patent application.

The main disadvantage of the process which has just been described is that it does not allow a maximum recording density since it necessitates, at least, one additional track of pre-engraving for one pre-engraved information track. Furthermore, it necessitates the use of two beams, one for the radial following of the pre-engraved track and the other for the writing or the reading of information on the track intended for the recording.

Neither are the media of the type termed single-track, comprising a pre-engraving, for example such as those described in the Japanese patent application J.A.5,622,227, without disadvantages. They

generally necessitate the use of two beams, one for recording and the other for radial tracking. In addition, if the pre-engraved track is easily discernible from the remainder of the disc (intertrack zones) in the absence of recording of information, the same is no longer true when the data are recorded. If precautions are not taken, this may result in reversals of contrast leading to tracking errors.

Therefore, to alleviate these disadvantages, it is proposed in the European patent application filed by the Applicant, on the same day as this application under the No. 83,400,427.7 (EP-A-89,263), a radial tracking device making use of an information medium comprising a pre-engraving used for radial track following constituted solely by "flags" distributed regularly or otherwise along the tracks.

According to that patent application, the pre-engraving is constituted by a succession of non-contiguous discrete elements materialising the average centrelines of the tracks. The spatial distribution of these discrete elements may or may not be uniform. According to a first variant, each discrete element comprises several portions defining a particular code. According to additional variants, each element comprises, apart from a portion centred on the average centrelines of the tracks, one or several portions offset with respect to the average centreline. In fact, each of the pre-engravings may itself be preceded by an auxiliary pre-engraving element used with a view to synchronisation. The track following device comprises photo-detector means, measurement circuits comprising sampler-blockers or memory-type integrator circuits and sampling circuits. A radial track following error signal is prepared from the changes in the signals detected during successive passes into an illuminated zone of the surface of the disc by a track following spot.

In addition to the correct radial tracking ensured by the preferred process which has just been described, a second requirement associated with the reading or writing of information on an optical medium, relates to the focusing of the beam or beams of light energy utilised. These beams must be focused on the medium in a spot which must continuously follow the fluctuations if any in level of the tracks.

To do this, it is known that correct focusing of the beam is generally obtained by means of a focusing control device comprising a feedback loop keeping the distance between the optical device and the engraved surface of the medium constant. The acquisition and the holding of the control device are achieved by detecting the fluctuations of an electrical signal derived in a first variant, from the reading of the recorded information and, in a second variant, from the detection of the pre-engraving materialising the tracks, for example in the form of a smooth groove.

The same difficulties are then encountered as those mentioned above in connection with radial tracking.

The invention is intended to alleviate the disadvantages of the known art and proposes an information medium and devices utilising such a medium to perform the radial tracking or the focusing while escaping the difficulties due to the losses of contrast in the conventional systems.

The object of the invention is therefore an information medium comprising in at least one optically recordable reference surface a set of adjacent track elements along which is arranged a succession of non-contiguous sites set apart for the storage of the information in an optically readable form, the said storage sites being separated from one another by interstitial sites comprising patterns for materialising the non-sinuous average centreline of the said track elements, this line representing the ideal path which the means for transcription of the said information has to follow; the said patterns appearing in the discrete and pre-engraved form of non-contiguous portions with closed contours of the said reference surface, characterised in that the said patterns are patterns arranged along two off-centre alignments which materialise the transverse position of the said average centreline by a symmetrical framing action; each interstitial site enclosing at least one of the said pre-engraving patterns; the law of distribution of the said pre-engraving patterns between the said alignments being such that a pre-engraving pattern occupying one of the alignments in one of the interstitial sites has as a corresponding part a pre-engraving pattern occupying the other alignment in the immediately neighbouring interstitial site to the exclusion of any pre-engraving pattern centred on

the centreline; the said law of distribution being a law indexed by means of at least one recurrent encoded structure uniting at least two pre-engraving patterns, the pre-engraving patterns being such that their length and/or their spatial distribution represents a selectively detectable code.

The invention has as a further object, optical devices for focusing and/or radial tracking, the optical devices for focusing being usable either with an information medium such as defined above or such as described in the European patent application filed by the Applicant, on the same day as this application under the number 83,400,427.7 (EP-A-089,263).

The invention will be better understood and other characteristics will become apparent with the help of the following description referring to the attached figures, among which:

- figure 1 shows a disc of the known art and a device for track following on such a disc and for focusing;
- figures 2 to 5 show a pre-engraving of a disc according to several constructional variants in accordance with the invention;
- figures 6 and 7 show the electrical diagrams of radial track following devices according to several constructional variants in accordance with the invention;
- figures 8 and 9 are diagrams explaining the operation of the devices;
- figure 10 shows the essential elements of a focusing device according to the invention:
- figures 11 to 13 are diagrams explaining the operation of this device;
- figure 14 shows an electrical diagram of a device permitting, according to a preferred variant of the invention, simultaneous radial track following and focusing.

Since the invention relates to an information medium and a device for radial following of one of the tracks on an information medium of pre-engraved type and also focusing, a reminder of the main constituent elements of a system for recording and/or reading of information media particularly of media in the form of optically

readable and writable discs, is useful.

Figure 1 shows an information medium 5 of the known art in the form of a circular disc rotatable in a plane XOY about an axis parallel to the third axis of a reference trihedron XYZ. The lower face of this disc is here assumed to be smooth; the upper face which is parallel with it is also smooth, but comprises a pre-engraved track 7 in the form of a smooth track the approximately constant width of which is of the order of or less than one micrometre.

Such a disc may be used, either to write information at a given point of one of the smooth tracks written beforehand, or to read information written at any point of this track. The disc, for example of a diameter of about 30 cm, is driven with a rotary movement communicated by a driving motor securely attached to the chassis of the optical recording-reading system. In this constructional example, the device for access to a given track of the disc comprises a fixed part comprising two sources of light energy (not shown in figure 1) and a movable part constituted by the recording head. As is known, the latter comprises an objective of the microscope type O_b, securely attached to an electromagnetic coil B moving in the magnetic field of a permanent magnet (not shown) providing the vertical control or the focusing and a galvanometric mirror M_1 providing the radial control. The sources of light energy, as is also known, comprise laser sources, for example He Ne gas lasers or semi-conductors. Gas lasers deliver a polarised parallel beam the section of which is very small. The laser beam has to be magnified so as to cover the input pupil of the objective, this whatever the position of the objective along the optical axis. To meet this requirement, it was proposed in French patent application FR-A-2,462,758 to interpose between the sources of light energy and the movable recording-reading head an afocal-type optical system.

For the reading, a parallel laser beam f_1 produced by a laser source (not shown in figure 1), is magnified by means of an afocal, the magnification of which is such that the emergent beam, also parallel, covers the entry pupil of the objective O_b. The mirror M_1 deviates the rays which are propagated parallel with a direction parallel with the axis OX. The objective O_b focuses the reading beam at the point 3 on

the information medium disc 5. This disc is driven with a rotary movement symbolised by the arrow 6. The objective and the mirror are securely attached to a movable apparatus constituting the recording-reading head. The advance of this movable assembly may be obtained by any known means.

The same afocal is then used for the recording beam f_e, this having been modulated beforehand. In order to differentiate the tasks of reading and of recording on the disc, the recording beam f_e is inclined very slightly with respect to the reading beam f_1 so that the off-centering of the recording beam on the entry pupil of the objective is very limited and so that the displacement of the beam during a radial displacement of the head can be disregarded. It follows that whatever the position of the objective along the optical axis, the writing beam is focused at the focus of the objective. The writing spot is focused at the point 4.

The pre-engraving of the track in the form of a "smooth" groove 7 may appear in different ways. It may for example be a question of a recessed pre-engraving, according to a set of elements of tracks arranged along concentric circles or organised along a spiral. The width of the track elements is chosen slightly less than the diameter of the luminous spot and these elements are separated by intertrack areas the width of which is slightly greater than the width of the track. The upper surface of the medium receives a thin layer adapted to writing by a thermo-optical process. This arrangement of elements enables the track to be explored before writing, since the interaction of the reading task with the track provides a dispersed radiation, whereas the intertrack areas do not generate any dispersion.

As far as the recording phase of the disc is concerned, the illumination of the sensitive layer serving for the writing is performed by a spot the intensity of which is modulated for example by an electrical signal in square waves of variable or constant widths depending on the applications which constitute the information medium. The incorporation of the information into the modulating signal is performed as the case may be, by frequency or phase modulation or by any method of encoding capable of supplying an encoded

message by pulses; the information may also be itself directly the modulating signal.

To detect the reading beams reflected by the disc, there is interposed, for example, a semi-transparent plate M_2 on the path of the beam f_1. The reflected beam is then sent towards photodetector and signal processing means which can deliver on the one hand an error signal whereby the motor 2 may be controlled enabling the position of the mirror M_1 to be controlled, thus forming a radial control system, and on the other hand an error signal ε', which enables the coil B, securely attached to the objective OB, to be controlled thus forming a focusing control system. All of these techniques are well known to the specialist and are outside the scope of the invention.

The processing means can also deliver a signal S(t) representative of the useful information recorded on the disc. In fact during the running of the elements recorded on the tracks 7, a signal S(t) is picked up in reading which faithfully translates the variations in time of the signal recorded on the track.

In writing phase, the reading beam f_1 is used to provide the radial control by means of the pre-engraving but may also be used with a view to checking in real time the information being recorded, or "monitoring" according to the English expression in current use.

Although necessitating only an area corresponding with the width of a single track, unlike the processes which utilise one or two pre-engraved tracks adjacent to or surrounding the useful track, the process of the known art which has just been summarised in connection with figure 1 does however have disadvantages.

Everything happens, from the detection point of view, as though for certain known thermosensitive materials the tracks were darker than the intertrack zones. Any track following deviation can therefore be easily detected by means of this amplitude contrast. When the layer covering the medium is subjected to the writing radiation, the written zones may be lightened for certain photosensitive materials, this contributing to the creation of a good contrast along the track. However these lightened zones tend to become merged with the lesser density of the neighbouring intertrack zones, and this

leads to radial loss of the contrast necessary to ensure good track following.

With other materials, the opposite effect is found: the intertrack zones are darker than the tracks but there is also loss of contrast during the writing.

It will be seen therefore that the writing impairs good radial identification of the tracks in all of the areas where the layer has stored data.

These disadvantages greatly limit the technological choices as regards the possible media.

Furthermore two different beams have to be used, at least during the writing periods: one writing beam and one reading and/or radial tracking beam.

To break free of these limitations, it is proposed in a French patent application mentioned above No. 82 94214 to use, for purposes of radial control, a pre-engraving of a special type.

In that patent application, an optical disc of pre-engraved type is proposed offering, among other advantages, simultaneously, a single-track configuration, requiring the use of only one beam, and this without interference of the pre-engraving with the engraving representing the useful information.

According to the main characteristic of the invention, the pre-engraving appears in the form of discrete elements or flags which alone define the average centreline of the track fo be followed. This track is therefore virtual. Taking into account the rotation speed of the disc, the spatial distribution of these pre-engraving elements must be sufficient to meet SHANNON's criterion: typically on a disc of 30 cm diameter, an 8 cm ring of which represents the useful recording zone, about 40,000 tracks are available, each comprising a number of flags of the order of 3,500.

In the following, the recording of numerical data being the main application envisaged in the context of this invention, without this being limitative, a medium will be described on which the tracks are distributed along concentric and equidistant circles.

The useful information is recorded between two successive flags. In this framework, if a recording configuration in block form is required the spatial distribution of the flags is preferably uniform.

The use of discrete pre-engraving enables the difficulties associated with radial tracking to be overcome.

By making a choice between the constructional variants proposed in the above-mentioned patent application, details of which variants will be set out in the following, it is also possible to obtain information necessary for correct focusing of the beam, or vertical control, from these same flags.

Figure 2 illustrates a first example of a flag usable in the context of this invention. The pre-engraving appears in the form of sections of smooth tracks 71 defining the average centrelines 70 of tracks along which the information can be recorded. Between two flags 71, there exists a zone 72, devoid of any information before recording. The direction of rotation of the disc is shown in figure 2 by the arrow R.

It must be clearly understood that the track 7 shown in the figure is a virtual track, the average centreline 70 of which represents the ideal path which a writing beam must follow.

To be usable in the specific context of this invention, the flags have the common characteristic of each comprising at least one pre-engraving section offset with respect to the average centreline 70 of the tracks 7, this being so that two successive offset sections are arranged on either side of this centreline.

In a first variant, the simplest, illustrated by figure 2, a first flag 71 comprises a section 710-L offset to the left of the average centreline of the track. The following flag 71' comprises a section 710-R offset to the right of the centreline. This succession is repeated. The separation between the offset sections and the centreline 70 of the track is of the order of a fraction of the width of the tracking spot.

In a second variant, each flag comprises at least one section offset to the left and one section offset to the right. This variant is illustrated by figure 3.

It may be advantageous to associate with the main flag 71, comprising sections offset on either side of the average centreline 70, a second flag 73 used for generating a synchronisation or flag start identification signal. Preferably the flag 73 represents a special code which enables it to be selectively identified with respect to the other information recorded. Such a configuration is illustrated by figure 4.

The precise manner in which the data are recorded falls beyond the scope of the invention. Any known process may be used. The flags 71, 71' and the useful information recorded in the zones 72 may, to give a clear idea, and without this being limitative, be constituted by recessed or projecting microreliefs, for example by ablation of a superficial layer by means of the writing laser beam. Preferably, the portions of flags all have the same width and the offset portions 710-L and 710-R have the same length and the same offset.

All variations and combinations starting from basic configurations of the flags remain within the scope of the invention. In particular, each flag 71 (or 71') may comprise more than one section offset in the same direction to the right and/or to the left.

Furthermore, the zones 72 reserved for the recording of useful information data may also be pre-engraved in the form of a smooth groove, this in order to improve the contrast depending on the layer of heat-sensitive material used.

The invention therefore has the fundamental characteristic of offsetting alternately the zones comprising recordings intended to be used by the means of radial and vertical (or focusing) control.

As far as radial control is concerned, the signals which are derived from the detection of the offset sections enable an error signal to be obtained by comparison. This process may come close to the method known as "wobbulation of the tracking spot" whereby a high frequency radial oscillation of constant amplitude about a mean position centred on the average centreline of the track when the tracking error is zero, is imparted to the tracking beam. It does,

however, have the advantage that the amplitude of the relative spot-track displacement is not limited by the rate of modulation of the high frequency signal read. Typically the peak amplitude of the oscillation is about 0.2 µm, this for tracks the width of which is of the order of 1 µm.

In the context of the invention, the amplitude of the equivalent oscillation due to the offset may be much greater and is limited only by the size of the reading spot. The amplitude modulation generated by the offset of the sections not affecting the high frequency signal of the post-engraved data.

The comparison of two signals derived from the successive detections of two sections offset in opposite directions, is made by sampling, provided that the rate is known at which these sections are running in the spot, i.e. that these sections can be differentiated. This differentiation can be performed using three main methods.

According to the first method each section is recognisable from its shape which indicates whether it is to the right or to the left of the average centreline 70. Instead of a single section, several sections can be recorded, the respective lengths and/or the spatial distribution of which represent a selectively detectable code. Again, there can be associated with each flag 71, in a manner similar to what is done in the configuration shown in figure 4, an additional flag representing a code indicating the direction of offset of the section which follows, or optionally there may exist a succession of sections offset on either side of the average centreline 70. The relative amplitudes of the signals derived from the detection of two sections offset in opposite directions by opto-electrical means, details of which will be given below, may thus be compared without ambiguity.

According to the second method, the information medium is sectorized. For example, in the case of a disc, typically, sixteen sectors are provided per revolution. A pre-engraved flag of special configuration is recorded then, according to this variant, which enables the start of a sector to be detected.

Such an arrangement is illustrated by figure 5. The start of each sector is marked by an encoded flag 74 followed by a repetitive succession: for example right section 710-R, useful information data recording zone 72, left section 710-G. These different sections, offset alternately in one direction and in the other, define two successions of analysis windows, F_1, F_3, ... F_{2n+1} and F_2, F_4, ... F_n respectively, (2n+1) being the total number of analysis windows, i.e. the total number of offset sections 710-R and 710-L. In the example shown in figure 5, the zones 72 are constituted by sections

of smooth grooves before recording. In another variant construction, as in the case of the configurations shown in figures 2 to 4, the zones 72 may be merged with the intertrack zones before recording.

The radial tracking signal error is obtained by integrating the signal detected by optoelectronic means during the analysis windows F_1 to F_{2n+1}, on the one hand and F_2 to F_{2n}, on the other hand, and by comparing them.

An electronic circuit enabling a radial tracking device according to this variant to operate is shown in figure 6. The system for recording-reading of data on the disc may be similar to that which was described in connection with figure 1. The identical elements will not be described again. Only the circuit marked 1, preparing the focusing and radial tracking error signal is specific.

It comprises an opto-electronic detection element which will be described in detail later. This element comprises at least one photodetector generating an output signal V_D transmitted to circuits 11 for preparing the radial tracking error signal ε. This signal is also sent to sampling circuits 12 adapted to authorise the operation of the circuits 11 solely during the time intervals corresponding to the analysis windows. To do this, these circuits comprise flag identification circuits 120, a counter 121 for example of binary type and a decoder 122. The flag identification circuits comprise a first circuit detecting the specific sector start flag 74 (figure 5) and, in response, generates a zero-setting signal for initialising of the counter 121 sent to a resetting input, and a second circuit detecting the passing of the offset portions 710-R and 710-L and generating at each passing an incrementation signal S_A of the counter 121. On the various outputs from this counter are permanently present the bits of a binary word S_B sent to a decoder. The latter generates, at each incrementation, pulses sent alternately on two control links S_1 and S_2 activating switches 110 and 111 during the analysis windows corresponding to the series F_1, F_3, ..., F_{2n+1}, and on the output S_2 pulses defining analysis windows corresponding to the series F_2, F_4 ..., F_{2n}.

The switches 110 and 111 each receive the signal V_D and send it conditionally during the analysis windows to an integrator with memory 112 comprising two differential inputs (+ and -) so as to make successive comparisons between the signals due to the interactions between the tracking spot and the sections offset respectively to the right and to the left.

The selective identification of the sections 710-R and 710-L by the circuits 120 can be done in different ways. Each section can for example be associated with an additional flag for synchronising the start of sampling in a manner similar to what is done in figure 4 (flag 73). One can also record several sections 710-R (or 710-L) the distribution and/or the respective lengths of which define a special offset section code distinct from those used for the recording of the other data.

If the medium-reading head speed is stable enough and the lengths of the zones 72 accurately defined, it is sufficient, once the counter 121 is reinitialised, to generate a succession of incrementation pulses by means of a clock, for example an oscillator of the voltage control type (better known by the initials from the English terminology "V.C.O."). Figure 7 shows this variant embodiment diagrammatically. The elements identical to those of figure 6 bear the same references and will not be redescribed. The zero-setting signal supplied by the circuits 120, which now comprise only one sector start (flag 74) detector circuit, is also sent to clock circuits 123 for its phase to be reset with the passing of the flag 74. Then the clock circuits generate a succession of pulses having a repetition frequency equal to 1/T, T being the time required for a zone 72 to run under the exploration spot. To avoid any risk of excessive phase displacement which would lead to the generation of an analysis window unsynchronised with respect to the passing of the offset sections, it is possible to multiply the number of type 74 flags per sector. A typical configuration is then obtained - by way of example - one flag 74 followed by sixteen offset sections.

In the two variant embodiments described in connection with figures 6 and 7, it is possible to replace the counter 121 with a shift register or any equivalent means, recording a logic "1" at the passing

of each flag 74 and shifting this bit at each fresh passing of offset sections.

In both variant embodiments the signal at the output from the integrator ε_N is a signal in the form of steps of a staircase, the amplitude of this signal being memorised between two offset sections as they pass. To be usable this signal must be "smoothed". To do this, a low-pass filter 113 may be used on the output of which the radial tracking error signal ε is available.

The diagram of figure 8 illustrates the three characteristic possibilities of the position of the track-following spot with respect to the average centreline of the track 70. In the upper part of the diagram, the curve V_1 illustrates the case in which the track-following spot is offset to the left of the average centreline of the track, it being understood that the direction of rotation is the one indicated by the arrow R in figure 5. In this case, the interaction of the section 710-L on the track-following beam is greater than that of the section 710-R. The curve V_1 shows a greater variation in amplitude, during the analysis window F_i (i being any number between 1 and 2n) which corresponds to the passing in the zone illuminated by the track-following spot of the portion 710-L, than the variation in amplitude during the analysis window F_{i+1} which corresponds to the passing of the portion 710-R. The differences in amplitude and in sign between these two signals ΔV are representative of the direction and of the amplitude of the offset of the spot with respect to the average centre-line of the track. Outside these windows, the signal supplied by the detection means is not sent to the circuits 112, the switches being open.

In the middle part of the diagram, the curve V_2 illustrates the case where the track-following spot is centred on the average centreline of the track. The variations of the signal supplied by the detection means 10 in the windows F_i and F_{i+1} are identical.

In the lower part of the diagram, the curve V_3 represents the case in which the track-following spot is offset to the right with respect to the average centreline of the track. The value of the signals thus sampled is then memorised until the next analysis window.

The circuit 112 supplies on its output a signal ε_N in the form of steps of a staircase representing the radial tracking error. To be genuinely usable, it is useful to smooth this signal by means of a low-pass filter 113 the output from which supplies the radial tracking error.

Figure 9 represents an example of variation in offset δ of the radial tracking spot 3 with respect to the average centreline 70 of a track, in terms of time. The lower part of the same diagram shows the corresponding variation ofthe error signal ε in terms of time, by means of the broken-line graph. The variation in the digital radial tracking error signal ε_N is also shown in this same diagram. The latter signal varies at the rate of the passing of the sections of the offset flags under the radial tracking spot and it remains constant between two successive passes.

According to the third method, close to the second which has just been described, between two zones 72, a flag is recorded comprising at least one pair of sections of opposite offset. The configuration is that already described in connection with figure 3.

As previously, these flags may be self-identifiable or associated with encoded additional flags, in a manner similar to the configuration described in connection with figure 4.

According to this method, the operating circuits are simplified since it is no longer necessary to distinguish between the two successions of analysis windows. Each time a flag passes it is sufficient to send the signal V_D alternately to the differential inputs of the integrator 112 by means of a two-way switch, this in relation with the passing of the successive offset sections.

Lastly, if the running speed is stable enough and the length of the zones 72 well defined, it is also possible to omit the flag detectors and to synchronise the generation of analysis windows by means of an external clock, which may be derived from that conventionally used to supply synchronisation signals during the writing and/or the reading of useful information data. The repetition frequency is that known as bit frequency, i.e. equal to the inverse of the time interval required for the writing/reading of an elementary item of information or bit. Tracking spot position situations are encountered

similar to those shown in the diagram of figure 8, with the exception that the output signals of the opto-electronic means of detection associated with the sections offset in opposite directions are contiguous in time and not situated in analysis windows separated by the time required for the inter-flag zone 72 to run in the tracking spot.

In all of the variants which have just been described, the integration system (figure 6: integrator 112) may be replaced by a peak detection system or a sampling-blocking system, also followed by a comparison of one pulse with the other, generation of a signal in the form of steps of a staircase ε_N and smoothing to obtain the final signal ε.

According to a fundamental characteristic of the invention, the flags may also be used to generate the focusing error signals necessary for the vertical control of the writing and/or reading head.

To do this, two photo-detector cells must be placed on either side of the optical axis of the focusing objective.

Figure 10 shows diagrammatically such a configuration reduced to the essential. An exploration beam which may be the reading beam f_1 of the device of figure 1 is focused in an exploration spot 3 on the average centreline 70 of the track 7. It is assumed in the example shown that the radial tracking is correctly performed by one of the devices which have just been described. The main elements described in connection with figure 1 are also found again: focusing objective O_b, focusing solenoid B driving the objective, radial tracking mirror M_1 driven by a motor 2 about the axis ΔY under the control of the radial tracking error signal ε; all elements which will not be redescribed.

Also found again in the figure are two photodiodes D_A and D_B on either side of the axis Z, passing through the optical axis of the objective O_b. These diodes are arranged in a plane XOY parallel with the plane of the disc bearing the track 7 and on either side of the axis OX parallel with the direction R, average running direction of the pre-engraving in the exploration spot 3.

Although shown above the mirror M_1, here semi-transparent, it must be clearly understood that the photodiodes may be securely attached to the circuits 1 as shown in figure 1, this by a set of redirecting mirrors M_1 and M_2. These photodiodes may again be situated under the disc, if the latter is read by transparency. The output signals of the photodiodes are sent to the electronic processing circuits comprised in the circuits 1, which will be explained later.

The process will be described in greater detail with the help of the diagrams of figures 11 to 9. It is assumed, to give a clear idea, that the case is that of a pre-engraving as was illustrated by figure 5: alternate sections to right and left, from one pre-engraving zone to the other.

If the focusing is correct, the incident exploration beam f_1 being assumed to be parallel, the latter is focused at the focus of the objective in the plane P_O merged with the plane of the disc comprising the track 7 to be followed. In this case, the pre-engraving, for example the section offset to the left 710-L, interferes with the beam f_1 and, according to the laws of optics, a diffraction results, producing orders of interference distributed symmetrically with respect to the plane ZOY. The energy refracted is detected in equal shares by the photodiodes D_A and D_B. The same will apply during the passing of the next offset section 710-R and so on.

In contrast, if a position away from the focusing plane is adopted, the symmetry is no longer respected. Depending on whether the pre-engraving section is offset to the right (710-R) or to the left (710-L), the effect of one of the half-beams, that is to say the parts of the beam f_1 to the right or to the left of the plane of symmetry ZOY, becomes preponderant. It also follows that the energy detected by the cells D_A and D_B is no longer identical depending on which pre-engraving section is running in the exploration beam.

If the track 7 to be followed is included in a plane P_I included between the objective and its focus (plane P_O), the signals detected by the photodiode D_A due to the sections offset to the right (710-R) are greater than those detected by the photodiode D_B. The opposite occurs during the passing of section offset to the left (710-L).

If the track 7 to be followed is included in a plane P_{II} further away from the objective than the plane P_o, effects are observed which are complementary in all respects to what has just been described. The three cases are shown together in the diagram of figure 12. The analysis windows θ_1 and θ_2 are determined by the passing times of the offset sections in the exploration spot in accordance with the processes which were described in connection with the determination of the radial tracking error. More precisely in the context of the example chosen in the manner described in connection with the device of figure 6. To determine the focusing error signal ε', the sigals V_A and V_B detected during the windows:

θ_1 : V_{A1} and V_{B1} respectively, and

θ_2 : V_{A2} and V_{B2} respectively are integrated or sampled, and the algebraic operation:

$$(V_{A1} + V_{B2}) - (V_{A2} + V_{B1}) \qquad (1)$$

is performed. The result is proportional to the focusing error signal, in sign and in amplitude.

Apart from the particular advantage of being able to break free of the effects of variations in contrast due to the recording of useful information along the tracks, whether or not materialised by a pre-engraving (smooth groove for example), effects which were mentioned above, the process according to this invention, which consists of also deriving the focusing error signals from non-contiguous flags, offers an additional advantage, namely that of not necessitating operations for precisely setting the positioning of the cells, this positioning operation generally being difficult to put into effect.

In fact, if for one reason or another the cells are offset with respect to the axis OZ (figure 10), one of the photodiodes, for example the photodiode D_A detects, all other factors remaining constant, less energy, the other, D_B receiving in this case more energy. This case is illustrated by the diagram of figure 13.

If V_{A1} to V_{B2} are the pulses detected at the correct positioning of the photodiodes and V'_{A1} to V'_{B2} the pulses detected at the actual position, whatever the state of the focusing, the following relationships are true:

$$V_{A1} > V'_{A1} \quad (2)$$

$$V_{A2} > V'_{A2} \quad (3)$$

$$V_{B1} < V'_{B1} \quad (4) \text{ and}$$

$$V_{B2} < V'_{B2} \quad (5)$$

If the calculation is performed according to relationship (1), it follows that there is total or at least partial compensation and that the focusing error signal does not vary much even if the pair of photodiodes D_A and D_B are off centre. In the majority of cases it is possible to omit all setting mechanisms except for an initial position setting performed once and for all.

Although the processes of generating radial tracking and vertical control or focusing error signals starting from non-contiguous discrete pre-engravings can be implemented autonomously, according to a preferred constructional variant of the invention these two control functions are performed simultaneously. To do this, in the context of the example chosen, the device of figure 6 has to be modified and added to.

A device of this type permitting correct focusing is shown diagrammatically in figure 14. The circuits common to figures 6 and 14 bear the same references and will not be described.

The detector comprising the two photodiodes D_A and D_B (figure 10) supplies the two output signals V_A and V_B. To be used by the sampling circuits 12 these signals may be merged into a single signal V_D, for example, by means of a summing amplifier 100, which signal is also sent as previously described to the circuits 11 for preparation of the radial tracking error signal. These circuits receive the two sampling signals S_1 and S_2, determining the windows θ_1 and θ_2. The device further comprises circuits for preparation of the focusing error signal ε'. To do this, it may comprise four memorising integrators 130 to 133, the operation of which is authorised respectively in the window θ_1 (signal S_1) for the integrators 130 and 132 and in the window θ_2 (signal S_2) for the integrators 131 and 133. These integrators supply the signals V_{A1}, V_{B2}, V_{A2} and V_{B1},

respectively at the outputs of the integrators 130, 131, 132 and 133. The outputs from the integrators 130 and 131 and the outputs from the integrators 132 and 133 are sent, for example, to the inputs of two summing amplifiers of unit gain, 134 and 135 respectively. The signals at the outputs of these two amplifiers 134 and 135 are each sent in turn to the differential inputs of an amplifier 136, for example of unit gain, the inputs "+" and "-" respectively, which supplements the calculation according to the relationship (1). In reality the output signal is a signal in the form of steps of a staircase ε'_N, the results being memorised between two calculations. To be usable the signal ε'_N has to be "smoothed" by a low-pass filter 137 the output from which supplies the analog-type focusing error signal ε'.

The invention is not limited solely to the arrangements which have just been described. In particular, devices simultaneously providing correct radial tracking and correct focusing may be obtained by modifying and adding to the radial tracking devices, this in a manner similar to what was done for the device of figure 5 to obtain the device of figure 14.

The fundamental characteristic of the invention is the use of discrete pre-engravings or flags, at least one section of which is offset with respect to the average centreline of the tracks to be followed, the generation of an electrical signal derived from the detection of the interaction of a focused beam with these pre-engravings and the processing of this signal by means of electronic circuits in differentiated manner depending on whether one wishes to generate a radial tracking or vertical control error signal.

The process according to the invention has the particular advantages of necessitating only one coarse setting of the positions of the photodetectors, of eliminating all means of external "wobbulation" which generally proves necessary when use is made of a conventional engraving, and of eliminating all interaction between the recording of useful information data and the radial track-following and the focusing.



CLAIMS

1. Information medium comprising in at least one optically recordable reference surface a set of adjacent track elements (7) along which is arranged a succession of non-contiguous sites (72) set apart for storage of the information in an optically readable form, the said storage sites (72) being separated from one another by interstitial sites (71) comprising patterns for materialising the non-sinuous average centreline (70) of the said track elements (7), this centreline representing the ideal trajectory which the means for transcribing the said information must follow; the said patterns appearing in the discrete and pre-engraved form of non-contiguous portions having closed contours of the said reference surface, characterised in that the said patterns are patterns arranged along two off-centre alignments which materialise the transverse position of the said average centreline (70) by a symmetrical framing action; each interstitial site enclosing at least one of the said pre-engraving patterns (710L, 710R); the distribution law of the said pre-engraving patterns between the said alignments being such that one pre-engraving pattern occupying one of the alignments in one of the interstitial sites has as a corresponding part a pre-engraving pattern occupying the other alignment in the immediately neighbouring interstitial site, to the exclusion of any pre-engraving pattern centred on the centreline; the said distribution law being a law indexed by means of at least one recurrent encoded structure (74) connecting at least two pre-engraving patterns, the pre-engraving patterns being such that their length and/or their spatial distribution represent a selectively detectable code.

2. Medium according to claim 1, characterised in that the said encoded structure being contained in each of the said interstitial sites (71), their spatial distribution along the said track elements (7) is uniform.

3. Medium according to either of claims 1 or 2, characterised in that the said distribution law is a law indexed by means of two recurrent and distinct encoded structures.

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4. Medium according to any of claims 1 to 3, characterised in that the said encoded structure comprises at least one pre-engraving pattern centered with respect to at least one of the said alignments.

5. Medium according to claim 1, characterised in that, in the same interstitial site, the said encoded structure is present on the said two alignments.

6. Medium according to claim 5, characterised in that the interstitial sites (71) which enclose the said encoded structure (74) frame a predetermined number of interstitial sites not provided with the said encoded structure (74).

7. Medium according to any of claims 1 to 6 characterised in that the medium being in disc form, the said average centrelines (70) of the said track elements (7) conform in the said reference surface to the form of equidistant concentric circles or whorls.

8. Medium according to any of the above claims, characterised in that the said pre-engraving patterns have a constant width in the direction perpendicular to the said average centreline (70).

9. Medium according to any of claims 1 to 8, characterised in that the said encoded structure is formed by the connection of two pre-engraving patterns.

10. Medium according to claim 9, characterised in that the content of an interstitial site (71) does not exceed four pre-engraving patterns.

11. Medium according to any of the above claims, characterised in that the said storage sites are provided with a zone (72) constituted by a pre-engraving pattern of lengthened shape which extends parallel with the average centreline (70).

12. Medium according to claim 11, characterised in that the said pre-engraving pattern of lengthened shape is centred with respect to the average centreline (70).

13. Medium according to claim 11, characterised in that the said zone (72) is merged with the inter-track zones before recording of the said information.

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14. Medium according to any of the above claims, characterised in that the said pre-engraving patterns appear in the form of surface irregularities corresponding to the said non-contiguous portions.

15. Optical device for following of a track appearing in the reference surface of an information medium in the form of a set of adjacent elements (7) along which is arranged a succession of non-contiguous sites (72) set apart for storage of the information in an optically readable form, the said storage sites (72) being separated from one another by interstitial sites (71) comprising pre-engraving patterns arranged along two off-centre alignments which materialise by a symmetrical framing action the transverse position of the non-sinuous average centreline (70) representing the ideal trajectory which the means of optical exploration of the said track must follow, which means is constituted by a luminous spot caused by the said device to keep following the said average centreline (70); the said patterns appearing in the discrete form of non-contiguous portions having closed contours of the said reference surface; each of the said interstitial sites (71) enclosing at least one of the said pre-engraving patterns; the distribution law of the said pre-engraving patterns between the said alignments being such that a pre-engraving pattern occupying one of the said alignments in one of the interstitial sites has as a corresponding part a pre-engraving pattern occupying the other alignment in the immediately neighbouring interstitial site; the said distribution law being a law indexed by means of at least one recurrent encoded structure connecting at least two pre-engraving patterns, which belongs to the interstitial sites (71); the said device comprising photodetector means (10) delivering in response to the radiation emerging from the portion of the said reference surface illuminated by the said spot an electrical signal sensitive to the transverse displacement of the said spot with respect to the said track elements; comparator means (11) using values of the said signal sampled exclusively during the exploration of the said interstitial sites to generate a compensating signal (εN)) intended to keep the said reading spot between the ideal trajectories of the two track framing elements, characterised in that means for decoding analyse the

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said electrical signal, so as selectively to recognise the exploration by the said spot of the said recurrent encoded structure; the said values sampled being selected in order to be compared two by two by control signals coming from sampling means (12) and derived from the recognition by the said decoding means of each phase of exploration of the said recurrent encoded structure; each value sampled in accordance with the said distribution law being significant of the optical interaction of the said spot with a pre-engraving pattern (710-R, 710-L) participating in the said symmetrical framing action; the said compensating signal (εN) changing in value in a discrete manner by changing the content of a memory circuit (112).

16. Device according to claim 15, characterised in that the said control signals (S1, S2) act on two switching means (110, 111) receiving the said electrical signal on their respective inputs; the outputs from the said switching means (110, 111) being connected to the inputs of a memory-type comparator circuit (112) which delivers the said compensating signal (εN); the said control signals performing alternate samplings of the said electrical signal ordered by the said sampling means (12) in accordance with the said distribution law.

17. Device according to claim 16, characterised in that the said control signals (S1, S2) are produced by decoding (112) of the digital output (SB) from a counting circuit (121) having a zero-setting input and an incrementation input; the zero-setting of the said counting circuit (121) occurring at the time of the recognition by an identification circuit (120) of the said recurrent encoded structure; the incrementation (SA) of the said counting circuit (121) being produced by a circuit for generating of pulses concordant with the exploration of the pre-engraving patterns (710-R, 710-L) arranged along the said alignments.

18. Device according to claim 17 characterised in that the said generating circuit is a circuit (120) which detects the exploration by the said spot of the pre-engraving patterns (710-R, 710-L) arranged along the said alignments.

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19. Device according to claim 17, characterised in that the said generating circuit is a clock (123) synchronised by the said decoding means (120).

20. Optical device for generation of an error signal of focusing of a beam of light in the reference surface of an information medium; the said beam exploring a track appearing in the form of a set of adjacent elements (7) along which is arranged a succession of non-contiguous sites (72) set apart for storage of the information in an optically readable form, the said storage sites (72) being separated from one another by interstitial sites (71) comprising pre-engraving patterns arranged along two off-centred alignments which materialise by a symmetrical framing action the transverse position of the non-sinuous average centreline (70) representing the ideal trajectory which a spot for exploration of the said average centreline projected by the said luminous beam must follow; the said patterns appearing in the discrete form of non-contiguous portions having closed contours of the said reference surface; each of the said interstitial sites (71) enclosing at least one of the said pre-engraving patterns; the distribution law of the said pre-engraving patterns between the said alignments being such that a pre-engraving pattern occupying one of the said alignments in one of the interstitial sites has as a corresponding part a pre-engraving pattern occupying the other alignment in the immediately neighbouring interstitial site; the said distribution law being a law indexed by means of at least one recurrent encoded structure connecting at least two pre-engraving patterns which belong to the interstitial sites (71), characterised in that it comprised two photodetector elements (DA, DB) arranged to intercept two fractions of the radiation emerging from the portion of the said reference surface illuminated by the said spot separated by a plane (ZOY) parallel with the exploration direction (Y) and with the normal (Z) to the said reference surface; decoding means (12), analysing the sum of the signals (VA, VB) produced by the said photodetector elements, in order selectively to recognise the exploration by the said spot of the said recurrent encoded structure; comparator means (13) using samplings made in accordance with the said distribution law from the said signals

(VA, VB) under the control of the signals coming from sampling means (12) and derived from the recognition by the said decoding means of each phase of exploration of the said structure; the said samplings constituting four memorised values VA1, VB2, VA2 and VB1 significant of the double optical detection of the interaction of the said luminous beam with two pre-engraving patterns defining the said symmetrical framing action; the comparison of the said values memorised by the said comparator means (13) producing the said focusing error signal (εN) in accordance with the relationship
N = (VA1 + VB2) - VA2 + VB1) N being proportional to the focusing error signal, in sign and in amplitude, the indices A and B relating to the two photodetector elements and the indices 1 and 2 to the two alignments serving to materialise the said average centreline (70).

21. Device according to claim 20, characterised in that the said comparator means (13) comprise four integrator circuits (130, 131, 132, 134), a differential amplifier (136) and two summing circuits (135, 134) respectively connecting the said integrator circuits two by two to the two additional inputs of the said differential amplifier (136).

22. Device according to either of claims 20 and 21, characterised in that it comprises means (11) for measuring the transverse position of the exploration spot with respect to the said average centreline (70) sampling the said sum of the signals (VA, VB); the said measurement means (11) being controlled by the said sampling means (12).

23. Device according to any of the claims 15 to 22, characterised in that the said comparator means (11, 13) delivering a signal in the form of steps of a staircase (εN, $\varepsilon' N$) the smoothing of which is performed by a low-pass filter (113, 117).