Optical scanning unit

The invention relates to an optical scanning unit for controlling and directing a radiation beam towards recording tracks of a surface to be scanned of an information carrier, which scanning unit comprises an objective, a translational-position and angular-position detection system for detecting the positions of the objective and an electro-magnetic actuating means for correcting the translational and the angular position of the objective relative to the information carrier depending on electric error signals supplied by the translational-position and angular-position detection system, the actuating means comprising a movable objective holder which comprises a cylindrical axially magnetized magnet body which at its axial ends is provided with magnet poles and the actuating means further comprising at least three sets of segment coils disposed in the magnet field of the magnet body, which sets are arranged adjacent one another viewed in the circumferential direction of the magnet body and cooperate magnetically with the magnet body via an air gap.

Such an optical scanning unit is known from German Patent Specification 32 34 288. In this axial scanning unit the objective is mounted in a movable axially magnetized permanent-magnetic sleeve whose two axial ends form magnetic poles. The stationary segment coils are constructed as flat coils of banana-like arcuate shape comprising two coil sections which are coaxial with said sleeve, the currents through the individual coil sections being directed oppositely to one another when the segment coils are energized. The known arrangement of the segment coils enables three forces directed along the three coordinate axes of an orthogonal axial system and two torques about two of said coordinate axes to be generated.

In principle, all the desired objective movements can be realized with the aid of the actuating means of the known scanning unit. These movements comprise an axial movement which is directed parallel to the optical axis of the objective and which serves for focussing a light beam so as to form a light spot in an information

plane of a rotating optical disc, two mutually perpendicular translational movements and/or two pivotal movements about two axes which are oriented perpendicularly to one another and to the optical axis. Said translational and pivotal movements serve for the radial and tangential tracking of the light spot and the pivotal movements may also be employed to provide a correction for an oblique position of the disc.

Said translational-position and pivotal-position detection system should control the segment coils in such a way that in the operating condition of the scanning unit the objective is brought into and is kept floating in a correct pivotal and translational position within the space formed by all the sets of segment coils. Such a system is known, for example, from US Patent Specification 4,425,043 and is also described in, for example, Netherlands Patent Application 8501665.

The individual detection signals supplied by the translational-position and pivotal-position detection system are processed in an electronic circuit to generate error signals for the translational and pivotal movements of the objective.

These error signals are converted into control signals which are employed in the scanning unit for energising the segment coils of the actuating unit. For this purpose each segment coil is electrically coupled to a separate amplifier, which amplifies the signal intended for the relevant segment coil to a suitable extent.

During operation of the scanning unit this ensures such a control that the objective occupies the correct translational position and pivotal position within the scanning unit.

However, the known actuating unit has the disadvantage that the magnetic forces acting between the segment coils and the magnetic sleeve vary as a function of the axial displacement of the objective in such a way that even for a small axial displacement of the objective out of its centre position between the coils the actuating unit is no longer capable of adequately moving the objective so as to obtain both the required focussing of the light beam and the required tracking of the light spot. The segment coils, which are arranged at a substantial axial spacing from one another, can move the objective over an adequate distance along its optical axis but the possibility of generating said other movements then rapidly decreases to such an extent that already

at a small distance from its centre position the objective is no longer driven adequately to guarantee a correct tracking of the light spot.

It is the object of the invention to improve the optical scanning unit of the type defined in the opening paragraph in such a way that by the use of a suitable number of segment coils, an accurate positioning of the segment coils, and an effective electrical coupling of the segment coils to one another it is achieved in a simple way that both the magnetic forces required for the focussing movement and the magnetic forces required for the focussing movement and the magnetic forces required for tracking remain constant or at least substantially constant when the objective is moved over a comparatively large axial distance.

To this end the optical scanning is characterized in that the sets of segment coils each comprise two peripheral coils which are each situated substantially within the magnet field near one of the axial ends of said magnet body, and at least one central coil arranged between the peripheral coils, and in that each set of segment coils is electrically connected to a matrix circuit via only two amplifiers, each set of segment coils having one of the terminals of one of the peripheral coils and one of the terminals of the central coil electrically connected to the output of a first amplifier, having one of the terminals of the other peripheral coil and the other terminal of the central coil electrically connected to the output of a second amplifier, and having the two other terminals of the peripheral coils electrically connected to earth.

The coil configuration in accordance with the invention described above enables the central coil of each set to be energized for a displacement of the objective in directions transverse to the optical axis and, moreover, the peripheral coils of each set to be energized for a displacement of the objective along the optical axis. If desired, all the peripheral coils may also be employed for tilting the objective about axes transverse to the optical axis. This means that for focussing a light beam to a light spot in an information plane of an optical disc the peripheral coils of the actuating means should be energized and for radial and tangential tracking of the light spot the central coil should be energized, as the case may be in combination with a selective drive of the peripheral coils.

The scanning unit in accordance with the invention has the advantage that when the coils are energized both the axially and radially directed magnetic forces exerted on the magnet body by the coils remain at least substantially constant in the case of an axial displacement of the objective over a distance large enough to focus and keep a light beam focussed in the information plane of an optical disc. From the non pre-published prior European Application EP-A-215,498 it is already known that sets of segment coils each comprise two peripheral coils, which are situated substantially in the proximity of the axial ends of a magnet body, and a central coil arranged between the peripheral coils.

In contrast, the scanning unit in accordance with the invention has the advantage that the number of amplifiers required for suitably amplifying the error signals supplied by the linear-position and angular-position detection system in order to ensure an adequate drive of the segment coils without crosstalk effects is only two thirds of the number of segment coils used.

All segment coils are employed for the displacement of the objective for the purpose of radial and tangential tracking by the use of only one matrix cuircuit, at least three sets of at least three segment coils each and a limited number of amplifiers, the required magnetic actuating forces in the radial and the tangential direction, remaining highly constant over a comparatively large axial displacement of the objective.

A suitable embodiment from the point of view of production engineering is characterized in that the segment coils of each set have the same winding direction.

If all the segment coils are made of the same winding wire and have the same dimensions the electrical impedance of the central coil will be only half the electrical impedance of the two peripheral coils of one set together. This means that if the above configuration of coils is energized the current in the central coil is twice as large as that in the peripheral coils of the same set. In certain cases this may be desirable, for example when the centre position of the objective very large actuating forces in the radial and tangential direction are required. However, it is alternatively possible to reduce the

difference in impedance between the central coil and the peripheral coils by giving the central coil a greater length. In this respect a further preferred embodiment is characterized in that of each set of segment coils the peripheral coils have equal impedances and the central coil has an impedance which is twice as large as the impedance of one of the peripheral coils. In this embodiment the segment coils of a set behave as a single coil with respect to the radially and tangentially directed actuating forces.

Exemplary embodiments of the invention are shown in the drawings and are described in more detail hereinafter. In the drawings:

Fig. 1 schematically shows a part of the scanning unit in accordance with the invention,

Fig. 2 is an exploded view of an example of the actuating means of the scanning unit in accordance with the invention,

Fig. 3 is a plan view of the actuating means shown in Fig. 2,

Fig. 4 is a sectional view taken on the line IV-IV in Fig. 2, and

Fig. 5 shows the circuit arrangement of the segment coils of the actuating means shown.

The scanning unit shown in Fig. 1 comprises a radiation source 1, for example a diode laser, a collimator 3 and an objective 5, which is mounted in an objective holder. Both the objective and the collimator may comprise a plurality of lens elements.

The collimator converts the divergent read beam b produced by the radiation source into a parallel beam which adequately fills the aperture of the objective 5. The objective focusses the read beam to form a diffraction-limited radiation spot V of a diameter of, for example, 1 µm in the plane of the information surface 9 of a disc-shaped record carrier 11, of which a small part is shown in radial cross-section in Fig. 1. The information is stored in concentric tracks 13 or in quasi-concentric tracks together forming a spiral track. This information may comprise a multitude of optically detectable information areas which alternate with intermediate areas. Suitably, the information surface 9 is situated at the upper side of the record carrier, so that the read beam traverses the transparent substrate 15 of the record carrier before it reaches the information surface.

Further, the information surface is preferably radiation reflecting, so that the read beam is reflected towards the radiation source.

As the record carrier is rotated relative to the scanning unit the beam reflected from the information surface is time-modulated in conformity with the sequence of information areas and intermediate areas in an information track to be read. In order to separate the modulated beam from the beam emitted by the radiation source a separating element 17 is arranged in the radiation path, which element may be, for example, a semi-transparent mirror or a prism, which may be polarisation-sensitive and whose interface 19 reflects at least a part of the radiation towards a radiation-sensitive information detector 21 in the form of, for example, a photo-diode. The information detector 21 converts the modulated read beam into an electric signal which is processed, in known manner, to form a signal which, depending on the type of information stored in the record carrier, is suitable for being displayed, reproduced or processed otherwise. The nature of the information and the processing of the signal from the information detector fall outside the scope of the present invention and are therefore not discussed in more detail.

The right-hand part of Fig. 1 shows an XYZ system of axes, whose origin is in reality situated in the centre M of the objective, so that the Z-axis coincides with the chief ray L. The direction of this axis may also be referred to as the axial direction. The tilt of the objective about the X-axis may be represented by the tilting angle α and that about the Y-axis by the tilting angle β. The X-axis and the Y-axis extend, for example, in the information plane parallel to the radial direction and the tangential direction respectively. The six theoretically possible independent degrees of freedom of the objective holder 7 comprise translations along said three axes and rotations about these axes, the rotation about the Z-axis being irrelevant here.

In order to ensure that the objective holder 5 substantially performs the movements relative to the scanning unit without any physical contact between the objective holder 7 with the objective 5 and the other elements of the scanning unit the objective is suspended in electro-magnetic actuating means which will be described in more detail with reference to Figs. 2, 3 and 4. This requires the use of a translational-position and angular-position detection system for

measuring deviations between the centre M of the objective and the chief ray L of the beam b along an X-axis situated in the plane of the drawing, along an Y-axis perpendicular to the plane of the drawing, and along a Z-axis perpendicular to the said axes, and to measure tilts of the objective lens about the X-axis and the Y-axis, so as to enable deviations from the translational position and tilts to be eliminated by means of a control system.

The translational-position and angular-position detection system comprises a conical-ring mirror 23 which is fixedly connected to the objective and a radiation-sensitive detection system 25. The mirror 23 reflects that part of the radiation beam b which falls within the aperture 27 but outside the pupil of the objective towards the separating element 17, which in its turn reflects a part of the radiation to the detection system 25. The detection system will not be described in more detail because it falls outside the scope of the present invention. A comprehensive description of a detection system can be found in the afore-mentioned Netherlands Patent Application 8501665. Moverover, reference is made to US Patent Specification 4,425,043 which describes a focus-error detection system.

The error signals obtained from the translational-position and angular-position detection system relate to the displacements along the X-axis, the Y-axis and the Z-axis and the tilts about the X-axis. and the Y-axis of the objective and by means of operations not described they are processed to form control signals designated Sx, Sy, Sz Sα and Sβ respectively.

Figs. 2, 3 and 4 show an electromagnetic actuating means of the scanning unit. The actuating means in principle comprises a movably suspended magnet body 30 secured to the objective holder 7 and a plurality of stationary coils arranged around this body in at least three sets 32, 34 and 36. The magnet body 30 is ring-shaped or cylindrical and is made of a permanent-magnet material such as neodymium-iron-boron or samarium-cobalt. The coils of the different sets are disposed mainly in specific parts of the magnetic field of force of said magnet body, which is axially magnetised. In order to enable the objective 5 to perform said desired movements free from parasitic resonance the objective is magnetically suspended within the actuating means without any physical contact between the magnet body 30

and the coils.

The axially magnetised body 30 exhibits a south pole Z and a north pole N at its axial ends, as is shown in Fig. 4. The sets 32, 34 and 36 of segment coils arranged around the magnet body 30 are secured to a mounting plate 38. Viewed in the circumferential direction of the magnet body 30 the sets are arranged adjacent each other and together substantially form a shell around the magnet body, an air gap 40 being formed between the sets and the magnet body. Each of the sets 32, 34 and 36 comprises two peripheral coils 32RU, 32RL; 34RU, 34RL and 36RU, 36RL respectively, which are disposed in areas where the magnetic lines of field of the magnet body 30, when in its central position, extend in substantially radial directions. The "centre position" is to be understood to mean an at least roughly central position of the magnet body relative to the peripheral coils. Each of the sets 32, 34 and 36 further comprises a central coil 32M, 34M and 36M respectively, positioned between the peripheral coils in a part of said magnet field where the lines of field extend in substantially axial directions.

In the present embodiment the segment coils are made of the same winding wire, the central coil having an axial dimention which is twice as large as that of the peripheral coils. The other dimensions of the coils are identical.

Fig. 5 shows schematically how the segment coils of the sets 32, 34 and 36 are electrically connected to each other and to the matrix circuit. The matrix circuit represented by the block 42 receives said control signals Sx, Sy, Sz, Sα and Sβ and translates them into suitable control signals of the correct polarity for the different sets 32, 34 and 36 of segment coils. By means of six amplifiers 43 and 44, 45 and 46, and 47 and 48 the matrix circuit is electrically coupled to the sets 32, 34 and 36, respectively, each set being arranged between two amplifiers. One terminal of each of the two peripheral coils of each set is electrically connected to the output o an amplifier and the other terminals are interconnected, the junction point being connected to earth. Both terminals of the central coils are electrically connected to the outputs of the relevant amplifiers. In the present example the segment coils 32RU, 32RL, 32M, 34RU, 34RL, 34M, 36RU, 36RL and 36M have the same winding direction viewed in the same axial direction, the peripheral coils also having the equal impedances.

Said matrix circuit 42 is constructed in such a way that a control signal Sx, Sy, Sz, Sα or Sβ applied to this circuit and corresponding to a specific degree of freedom of the objective 5 is transferred to the amplifers 43, 44, 45, 46, 47 and 48 in such a way that the current through the segment coils 32RU, 32RL, 32M, 34RU, 34RL, 34M, 36RU, 36RL and 36M mainly result in a correction movement of the objective 5 in conformity with the relevant degree of freedom without causing any significant displacement of the objective in accordance with any of the other degrees of freedom. This will be explained by means of the following Table.

	Sx	Sy	Sz	Sα	Sβ
32RU	$-k_1.x$	$+y$	$+z$	$+\alpha'$	$-k_2.\beta'$
32RL	$+k_1.x$	$-y$	$+z$	$+\alpha'$	$-k_2.\beta'$
32M	$-k_1.k.x$	$-k.y$	0	0	0
34RU	$+x$	0	$+z$	0	$+\beta'$
34RL	$-x$	0	$+z$	0	$+\beta'$
34M	$+k.x$	0	0	0	0
36RU	$-k_1.x$	$-y$	$+z$	$-\alpha'$	$-k_2.\beta'$
36RL	$+k_1.x$	$+y$	$+z$	$-\alpha'$	$-k_2.\beta'$
36M	$+k_1.k.x$	$-k.y$	0	0	0

The Table gives a matrix which qualitatively shows which coils should be energized with a current of a specific phase in order to obtain a specific displacement X, Y or Z or tilt α or β of the objective. The symbols x, y, z, α' and β' in the Table must be thought to be preceded by a proportionality factor for the signals Sx, Sy, Sz, Sα and Sβ respectively. Moreover, there may be further proportionality factors such as the factors k, k_1 and k_2 given in the Table. The factor k allows for the ratio between the impedance of the central coils and the impedance of the peripheral coils. Suitable, k=1 if the impedance of the central coil of a set of segment coils is twice as large as the impedance of one of the peripheral coils. If the central coil has an impedance smaller or larger than twice the imperdance of a peripheral coil, this will result in $k > 1$ and $k < 1$ respectively. It has been demonstrated theoretically and experimentally that the facotors k_1 and k_2 should preferably be 1/2 because for this value the crosstalk is

minimal in the sense that no displacements in the Z-direction are produced when the objective is corrected in the X and ß directions.

As will be evident from the matrix the centre coils 32M, 34M and 36M should be energized only for translational movements in the X and Y direction of the objective. The energization of the coils as given in the table can be obtained in a suitable manner by arranging and connecting the coils as shown in Fig. 5.

The above Table shows that the matrix circuit transfers the following control signals to the inputs of the amplifiers 43 to 48:

amplifier 43: $-k_1.x'.Sx + y'.Sy + z'.Sz + \alpha''.S\alpha - k_2.ß''.Sß$

amplifier 44: $k_1.x'.Sx - y'.Sy + z'.Sz + \alpha''.S\alpha - k_2.ß''.Sß$

amplifier 45: $x'.Sx + z'.Sz + ß''.Sß$

amplifier 46: $-x'.Sx + z'.Sz + ß''.Sß$

amplifier 47: $-k_1.x'.Sx - y'.Sy + z'.Sz - \alpha''.S\alpha - k_2.ß''.Sß$

amplifier 48: $k_1.x'.Sx + y'.Sy + z'.Sz - \alpha''.S\alpha - k_2.ß''.Sß$

The symbols x', y', z', α'' and ß" should be read as portionality factors for the control signals Sx, Sy, Sz, $S\alpha$ and Sß.

PATENT CLAIMS:

1. An optical scanning unit for controlling and directing a radiation beam towards recording tracks of a surface to be scanned of an information carrier (11), which scanning unit comprises an objective (5), a translational-position and angular-position detection system for detecting the positions of the objective and an electro-magnetic actuating means for correcting the translational and the angular position of the objective relative to the information carrier depending on electric error signals supplied by the translational-position and angular-position detection system, the actuating means comprising a movable objective holder (7) which comprises a cylindrical axially magnetized magnet body (30) which at its axial ends is provided with magnet poles (N; Z) and the actuating means further comprising at least three sets (32; 34; 36) of segment coils disposed in the magnet field of the magnet body, which sets are arranged adjacent one another viewed in the circumferential direction of the magnet body and cooperate magnetically with the magnet body via an air gap, characterized in that the sets of segment coils each comprise two peripheral coils (32RU, 32RL; 34RU, 34RL; 36RU, 36RL) which are each situated substantially within the magnet field near one of the axial ends of said magnet body, and at least one central coil (32M; 34M; 36M) arranged between the peripheral coils, and each set of segment coils is electrically connected to a matrix circuit (42) via only two amplifiers (43, 44; 45, 46; 47, 48), each set (32; 34; 36) of segment coils having
- one of the terminals of one of the peripheral coils (32RU; 34RU; 36RU) and one of the terminals of the central coil (32M; 34M; 36M) electrically connected to the output of a first amplifier (43; 45; 47), having
- one of the terminals of the other peripheral coil (32RL; 34RL; 36RL) and the other terminal of the central coil (32M; 34M; 36M) electrically connected to the output of a second apmlifier (44; 46; 48), and having
- the two other terminals of the peripheral coils (32RU, 32RL; 34RU, 34RL; 36RU, 36RL) electrically connected to earth.



2. An optical scanning unit as claimed in Claim 1, characterized in that the segment coils of each set (32; 34; 36) have the same winding direction.

3. An optical scanning unit as claimed in Claim 2 or 3, characterized in that of each set (32; 34; 36) of segment coils the peripheral cois have equal electrical impedances and the central coil has an impedance which is twice as large as the impedance of one of the peripheral coils.

4. An optical scanning unit as claimed in Claim 2, characterized in that the matrix circuit (42) transfers a control signal applied to said matrix circuit and corresponding to a specific degree of freedom of the objective (5) to the apmlifiers (43, 44; 45, 46; 47, 48) in such a way that the currents through the segment coils mainly result in a correction movement of the objective in accordance with the relevant degree of freedom without any significant displacement of the objective in accordance with any of the other degrees of freedom.