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Description

The invention relates to an opto-electronic apparatus for writing and/or reading recording tracks in a recording surface of a record carrier by means of a radiation beam, such as the scanning by means of a light beam of video and/or audio recording tracks or digital data recording tracks in a reflecting recording surface of a rotating video or audio disc or a data disc respectively, which apparatus comprises: a frame, an objective holder provided with an objective having an optical axis and having a lens system for concentrating the radiation beam so as to form a radiation spot in a focussing plane, a bearing arrangement for supporting the objective holder for movement relative to the frame in accordance with a desired number of degrees of freedom out of six theoretically possible, independent degrees of freedom, said bearing arrangement including counteracting means for counteracting movements of the objective holder relative to the frame which are in accordance with other, undesired degrees of freedom, and actuator means comprising parts which are connected to the frame and to the objective holder respectively and which cooperate magnetically with each other via an air gap, for driving the objective holder relative to the frame with electromagnetic actuator forces in accordance with the said desired degrees of freedom, which actuator means comprise at least one actuator coil for said desired degrees of freedom. Such an opto-electronic apparatus is known from the United States Patent Specification 4 135 206.

The theoretical background of the invention is explained with reference to Figure 1. An optical disc 1 rotates about an axis of rotation 2. The disc comprises a transparent substrate 3, on whose upper surface recording tracks 4 are located. A symbolically represented objective 5 scans the recording tracks of the optical disc by means of a light beam 6. The objective is mounted in an objective holder 7, which is supported by a frame 8. The origin of an orthogonal X-Y-Z system of axes is situated in the centre of the objective. The Z-axis is parallel to the axis of rotation 2 of the optical disc and the X-axis intersects the axis of rotation 2 perpendicularly, so that the X-axis is parallel to a radial line of the optical disc. The Y-axis is perpendicular to both the X-axis and the Z-axis and consequently extends in a tangential direction. The six independent degrees of freedom of the objective holder 7 and thus of the objective 5 which are theoretically possible are translational movements along the three axes and rotational movements about these axes. This yields a total of three directions of translational movement and three of rotational movement, so that six independent degrees of freedom are obtained.

In principle, any material body can move in accordance with six independent degrees of freedom. In principle, a bearing arrangement is a device which serves to ensure that a material

body can perform movements only in accordance with some of the theoretically possible independent degrees of freedom, namely the desired degrees of freedom, and which counteracts movements in accordance with all the other degrees of freedom. Most bearing arrangements allow only one or two movements, for example a single rotational or translational movement, a combination of the two, or two rotational movements. Opto-electronic apparatuses for writing and/or reading recording tracks on a rotating optical disc are known, in which the objective holder can move in accordance with two or three degrees of freedom. Movements along the Z-axis are required in order to focus the radiation beam on the recording tracks. Movements along the X-axis may be required in order to follow oscillations of the recording tracks. Finally, movements along the Y-axis may be required in order to correct time errors resulting from an eccentricity of the recording tracks (United States Patent Specification 4,135,206).

For a correct movement of the objective holder in accordance with the desired degrees of freedom electronic control circuits are required which determine deviations of the radiation spot relative to the track along said axes and which ensure that the objective holder performs the appropriate compensating movements. The optical disc reflects the light beam and modulates it with the information contained in the recording tracks. The light beam modulation is converted into an electrical modulation, so that an electric signal is obtained which contains the information stored in the optical disc. This signal also contains information on the position of the light spot relative to the recording track to be followed, so that error signals for said control circuits can be derived from this signal. Thus, the position of the objective holder along said axes is determined dynamically by the control circuits and the objective holder is free to move in accordance with said desired degrees of freedom. The bearing arrangement of the objective holder is such that the objective holder is capable of performing the desired movements.

Alternative versions of opto-electronic apparatuses are known in which, instead of a translational movements of the objective holder along the X-axis, a rotational movement about the Y-axis is used. Instead of a small translational movement along the Y-axis it is possible to use a small rotational movement about the X-axis. Since the optical disc in the version shown is flat, small rotational movements about the X or the Y-axis will give rise to a certain focussing error of the light beam 6, but this error is so small that no significant interaction with the control of the translational movements along the Z-axis will occur. Moreover, opto-electronic devices are known, for example from United States Patent Specification 4,021,101, in which the bearing arrangement only permits movements along the Z-axis. For moving the radiation spot 9 along the X-axis and the Y-axis, the objective is not moved

but the light beam is moved relative to the objective by means of an electromagnetically actuated mirror. Such an electromagnetically actuated mirror is, for example, known from United States Patent Specification 4,129,930.

Generally, said compensation movements of the objective holder should be effected at high speed, which means that the required control circuits should have a large dynamic bandwidth. Bandwidths of at least 3 kHz are desirable, but preferably they should be 5 kHz. It has been found that the bearing arrangements of objective holders and of pivoting mirrors used until now substantially limit the desired bandwidths. This is because the bearing arrangements comprise either surfaces which frictionary cooperate with each other or moving elastic parts, which introduce an amount of frictional damping or interal damping into the control system which is difficult to control. Resonance phenomena in the bearing arrangement also give rise to problems. In the case of bearing arrangements with moving elastic parts the choice of the spring constant of the elastic parts is a difficult problem. If the stiffness is too low this gives rise to resonances at low frequencies and if the stiffness is too high the power required for driving is too high, giving rise to problems with respect to heat dissipation and the dimensioning of the control circuits.

It is an object of the invention to improve opto-electronic apparatus of the type mentioned in the opening paragraph in such a way that large bandwidths are attainable with a low power consumption. To this end the invention is characterized in the apparatus comprises an objective-position measuring device for continuously measuring the position of the objective holder relative to the frame in accordance with said undesired degrees of freedom and generating a positional-error signal, the bearing arrangement supports the objective holder solely by electromagnetic forces and comprises only electromagnetic counteracting means comprising at least one levitation coil secured to one of said frame and objective holder and magnetic means arranged on the other of said frame and objective holder, said magnetic means, cooperating with said levitation coil via an air gap so as to produce an electromagnetic levitation force which counteracts undesired movements of the objective holder in accordance with said undesired degrees of freedom, and a levitation control circuit is provided which compares the positional-error signal from the objective-position measuring device with a reference signal of specific value and which comprises at least one output for applying an electric levitation current whose value depends on the error signal to a levitation coil for maintaining substantially constant the position of the objective relative to the frame in accordance with said undesired degrees of freedom.

The word "levitation" in a narrower sense means balancing the force of gravity. In the present text the word is used in a broader sense in

order to indicate that the objective holder is supported by the frame in a substantially invariable position, by remotely exerted field forces, in relation to one or more degrees of freedom.

The opto-electronic apparatus in accordance with the invention employs two different types of control circuit. The position of the light spot relative to the recording tracks on the record carrier is controlled by pressing and scanning control circuits, being actuator control circuits, which automatically control the position of the objective and eventually also of other optical elements such as an articulated mirror relative to the recording surface of the disc. Deviations in the position of the recording surface at the location of the light spot owing to an oblique position of the disc or undulations in the recording surface, deviations of the position of the recording track owing to an eccentricity of the disc centre relative to an axis of rotation etc., are automatically compensated for by these actuator control circuits. In addition there are provided one or more levitation control circuits which do not control the position of the objective relative to the recording surface and the recording track to be followed but relative to the frame of the apparatus. Thus, the levitation control circuits have a distinct other function and should be regarded as a part of an electromagnetic bearing arrangement of the objective on the frame.

In the apparatus according to the invention not a single kind of mechanical damping or resonance occurs, the objective holder is entirely free-floating in space and is subject only to field forces, namely those as a result of the gravitational field of the earth and the magnetic fields produced by the actuator and levitation coils. The absence of mechanical damping and resonance in the electromagnetic part of the bearing arrangement permits a larger bandwidth of the control circuits which control the desired movements of the objective. Such an opto-electronic apparatus can be stable from the point of view of control technology. For the stability a certain damping is necessary, which can be provided in the electronic control circuits and whose value is optional and easy to control.

It is noted that from the United States Patent Specification 4 175 832 a mirror control apparatus is known which comprises a bearing arrangement consisting of mechanical and magnetic means. The mechanical means comprise a supporting member having a pointed end on which the mirror is pivotally supported. The magnetic means comprise a permanent magnet and a member of ferromagnetic material located near the magnet, which magnetic means prevent rotation of the mirror on the supporting member. Actuator means comprising two pairs of drive coils arranged around a magnet serve for driving the mirror relative to the frame.

Another publication viz. the United States Patent Specification 4 100 576 shows an apparatus which has mechanical bearing means

nearly similar to the mechanical means of the above-mentioned known apparatus. This known apparatus further shows two electromagnetic pairs each consisting of two coils which are positioned near a central magnet mounted on the mirror. One coil of each pair is employed as a deflection coil responsive to energization by correction signals from an amplifier to develop a field to react with the field of the magnet. The other coil of each pair, on the other hand, assumes the role of a sensing coil in that any undesired movement of the mirror will cause a voltage proportional to the velocity of such undesired movement to be generated in that coil. This voltage is amplified in the amplifier and applied to the deflection coil in question to counteract the undesired movement of the mirror.

In both of the above mentioned apparatus the mirror is only able to perform rotational movements in accordance with two and three of the six independent degrees of freedom, respectively, while the three undesired translational movements are counteracted by mechanical bearing means. Such constructions limit substantially the dynamic bandwidth of the control circuits, this is caused by the bearing surfaces which frictionally cooperate with each other and which thereby introduce frictional damping into the control system which is difficult to control. Furthermore resonance problems may be caused.

An embodiment of the invention may be used which is characterized in that: the objective holder is ferromagnetic and annular; at least three ferromagnetic armatures are arranged on the objective holder at equal radial distances from the optical axis and uniformly spaced around the circumference of the holder; a radially magnetized permanent magnet is arranged between each armature and the objective holder; each armature comprises two teeth which extend in a substantially tangential direction and which are spaced from each other in a direction parallel to the optical axis of the objective; for each armature tooth combination coil having an elongate shape in a direction parallel to the optical axis is arranged on the frame, which coil functions both as actuator coil and as levitation coil and comprises turns which are disposed substantially in planes containing the optical axis of the objective and each have a central opening which receives the teeth with clearance; and for translational movements along the optical axis there is provided an actuator coil whose centre lies on the optical axis. An opto-electronic apparatus in this embodiment may comprise six combination coils and one further actuator coil in total. In the description an embodiment will be described comprising eight combination coils and one further actuator coil.

It is possible to employ an embodiment of the invention comprising an objective holder which is at least partly made of a ferromagnetic material and which is further characterized in that all actuator coils and levitation coils are rigidly

mounted on the frame and cooperate magnetically with ferromagnetic parts of the objective holder. In principle, it is favourable to use an embodiment without moving coils. A disadvantage of moving coils is that a movable connection is required between the coil and an electronic control circuit, which connection may give rise to problems because of its mobility.

An embodiment of the invention requiring neither moving coils nor permanent magnets is characterized in that: the objective holder comprises a ferromagnetic mounting ring which is concentric with the optical axis of the objective; for movements in accordance with all the degrees of freedom of the objective, except for rotational movements about the optical axis, these are arranged on the frame a plurality of coils, which are situated on axially opposite sides of the mounting ring and which exert axially opposite magnetic force components on the mounting ring, and a plurality of coils which are situated on diametrically opposite sides of the mounting ring and which exert diametrically opposite magnetic force components on the mounting ring, which coils function as actuator coils, as levitation coils, or both as actuator coils and levitation coils.

For measuring the position of the objective relative to the frame an embodiment of the invention may be used which is characterized in that the objective-position measuring device at least comprises: a) two capacitive elements arranged in series, which elements comprise a facing stationary plates of an electrically conductive material on the frame and facing movable plates of an electrically conductive material on the objective holder; b) a high-frequency alternating-current source; c) a voltage difference circuit which is inductively coupled to the high frequency alternating-current source and connected to the two capacitive elements; and d) means for applying the output signal of the voltage difference circuit to the levitation control circuit.

The movable plates of an electrically conductive material on the objective holder may have a very low mass and may for example comprise thin metal layers which are physically or chemically deposited. In addition to a capacitive objective-position measuring device it may also be advantageous to use an embodiment of the invention which is characterized in that the apparatus comprises an opto-electronic objective-position measuring device, which device comprises: a) a radiation source on the frame for emitting a radiation beam towards the objective holder; b) a radiation-sensitive detection system on the frame, which system comprises a plurality of detectors, each divided into at least two sub-detectors, the separating lines between the sub-detectors being parallel to each other; c) a beam-splitting optical element on the objective holder for splitting the radiation beam emitted by the radiation source in the direction of the radiation-sensitive detection system into sub-beams, the radiation distribution among the sub-detectors being determined by the position of the

optical element and thus of the objective holder relative to the frame; and d) an electronic circuit for supplying position-error signals, which circuit comprises inputs which are each individually connected to a sub-detector of the detection system.

Such an objective-position measuring device is known *per se* from the Applicant's previous European Patent Application 0063830. Only a small additional mass is added to the moving part of the apparatus, because the beam-splitting element can be small and light. This embodiment of the invention concerns a novel use of the opto-electronic objective-position measuring devices described in the said Patent Application in a levitation circuit, for automatically maintaining the position of an objective constant relative to the frame by electronic means.

The invention will now be described in more detail with reference to the drawings, in which the principles of a number of embodiments of the invention are represented and in which:

Figure 2 is a partly sectional view of an opto-electronic apparatus with permanent magnets, in which the objective holder is fully free-floating relative to a surrounding frame and comprises a plurality of tangentially projecting pole shoes,

Figure 3 is a side view of the objective holder and objective of the objective of the apparatus of Figure 2,

Figure 4 is a plan view of the apparatus of Figure 2,

Figure 5 schematically represents two actuator control systems for the apparatus of Figures 2-4,

Figure 6 relates to an objective-position measuring device,

Figure 7 is a circuit diagram of an electronic circuit for generating positional-error signals,

Figure 8 is a symbolic diagram of a levitation control circuit,

Figure 9 is a sectional view of an other embodiment of the invention which concerns an opto-electronic apparatus without permanent magnets and with an objective which is mounted in a ferromagnetic objective holder which is fully free-floating relative to a surrounding frame in the magnetic field of a number of combination coils,

Figure 10 is a plan view of the apparatus of Figure 9, some of the parts being omitted for the sake of clarity,

Figure 11 schematically represents a levitation circuit for the apparatus of Figures 9 and 10, and

Figure 12 is a circuit diagram of a capacitive objective-position measuring device for use in conjunction with the levitation control circuit of Figure 11.

All the embodiments of an opto-electronic apparatus shown in the drawing are in principle intended for scanning video and/or audio recording tracks or digital data recording tracks in a reflecting recording surface of a rotating disc by means of a laser light beam. However, in principle they may also be used for recording and/or reading the recording tracks in a recording

surface of a different type of record carrier, for example a rectangular record carrier which is linearly reciprocated or record carriers which are stationary.

The opto-electronic apparatus shown in Figures 2 to 4 comprises a frame 10 and an objective holder 11, which carries an objective 12 having an optical axis 13. The objective 12 is only shown schematically and has a lens system which comprises a bi-aspherical lens 14. The objective 12 concentrates a light beam 15 so as to form a light spot 16 in a focussing plane 17. The desired degrees of freedom comprise translational movements along the Z-axis, that is, the optical axis 13, so-called "focussing" movements, translational movements along an X-axis perpendicular to the Z-axis, so-called "tracking" movements, and translational movements along a Y-axis which is perpendicular to the X-axis as well as to the Z-axis, so-called "time-error correction" movements. The bearing arrangement for the objective holder 11 allows said movements relative to the frame in accordance with said desired degrees of freedom but substantially counteracts movements in accordance with the three other degrees of freedom. For driving the objective holder along the Z-axis there is provided an annular actuator coil 19. The objective holder carries an annular and axially magnetized permanent magnet 20, which is coaxially movable within the coil 19 with clearance, so that the actuator coil and the permanent magnet magnetically cooperate with each other via an air gap formed between them. The actuator coil 19 is included in a focussing system which falls beyond the scope of the invention and which serves to ensure that the focussing plane 17 constantly coincides with the recording surface of a video disc. This will be explained later, with reference to Figure 5 which schematically represents the opto-electronic apparatus of Figures 2 to 4 when used in an apparatus for reading a video disc 21.

The round disc-shaped video record is shown in a radial cross-section in Figure 5, so that the recording tracks 22 extend perpendicularly to the plane of drawing, that is in the Y-direction. The light beam 15 produced by a light source 23, for example a gas laser or a semiconductor diode laser, is reflected onto the video disc by a mirror 24, the beam being focussed by the objective 12 to form the radiation spot 16 of minimal dimensions on the reflecting recording surface in which the recording tracks 22 are disposed. The video disc 21 is disposed on a spindle 27 and is rotated by a motor 28.

When reading the video disc a beam 15R is used which is reflected by the recording tracks. This beam traverses the objective, is reflected by the mirror 24 and is subsequently separated from the beam 15 emitted by the source 23, for example by means of a semitransparent mirror 25, which reflects the beam 15R onto a radiation-sensitive detection system 26. As the video disc is rotated by the spindle 28 which is driven by the motor 27 the intensity of the beam 15R varies with

a high frequency in conformity with the information stored in the recording track.

In equipment in which information is to be recorded the intensity of the beam 15 may be modulated in conformity with the information to be recorded. For this purpose a modulator 29, for example an electro-optical or an acousto-optical modulator, may be arranged in the radiation path. The signal to be recorded is applied to the input terminals 30A, 30B. If the light source is a diode laser, this laser may be modulated directly and no separate modulator is needed.

For reading the recording tracks the detection system 26 may in principle comprise one radiation-sensitive detector, which converts the intensity modulation of the beam 15R into an electric signal. A tracking system is necessary to correct the position of the radiation spot 16 relative to a recording track. A deviation of the position of the centre of the radiation spot relative to the recording track may be detected in, for example, the manner shown in Figure 5. The detection system 26 in this Figure comprises two detectors 26A and 26B, which are arranged adjacent each other in the X-direction, that is in the direction transverse to the recording tracks. The output signals of these detectors are applied to the inputs of a differential amplifier 31, on whose output a positional-error signal S2 is available. This signal is applied to a controller 32 which controls actuator means 33 by means of which the objective system can be moved translationally along the X-axis. If the radiation spot 16 has shifted to the left or the right, relative to the centre of a recording track, one of the detectors, 26A or 26B respectively, receives a greater radiation intensity than the other, so that the signal S2 increases or decreases respectively. As a result of this the objective holder is moved to the right or to the left respectively.

By adding the signals from the detectors 26A and 26B in a summing device 34 a signal Si is obtained, which contains the information read. This signal is applied to an electronic processing circuit 35, which makes the signal suitable for reproduction by means of a television set.

During read-out with the minute light spot 16 the correct focussing of the radiation beam 15 at the recording surface should be checked, constantly. Figure 5 represents a focussing servo-system which is known *per se*. By means of a semi-transparent mirror 36 a part of the reflected beam 15R is directed into a second radiation-sensitive system 37. By means of a lens 38 the directed beam 39 is focussed at a wedge 40. This wedge splits the beam into two sub-beams 39A and 39B, the directions of said beams being dependent on the degree of focussing of the beam 15 at the recording surface. The detection system 37 comprises four detectors 37A to 37D. The signals from the detectors 37A and 37D are together applied to a first input of a differential amplifier 41 and the signals from detectors 37B and 37C are applied to a second input of said amplifier. The error signal Sf supplied by the

differential amplifier is applied to a controller 42. The controller 42 controls the actuator current through the actuator coils 19. If the beam 15 is focussed exactly at the recording surface, the beam 39 is focussed exactly at the apex of the wedge 40 and the respectively beam 39A or 39B in symmetrically incident on the detectors 37A, 39B or 37C, 37D respectively and the signal Sf is zero. When the light spot 16 is moved along the Z-axis the two beams 39A and 39B move inward or outward, depending on the direction of movement of the light spot, and the actuator current through the actuator coil 19 is varied.

By means of the tracking system described in the foregoing the position of the light spot 16 can be corrected very accurately in the radial direction, that is in the X-direction. This system is intended for fast fine control and has a small range. In practice, this fine control system will be combined with a coarse control system. This is a second tracking system which provides coarse control of the radial position of the light spot. This second tracking system comprises a system for controlling the position, in the X-direction, of a carriage on which the frame 10 is mounted. This means that the frame in the video disc player is semi-stationary.

It is desirable to measure translational movements of the objective holder 11 along the X-axis relative to the semi-stationary frame 10, in order to ascertain whether during reading the fine control system is approaching the end of its control range, which is a few millimetres at the most, so that a signal for rendering the coarse control system operative is obtained. Furthermore, when the video disc is started, and does not yet supply a signal S2, it is desirable to measure the position of the objective holder, so that it can be set to its centre position relative to the frame. In accordance with the invention, it is further necessary to have an objective-position measuring device for measuring the position of the objective holder 10 relative to the frame 11 with respect to the three undesired rotational movements about the X, Y and Z-axes and for generating positional-error signals.

For simultaneously measuring the said translational and rotational movements of the objective holder relative to the frame a prism 43 is arranged on the objective holder. This prism forms part of an objective-position measuring device, which is schematically represented in Figure 6. It is assumed that the refracting edge 46 of the prism should be disposed in the Y-Z plane and should be parallel to the Z-axis. An auxiliary radiation source 44, for example a diode laser, emits a radiation beam 45, which is incident on the prism 43. If the beam is incident on the refracting edge 46 of the prism, two sub-beams 45A and 45B are formed, which are reflected to two detectors 47 and 48. Each of these detectors comprises four sub-detectors 47A to 47D and 48A to 48D respectively. The two separating lines of the sub-detectors respectively extend transversely of the refracting edge 46 of the prism 43

and in the longitudinal direction thereof. The detectors are arranged on a common support 49, in which a hole is formed for the passage of the beam 45. A lens 50 converts the diverging beam 45 into a parallel beam. The radiation source 44 is also arranged on the support 49.

If the objective holder occupies its centre position along the X-axis, the centre of the radiation beam 45 is exactly incident on the refracting edge 46 of the prism 43. The radiation spots 51 and 52 formed on the detectors 47 and 48 by the reflected beams 45A and 45B then have the same intensity. If the objective holder is out of its centre position, the beam 45 is asymmetrically incident on the prism and one of the reflected 45A and 45B will convey more radiation energy than the other.

If the detectors are correctly aligned relative to the radiation source 44 and the refracting edge 46 of the prism 43 is parallel to the Z-axis, the radiation spots 51 and 52 will be disposed symmetrically relative to the respective detectors 47A to 47D or 48A to 48D. The arrangement shown enables translational movements along the X- and Y-axes and rotational movements about the three axes X, Y and Z to be measured simultaneously.

If the positional-error signals for the said translational movements are designated S_{TX} and S_{TY} and those for the said undesired rotational movements are designated S_{RX} , S_{RY} and S_{RZ} , the signals from the detectors being designated S_{47A} , S_{47B} , etc., the relationships between these signals are as follows.

$$S_{TX} = (S_{47A} + S_{47B} + S_{47C} + S_{47D}) - (S_{48A} + S_{48B} + S_{48C} + S_{48D})$$

$$S_{TY} = (S_{47A} + S_{47D} + S_{48B} + S_{48C}) - (S_{47B} + S_{47C} + S_{48A} + S_{48D})$$

$$S_{RX} = (S_{47A} + S_{47B} + S_{48A} + S_{48B}) - (S_{47C} + S_{47D} + S_{48C} + S_{48D})$$

$$S_{RY} = (S_{47A} + S_{47B} + S_{48C} + S_{48D}) - (S_{47C} + S_{47D} + S_{48A} + S_{48B})$$

$$S_{RZ} = (S_{47A} + S_{47D} + S_{48A} + S_{48D}) - (S_{47B} + S_{47C} + S_{48B} + S_{48C})$$

Only the last three positional-error signals are of interest for the present invention, because they relate to movements in accordance with the three undesired degrees of freedom of the objective holder 11. For adding and subtracting the detector signals a circuit 71 as shown in Figure 7 may be used. The circuit comprises a number of adder amplifiers, represented by squares, and a number of subtractor amplifiers, represented by triangles, and requires no further description.

Eight actuator coils 53A,B to 56A,B are arranged on the frame 10. These coils form parts of electromagnetic actuator means, which in addition comprise four ferromagnetic armatures 57 to 60 which are disposed at equal radial distances from the optical axis 13 and which are uniformly spaced around the circumference of the objective holder 11. Each armature comprises two teeth 57A,B to 60A,B which extend in substantially tangential directions and which are spaced from each other in a direction parallel to the optical axis 13 of the objective. The actuator coils 53A,B to 58A,B have an elongate shape in the axial direction, i.e. the direction parallel to the optical axis 13, so that the armature teeth have some axial freedom of movement in the actuator coils. The actuator coils have turns which are disposed substantially in planes containing the optical axis 13 of the objective and each have a central opening in which the associated armature tooth is situated with a clearance such that the objective holder 11 is movable to a limited extent in accordance with all the degrees of freedom. The objective holder 11 is annular and consists of a ferromagnetic material. Between the armatures 57 to 60 and the objective holder 11 radially magnetized permanent magnets 61 to 64 are

arranged. Thus, some of the turns of each actuator coil are situated between an armature tooth and the annular ferromagnetic objective holder and consequently in a permanent magnetic field which extends radially from the armature teeth to the ferromagnetic objective holder.

The objective holder 11 can be subjected to electromagnetic actuator forces for driving the objective holder in the desired directions of movement, that is, translational movements along the X-axis and the Y-axis. For a movement of the objective holder 11, and thus of the objective 12, along the X-axis, electric actuator currents of equal magnitude are simultaneously applied to the actuator coils 55A and 55B. The actuator coils 53A and 53B receive actuator currents of opposite polarity and equal absolute magnitude. In a similar way the objective holder can be moved along the Y-axis by means of the actuator coils 54A,B and 56A,B.

In the opto-electronic apparatus shown in Figures 2 to 4 the bearing arrangement for the objective holder 11 comprises a number of electromagnetic bearing means which are connected to the frame 10 and the objective holder 11 respectively and which electro-magnetically co-operate with each other via air gaps, for counteracting the undesired rotational movements about the X-axis, the Y-axis and the Z-axis by means of electromagnetic levitation forces. The actuator coils 53A,B to 56A,B in this apparatus also serve as levitation coils, for which reason they are referred to hereinafter as "combination coils". All bearing means for counteracting movement of the objective holder 11 in accordance with the undesired degrees of freedom comprise only

electromagnetic bearing means, so that the objective holder 11 is supported on the frame 10 only by electromagnetic actuator forces and electromagnetic levitation forces.

The aforesaid positional-error signals (S_{RX} , S_{RY} and S_{RZ}) from the objective-position measuring device (see Figure 7) are each applied to a levitation control circuit, which compares the positional-error signal with a reference signal of predetermined value and which comprises an output for applying electric levitation currents whose values depend on the error signal to the relevant combination coils in order to maintain the position of the objective 12 relative to the frame 10 in accordance with the relevant undesired degree of freedom substantially constant.

How the appropriate levitation coils can be exerted on the objective holder 11 by means of a levitation control circuit and by means of combination coils will be described, by way of example, with reference to Figure 8. The signal S_{RX} is applied to a symbolically represented electronic controller C_{RX} . The controller compares the signal S_{RX} with a signal F_{RX} of preset value. Since it will generally be desirable to maintain the objective holder in a position which is as level as possible relative to the frame, the signal F_{RX} will have a value which corresponds to this level position, for example a value 0. The controller C_{RX} comprises two outputs 65 and 66 and generates levitation currents of equal absolute value but opposite sign L_{CRX} and $-L_{CRX}$ on the two outputs 65 and 66. Each of these levitation currents is applied to two combination coils. One of the two levitation currents is applied to the two combination coils 53A and 55A and the other levitation current is applied to the two combination coils 53B and 55B. As a result of this the teeth 57A and 59A are subject to a tangential electromagnetic force which is opposite but equal in absolute magnitude to the electromagnetic forces exerted on the teeth 57B and 59B. Consequently, a torque is exerted on the objective holder 11 which counteracts the undesired rotational movement. Rotational movements about the Y-axis are counteracted in a similar manner. For rotational movements about the Z-axis a controller having only one output can be used, the levitation current being applied to all eight combination coils in equal proportion.

The objective-position measuring device described in the foregoing with reference to Figures 5 to 7 has already been described in the Applicant's afore-mentioned European Patent Application 0063830. However, the use of said objective-position measuring device in a levitation control circuit as described here is novel, some of the positional-error signals produced being employed in order to maintain an objective holder in a substantially invariable position relative to a frame by means of levitation coils, in other words for use in an electromagnetic bearing arrangement of an objective holder in a frame.

In Figures 5 and 6 the prism 43 is shown in such a position relative to the X-axis, the Y-axis and the

Z-axis that, as already stated, the refracting edge 46 of the prism is disposed substantially in the Y-Z plane and parallel to the Z-axis. As is shown in Figure 4, this is not readily possible with the opto-electronic apparatus described so far, because the X-axis and the Y-axis intersect with the coils 53A,B to 56A,B so that these coils form an obstruction to the light beam 45. Therefore, the prism 43 is arranged at an angle α relative to the X-axis. This gives rise to a complication as regards the control method. Viewed from the support 49, the refracting prism 46, when the objective holder 11 moves along the X-axis, moves not only in the X-direction but also in the Y-direction, the displacement in the Y-direction being related to the displacements in the X-direction in accordance with a sine function. Since the angle α has a fixed value, compensating measures may be taken in the circuit of Figure 7. As these measures fall beyond the scope of the present description and are obvious to those skilled in the art of control technology, they will not be described in more detail.

As can be seen in Figure 4 the frame 10 has recesses 67 to 70 adjacent the pole shoes such that the objective holder 11 can be manually positioned so that, by a small rotary movement about the Z-axis, the armature teeth no longer project into the combination coils. The objective holder can then be removed from the frame along the Z-axis. Since no electrical wiring is connected to the objective holder, this embodiment is highly suitable in those cases in which objectives should be rapidly and readily exchangeable.

Another embodiment of an opto-electronic apparatus in accordance with the invention will now be described with reference to Figures 9 to 13. This embodiment also concerns an apparatus in which all bearing means for counteracting movements of the objective holder in accordance with undesired degrees of freedom comprise only electromagnetic bearing means. The objective holder 72 is supported on the frame 73 only by electromagnetic actuator forces and by electromagnetic levitation forces. The objective comprises a single aspherical lens 74. The undesired degrees of freedom comprise rotational movements about the X-axis and about the Y-axis. Rotational movements about the Z-axis do not affect the optical operation of the apparatus and are therefore regarded neither as desired nor as undesired movements. For this reason no bearing means are provided which counteract rotational movements about the Z-axis. The Z-axis coincides with the optical axis of the lens 74.

The objective holder 72 comprises a ferromagnetic mounting ring which is concentric with the optical axis of the objective 74. The lens is glued into the mounting ring. All actuator coils and levitation coils are rigidly mounted on the frame 73 and cooperate magnetically with the ferromagnetic ring 72. In the bottom of the frame 73 an opening 75 is formed for the passage of a light beam. At the top of the frame is a cover 76 with an opening 77 for the light beam. Inside the

(16)

assembly comprising the frame 73 with the cover 76 three ferromagnetic yokes 78, 79 and 80 are arranged. The yoke 78 carries eight combination coils 81 which serve as actuator coils and as levitation coils. On the axially opposite side of the mounting ring 72 from the coils 81 identical combinations coils 82 are arranged on the yoke 80. The coils 81 and 82 are arranged around limbs 83 and 84 respectively of the yokes 78 and 80 respectively. Said coils exert axially opposed magnetic force components on the mounting ring 72. The yoke 79 carries eight combination coils 85 which are arranged around limbs 86 of the yoke 79. These combination coils exert radial forces on the mounting ring 72, combination coils 85 situated on diametrically opposite sides of the mounting ring exerting diametrically opposed magnetic force components. The special feature of this embodiment of the invention is that no permanent magnets are used and that the objective holder 72 with the objective 74 is kept floating within the frame 73 by means of electromagnetic forces only, which forces are exerted on the mounting ring 72 in opposite directions. For moving the objective holder in the direction of the Z-axis equal currents must be applied to all the coils 81 and all the coils 82 should also be energized with mutually equal currents. For tilting the objective holder about the X-axis different currents should be applied to those coils 81 which are diametrically opposed in the Y-direction, equal currents being applied to coils which are diametrically opposed in the X-direction. The same applies to the coils 82. Tilting about the Y-axis is possible in a similar way. Translational movements in the X-direction or in the Y-direction are effected by applying mutually different currents to diametrically opposite coils 85 on the yoke 79.

The position of the objective ring 72 relative to the frame 73 in accordance with all the degrees of freedom, except for rotational movements about the Z-axis, are measured by means of a capacitive objective-position measuring device. At the top of the objective holder an annular plate 87 of an electrically conductive material is arranged, an identical plate 88 being arranged at the bottom. A cylindrical sleeve 89 is arranged around the entire circumference. Opposite the plate 87 four stationary plates 90 are arranged on the yoke 80 and opposite the plate 88 four identical stationary plates 91 are arranged on the yoke 78. These stationary plates are disposed between the limbs 84 of the yoke 80 and between the limbs 83 of the yoke 78 respectively. Between the limbs 86 of the yoke 79 four stationary plates 92 are disposed. Each of these stationary plates constitutes a capacitive element with the facing movable plate on the objective holder 72. The capacitance of each of these capacitive elements depends on the distance between the plates. For each of the five degrees of freedom which are of importance there is provided an objective-position measuring device. Two of these objective-position measuring devices are only used for counteracting the

undesired rotational movements about the X-axis and about the Y-axis and are included in levitation control circuits. The other objective-position measuring devices have functions in the actuator control circuits for controlling the position of a read spot relative to a recording track in an information carrier. The electronic part of an objective position measuring device will be described with reference to Figures 11 and 12. For the sake of convenience identical parts in Figure 11 which are situated to the left and right of the Z-axis in the drawing are distinguished from each other by adding an L or an R respectively to the reference numeral.

The stationary plates 90L and 91L are connected to an objective-position measuring device 93L and the stationary plates 90R and 91R are connected to an identical objective-position measuring device 93R. Figure 12 shows an objective position measuring device 93 in greater detail. The objective mounting ring 72 may be regarded as being earthed because of its comparatively high capacitance relative to its surroundings. A voltage is induced into a coil T by a high-frequency voltage source a, which may be common to a plurality of objective-position measuring devices. The voltage induced in T causes equal currents through the two capacitances constituted by the capacitive elements 87—90L and 88—91L. Since the stationary plates 90L and 91L have equal surface areas the dielectric strain and thus the field strength in the two capacitive elements is the same. Therefore, the voltages across the capacitive elements are proportional to the distance between the relevant plates, their sum being constant.

These voltages are rectified with opposite sign by means of two diodes D1 and D2 and are added to each other at the junction U of a bridge comprising two identical resistors R. The voltage S on this junction is therefore proportional to the difference of the voltage across the capacitive elements and hence proportional to the position of the objective holder 72 relative to the frame along the Z-axis. The output signal S is zero if the objective holder 72 is in a centre position.

The output signals SL and SR appearing on the respective outputs UL and UR of the objective-position measuring devices 93L and 93R respectively are used as positional error signals in the levitation control circuit shown in Figure 11 for counteracting rotational movements about the X-axis. The circuit of Figure 11 comprises two types of loops the loops partly designated A belong to the levitation control circuit which counteracts rotational movements about the X-axis and the loops with the designation B belong to a Z-axis actuator control circuit which responds to a positional error signal E_z generated elsewhere (applied to an amplifier V_3). An explaining the operation it is assumed that the levitation control circuit is in a balanced condition. Assume that the objective holder now rotates about the X-axis, for example in an anticlockwise direction.

The output signal S_R increases and the output signal S_L decreases to the same extent. The two signals are added to each other in an amplifier V_2 whose output signal does not vary; consequently, the loop does not become active. In a differential amplifier S_R and S_L are subtracted from each other. A first output signal $S_R - S_L$ increases and a second output signal $-(S_R - S_L)$ decreases. An amplifier V_4 raises the levitation current through the coil 81R and reduces the levitation current through the coil 82R. An amplifier V_5 reduces the levitation current through the coil 81L and raises the levitation current through the coil 82L.

This results in a downward levitation force at the right-hand side of the objective and an upward levitation force at the left-hand side. The torque exerted by these forces counteracts the original rotary movement and returns the objective holder to its neutral position relative to the frame.

In a similar way an upward translational movement of the objective holder along the Z-axis results in an equal increase of the two output signals S_L and S_R . The output signals of the differential amplifier V_1 consequently do not change. Added in amplifier V_2 and inverted in amplifier V_3 , they produce a signal $E_z - \frac{1}{2}(S_L + S_R)$ which causes an equal increase of the actuator currents in the coils 81L and 81R and an equal decrease of the actuator currents in the coils 82L and 82R. As a result of this, a downward actuator force is exerted, which corrects the position of the read spot relative to the recording surface along the X-axis. In order to obtain control circuits with suitable responses the use of appropriate filter networks and suitable linearization of the loops by means of bias currents in the coils are essential. These and other steps are obvious to those skilled in the art of control technology and are therefore not discussed in more detail.

Claims

1. An opto-electronic apparatus for writing and/or reading recording tracks in a recording surface of a record carrier by means of a radiation beam, such as the scanning by means of a light beam of video and/or audio recording tracks or digital data recording tracks in a reflecting recording surface of a rotating video or audio disc or a data disc respectively, which apparatus comprises:

- a frame (10, 73),
- an objective holder (11, 72) provided with an objective having an optical axis and having a lens system for concentrating the radiation beam so as to form a radiation spot in a focussing plane,
- a bearing arrangement for supporting the objective holder for movement relative to the frame in accordance with a desired number of degrees of freedom out of six theoretically possible, independent degrees of freedom, said bearing arrangement including counter-

acting means for counteracting movements of the objective holder relative to the frame which are in accordance with other, undesired degrees of freedom, and

- actuator means comprising parts which are connected to the frame and to the objective holder respectively and which cooperate magnetically with each other *via* an air gap, for driving the objective holder relative to the frame with electromagnetic actuator forces in accordance with the said desired degrees of freedom, which actuator means comprise at least one actuator coil for said desired degrees of freedom,

characterized in that:

- the apparatus comprises an objective-position measuring device for continuously measuring the position of the objective holder (11; 72) relative to the frame (10; 73) in accordance with said undesired degrees of freedom and generating a positional-error signal,
- the bearing arrangement supports the objective holder solely by electromagnetic forces and comprises only electromagnetic counteracting means comprising at least one levitation coil (53A,B—56A,B; 81, 82, 85) secured to one of said frame and objective holder and magnetic means arranged on the other of said frame and objective holder, said magnetic means, cooperating with said levitation coil *via* an air gap so as to produce an electromagnetic levitation force which counteracts undesired movements of the objective holder in accordance with said undesired degrees of freedom, and
- a levitation control circuit is provided which compares the positional-error signal from the objective-position measuring device with a reference signal of specific value and which comprises at least one output for applying an electric levitation current whose value depends on the error signal to a levitation coil for maintaining substantially constant the position of the objective (12) relative to the frame in accordance with said undesired degrees of freedom.

2. An opto-electronic apparatus as claimed in claim 1, characterized in that

- the objective holder (11) is ferromagnetic and annular,
- at least three ferromagnetic armatures (57—60) are arranged on the objective holder at equal radial distances from the optical axis (13) and uniformly spaced around the circumference of the holder,
- a radially magnetized permanent magnet (61—64) is arranged between each armature and the objective holder,
- each armature comprises two armature teeth (57A, B to 60A, B) which extend in a substantially tangential direction and which are

The output signal S_R increases and the output signal S_L decreases to the same extent. The two signals are added to each other in an amplifier V_2 whose output signal does not vary; consequently, the loop does not become active. In a differential amplifier S_R and S_L are subtracted from each other. A first output signal $S_R - S_L$ increases and a second output signal $-(S_R - S_L)$ decreases. An amplifier V_4 raises the levitation current through the coil 81R and reduces the levitation current through the coil 82R. An amplifier V_5 reduces the levitation current through the coil 81L and raises the levitation current through the coil 82L.

This results in a downward levitation force at the right-hand side of the objective and an upward levitation force at the left-hand side. The torque exerted by these forces counteracts the original rotary movement and returns the objective holder to its neutral position relative to the frame.

In a similar way an upward translational movement of the objective holder along the Z-axis results in an equal increase of the two output signals S_L and S_R . The output signals of the differential amplifier V_1 consequently do not change. Added in amplifier V_2 and inverted in amplifier V_3 , they produce a signal $E_z - \frac{1}{2}(S_L + S_R)$ which causes an equal increase of the actuator currents in the coils 81L and 81R and an equal decrease of the actuator currents in the coils 82L and 82R. As a result of this, a downward actuator force is exerted, which corrects the position of the read spot relative to the recording surface along the X-axis. In order to obtain control circuits with suitable responses the use of appropriate filter networks and suitable linearization of the loops by means of bias currents in the coils are essential. These and other steps are obvious to those skilled in the art of control technology and are therefore not discussed in more detail.

Claims

1. An opto-electronic apparatus for writing and/or reading recording tracks in a recording surface of a record carrier by means of a radiation beam, such as the scanning by means of a light beam of video and/or audio recording tracks or digital data recording tracks in a reflecting recording surface of a rotating video or audio disc or a data disc respectively, which apparatus comprises:

- a frame (10, 73),
- an objective holder (11, 72) provided with an objective having an optical axis and having a lens system for concentrating the radiation beam so as to form a radiation spot in a focussing plane,
- a bearing arrangement for supporting the objective holder for movement relative to the frame in accordance with a desired number of degrees of freedom out of six theoretically possible, independent degrees of freedom, said bearing arrangement including counter-

acting means for counteracting movements of the objective holder relative to the frame which are in accordance with other, undesired degrees of freedom, and

- actuator means comprising parts which are connected to the frame and to the objective holder respectively and which cooperate magnetically with each other via an air gap, for driving the objective holder relative to the frame with electromagnetic actuator forces in accordance with the said desired degrees of freedom, which actuator means comprise at least one actuator coil for said desired degrees of freedom,

characterized in that:

- the apparatus comprises an objective-position measuring device for continuously measuring the position of the objective holder (11; 72) relative to the frame (10; 73) in accordance with said undesired degrees of freedom and generating a positional-error signal,
- the bearing arrangement supports the objective holder solely by electromagnetic forces and comprises only electromagnetic counteracting means comprising at least one levitation coil (53A, B—56A, B; 81, 82, 85) secured to one of said frame and objective holder and magnetic means arranged on the other of said frame and objective holder, said magnetic means, cooperating with said levitation coil via an air gap so as to produce an electromagnetic levitation force which counteracts undesired movements of the objective holder in accordance with said undesired degrees of freedom, and
- a levitation control circuit is provided which compares the positional-error signal from the objective-position measuring device with a reference signal of specific value and which comprises at least one output for applying an electric levitation current whose value depends on the error signal to a levitation coil for maintaining substantially constant the position of the objective (12) relative to the frame in accordance with said undesired degrees of freedom.

2. An opto-electronic apparatus as claimed in claim 1, characterized in that

- the objective holder (11) is ferromagnetic and annular,
- at least three ferromagnetic armatures (57—60) are arranged on the objective holder at equal radial distances from the optical axis (13) and uniformly spaced around the circumference of the holder,
- a radially magnetized permanent magnet (61—64) is arranged between each armature and the objective holder,
- each armature comprises two armature teeth (57A, B to 60A, B) which extend in a substantially tangential direction and which are





- spaced from each other in a direction parallel to the optical axis (13) of the objective (12),
- for each armature tooth a combination coil (53A, B—56A, B) having an elongate shape in a direction parallel to the optical axis is arranged on the frame, which coil functions both as actuator coil and as levitation coil and comprises turns which are disposed substantially in planes containing the optical axis (13) of the objective (12) and each have a central opening which receives the tooth with clearance, and
 - for translational movements along the optical axis there is provided an actuator coil (19) whose centre lies on the optical axis.

3. An opto-electronic apparatus as claimed in claim 1 or 2, characterized in that

- the objective holder (72) is at least partly made of a ferromagnetic material, and
- all actuator coils and levitation coils (81, 82, 85) are rigidly mounted on the frame (73, 76) and cooperate magnetically with ferromagnetic parts of the objective holder.

4. An opto-electronic apparatus as claimed in claim 3, characterized in that

- the objective holder (72) comprises a ferromagnetic mounting ring which is concentric with the optical axis (Z) of the objective (74),
- for movements in accordance with all the degrees of freedom of the objective, except for rotational movements about the optical axis, there are arranged on the frame a plurality of coils (81, 82) which are situated on axially opposite sides of the mounting ring (72) and which exert axially opposite magnetic force components on the mounting ring, and a plurality of coils (85) which are situated on diametrically opposite sides of the mounting ring (72) and which exert diametrically opposite magnetic force components on the mounting ring, which coils function as actuator coils, as levitation coils, or both as actuator coils and levitation coils.

5. An opto-electronic apparatus as claimed in claim 1, characterized in that the objective-position measuring device at least comprises:

- a) two capacitive elements (90L—87; 88—91L) arranged in series, comprising facing stationary plates (90L, 91L) of an electrically conductive material on the frame and facing movable plates (87, 88) of an electrically conductive material on the objective holder,
- b) a high-frequency alternating current source (a),
- c) a voltage difference circuit which is inductively coupled to the high-frequency alternating current source and connected to the two capacitive elements, and
- d) means for applying the output signal (S₁) of the voltage difference circuit to the levitation control circuit.

6. An opto-electronic apparatus as claimed in claim 1, characterized in that the apparatus comprises an opto-electronic objective-position measuring device, which device comprises:

- a) a radiation source (44) on the frame (10) for emitting a radiation beam towards the objective holder (11),
- b) a radiation-sensitive detection system on the frame, which system comprises a plurality of detectors (47, 48), each divided into at least two sub-detectors, the separating lines between the sub-detectors being parallel to each other,
- c) a beam-splitting optical element (43) on the objective holder for splitting the radiation beam (45) emitted by the radiation source in the direction of the radiation-sensitive detection system into sub-beams (45A,B), the radiation-distribution among the sub-detectors being determined by the position of the optical element and thus of the objective holder relative to the frame, and
- d) an electronic circuit for supplying positional-error signals, which circuit comprises inputs which are each individually connected to a sub-detector of the detection system.

Patentansprüche

1. Optoelektronische Anordnung zum mit einem Strahlungsbandel Einschreiben und/oder Auslesen von Aufzeichnungsspuren in einer Aufzeichnungsfläche eines Aufzeichnungsträgers, wie zum mit Hilfe eines Lichtbündels Abtasten von Video- und/oder Audioaufzeichnungsspuren oder digitalen Datenaufzeichnungsspuren in einer reflektierenden Aufzeichnungsfläche einer sich drehenden Video- oder Audioplatte bzw. digitalen Datenplatten, welche Anordnung die folgenden Elementen umfasst:

- ein Gestell (10, 73)
- eine Objektivhalterung (11, 72) mit einem Objektiv mit einer optischen Achse und mit einem Linsensystem zum Konzentrieren des Strahlungsbandels zu einem Strahlungsflecken in einer Fokussierebene,
- eine Lagerung für die Objektivhalterung mit Lagermitteln, die Bewegungen der Objektivhalterung gegenüber dem Gestell zulassen entsprechend einer Anzahl gewünschter Bewegungsfreiheitsgrade der sechs theoretisch möglichen unabhängigen Bewegungsfreiheitsgrade und die Bewegungen der Objektivhalterung gegenüber dem Gestell im wesentlichen entsprechend restlichen unerwünschten Bewegungsfreiheitsgraden vermeiden und
- mit dem Gestell bzw. der Objektivhalterung verbundene über einen Luftspalt miteinander magnetisch zusammenarbeitende Betätigungsmittel zum mit elektromagnetischen Betätigungskräften Antreiben der Objektivhalterung gegenüber dem Gestell entsprechend den genannten gewünschten Bewegungsfreiheitsgraden und mit mindestens einer



Betätigungsspule für jeden gewünschten Bewegungsfreiheitsgrad,

dadurch gekennzeichnet,

- dass die Anordnung eine Objektivlagenmessanordnung umfasst zum ständigen Messen der Lage der Objektivhalterung (11; 72) gegenüber dem Gestell (10; 73) entsprechend mindestens einem der genannten unerwünschten Bewegungsfreiheitsgrade und zum Erzeugen eines Lagenfehlersignals, 5
- dass die Lagerung mit dem Gestell bzw. mit der Objektivhalterung verbunden und über einen Luftspalt miteinander magnetisch zusammenarbeitende Lagermittel umfasst zur Vermeidung unerwünschten Bewegungen der Objektivhalterung entsprechend mindestens einem der genannten unerwünschten Bewegungsfreiheitsgrade mit Hilfe elektromagnetischer Freischwebekräfte und mit mindestens einer Freischwebespule für jeden unerwünschten Bewegungsfreiheitsgrad entsprechend dem eine unerwünschte Bewegung der Objektivhalterung durch elektromagnetische Freischwebekräfte vermieden wird und 10
- dass eine Freischweberegelschaltung vorhanden ist, die das Lagenfehlersignal, das von der Objektivlagenmessanordnung herrührt, mit einem Bezugssignal festgesetzten Wertes vergleicht und mindestens einen Ausgang hat zum Zuführen eines elektrischen Freischwebestromes mit einem von dem Fehlersignal abhängigen Wert zu einer vorhandenen Freischwebespule zum im wesentlichen Konstanthalten der Lage des Objektivs gegenüber dem Gestell entsprechend einem unerwünschten Freiheitsgrad, 15
- dass die Lagerung die Objektivhalterung nur durch elektromagnetische Kräfte trägt und nur elektromagnetische Entgegenwirkungsmittel aufweist, die wenigstens eine Freischwebespule (53A, B; 56A, B; 81, 82, 85) aufweisen, die entweder mit dem einem der Teile befestigt ist, die aus dem Gestell und der Objektivhalterung bestehen und magnetische Mittel, die mit dem anderen der genannten Teile befestigt sind, die aus dem genannten Gestell bzw. der Objektivhalterung bestehen, wobei die genannten magnetischen Mittel über einen Luftspalt mit der genannten Freischwebespule zusammenarbeiten zum Erzeugen einer elektromagnetischen Freischwebekraft, die den unerwünschten Bewegungen der Objektivhalterung entsprechend den genannten unerwünschten Freiheitsgraden entgegenwirkt, und 20
- dass eine Freischweberegelschaltung vorhanden ist, die das Lagenfehlersignal, das von der Objektlagenmessanordnung herrührt, mit einem Bezugssignal festgesetzten Wertes vergleicht und mindestens einen Ausgang hat zum Zuführen eines elektrischen Freischwebestromes mit einem von dem Fehlersignals 25

abhängigen Wert zu einer vorhandenen Freischwebespule zum im wesentlichen Konstanthalten der Lage des Objektivs (12) gegenüber dem Gestell entsprechend den genannten unerwünschten Freiheitsgraden.

2. Optoelektronische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass

- die Objektivhalterung (11) ferromagnetisch und ringförmig ist, 30
- auf der Objektivhalterung in gleichen diametralen Abständen von der optischen Achse (13) und gleichmässig am Umfang verteilt mindestens drei ferromagnetische Anker (57—60) angeordnet sind,
- sich zwischen jedem Anker und der Objektivhalterung ein radial magnetisierter Dauermagnet (61—64) befindet, 35
- jeder Anker zwei im wesentlichen tangentiell gerichtete und betrachtet entsprechend der optischen Achse (13) des Objektivs (12), in gewissem axialem Abstand voneinander angeordnete Zähne (57A, B bis 60A, B) aufweist,
- auf dem Gestell je Zahn eines Ankers eine in axialer Richtung längliche Kombinationsspule (53A, B—56A, B) vorhanden ist, die gleichzeitig als Betätigungsspule und als Freischwebespule wirksam ist und Windungen aufweist die im wesentlichen in einer Ebene durch die optische Achse (13) des Objektivs (12) liegen und mit einer zentralen Öffnung versehen sind, die den Zahn mit Spielraum aufnimmt und 40
- für geradlinige Bewegungen entsprechend der optischen Achse eine zu der optischen Achse konzentrische Betätigungsspule (19) vorhanden ist. 45

3. Optoelektronische Anordnung nach Anspruch 1 oder 2, dadurch gekennzeichnet,

- dass die Objektivhalterung (72) wenigstens teilweise aus ferromagnetischem Werkstoff besteht und 50
- dass alle Betätigungsspulen und Freischwebespulen (81, 82, 85) ortsfest auf dem Gestell (73, 76) angeordnet sind und mit ferromagnetischen Teilen der Objektivhalterung magnetisch zusammenarbeiten. 55

4. Optoelektronische Anordnung nach Anspruch 3, dadurch gekennzeichnet,

- dass die Objektivhalterung (72) aus einem ferromagnetischen und gegenüber der optischen Achse (Z) des Objektivs (74) konzentrischen Fassungsring besteht, 60
- dass auf dem Gestell für Bewegungen entsprechend allen Bewegungsfreiheitsgraden des Objektivs, abgesehen von Drehungen um die optische Achse, eine Anzahl von axial an mehreren Seiten des Fassungsringes (72) liegender und axial entgegengesetzte magne- 65



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tische Kraftkomponenten auf den Fassungsring ausübender Spulen (81, 82) und eine Anzahl diametral an mehreren Seiten des Fassungsringes (72) liegender und diametral entgegengesetzte magnetische Kraftkomponenten auf den Fassungsring ausübender Spulen (85) vorhanden sind, die als Betätigungsspule, als Freischwebespule oder gleichzeitig als Betätigungsspule und als Freischwebespule wirksam sind.

5. Optoelektronische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass die Objektivlagenmessanordnung mindestens die folgenden Elemente umfasst:

a) zwei in Reihe angeordnete kapazitive Elemente (90L—87; 88—91L), die aus einander gegenüberliegenden ortsfesten Platten (90L, 91L) aus elektrisch leitendem Werkstoff auf dem Gestell bestehen und gegenüber einander liegenden Platten (87, 88) aus elektrisch leitendem Werkstoff auf der Objektivhalterung,

b) eine HF-Wechselstromquelle (a),

c) eine Spannungsdifferenzschaltung, die mit der HF-Wechselstromquelle induktiv gekoppelt und mit zwei kapazitiven Elementen verbunden ist,

d) Mittel zum Zuführen des Ausgangssignal (S_L) der Spannungsdifferenzschaltung zu der Freischweberegelschaltung.

6. Optoelektronische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass die Anordnung eine optoelektronische Objektivlagenmessanordnung aufweist, die die folgenden Elemente aufweist:

a) eine Strahlungsquelle (44) auf dem Gestell (10) zum Ausstrahlen eines Strahlungsbündels zu der Objektivhalterung (11),

b) ein strahlungsempfindliches Detektionssystem auf dem Gestell, das mehrere Detektoren (47, 48) umfasst, die je in mindestens zwei Teildetektoren aufgeteilt sind, wobei die Trennlinien zwischen den Teildetektoren sich parallel zueinander erstrecken,

c) ein bündelspaltendes optisches Element (43) auf der Objektivhalterung zum in Teilbündel (45A, B) Aufteilen des von der Strahlungsquelle ausgestrahlten Strahlungsbündels (45) in Richtung des strahlungsempfindlichen Detektionssystems, wobei die Strahlungsverteilung über die Teildetektoren durch die Lage des optischen Elementes und folglich der Objektivhalterung gegenüber dem Gestell bestimmt wird und

d) eine elektronische Schaltungsanordnung zum Liefern der Lagenfehlersignale mit Eingängen, die je einzeln mit einem Teildetektor des Detektionssystems verbunden sind.

Revendications

1. Appareil opto-électronique pour l'enregistrement et/ou la lecture de pistes d'information dans une surface d'enregistrement d'un support d'information au moyen d'un faisceau de rayonnement, tels que le balayage au moyen d'un

faisceau lumineux de pistes d'information vidéo et/ou audio ou de pistes d'enregistrement de données numériques dans une surface d'enregistrement réfléchissante d'un disque vidéo ou audio en rotation d'une part ou d'un disque de mémorisation de données d'autre part, appareil comportant:

— un châssis (10, 73),

— un porte-objectif (11, 72) muni d'un objectif ayant un axe optique et comportant un système de lentilles pour concentrer le faisceau de rayonnement de façon à former un spot de rayonnement dans un plan de focalisation,

— des moyens d'appui servant à supporter le porte-objectif dans son mouvement par rapport au châssis suivant un nombre souhaité de degrés de liberté parmi six degrés de liberté indépendants théoriquement possibles, moyens d'appui comportant des moyens servant à contrarier des mouvements du porte-objectif par rapport au châssis suivant d'autres degrés de liberté non souhaités et,

— des moyens d'actionnement comportant des parties réunies respectivement au châssis et au porte-objectif et coopérant magnétiquement à travers un entrefer, moyens qui sont conçus pour commander le porte-objectif par rapport au châssis par des forces d'actionnement électromagnétiques suivant lesdits degrés de liberté souhaités et qui comportent au moins une bobine d'actionnement pour lesdits degrés de liberté souhaités,

caractérisé en ce que

— l'appareil comporte un dispositif de mesure de la position de l'objectif servant à mesurer de façon continue la position du porte-objectif (11; 72) par rapport au châssis (10; 73) suivant lesdits degrés de liberté non souhaités et à engendrer un signal d'erreur de position,

— les moyens d'appui supportent le porte-objectif exclusivement par des forces électromagnétiques et ne comportent que des moyens à contrarier électromagnétiques munis d'au moins une bobine de lévitation (53A, B—56A, B; 81, 82, 85) fixée à l'un des éléments formés par ledit châssis et ledit porte-objectif et de moyens magnétiques disposés sur l'autre des éléments formés par ledit châssis et ledit porte-objectif, moyens magnétiques qui coopèrent avec ladite bobine de lévitation à travers un entrefer de façon à engendrer une force de lévitation électromagnétique contrariant des mouvements non souhaités du porte-objectif selon lesdits degrés de liberté non souhaités et

— il est prévu un circuit de réglage de la lévitation qui compare le signal d'erreur de position provenant du dispositif de mesure de la position de l'objectif avec un signal de référence de valeur spécifique et qui comporte au moins une sortie pour fournir un courant de lévitation



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tion électrique dont la valeur dépend du signal d'erreur à une bobine de lévitation pour maintenir la position de l'objectif (12) sensiblement constante par rapport au châssis suivant lesdits degrés de liberté non souhaités.

2. Appareil opto-électronique selon la revendication 1, caractérisé en ce que

- le porte-objectif (11) est ferromagnétique et annulaire, 10
- au moins trois armatures ferromagnétiques (57—60) sont disposées sur le porte-objectif à des distances radiales égales de l'axe optique (13) tout en étant uniformément réparties sur le pourtour du porte-objectif, 15
- un aimant permanent (61—64) à aimantation radiale est disposé entre chaque armature et le porte-objectif,
- chaque armature présente deux dents d'armature (57A, B à 60A, B) s'étendant dans une direction sensiblement tangentielle et séparées l'une de l'autre dans une direction parallèle à l'axe optique (13) de l'objectif (12), 20
- pour chaque dent d'armature, est disposée sur le châssis une bobine combinée (53A, B—56A, B) ayant une forme allongée dans une direction parallèle à l'axe optique et servant à la fois de bobine d'actionnement et de bobine de lévitation, bobines qui comportent des spires situées sensiblement dans des plans contenant l'axe optique (13) de l'objectif (12) et qui présentent chacune une ouverture centrale recevant le dent avec jeu et 25
- il est prévu, pour des mouvements de translation suivant l'axe optique, une bobine d'actionnement (19) dont le centre est situé sur l'axe optique. 30

3. Appareil opto-électronique selon la revendication 1 ou 2, caractérisé en ce que 40

- le porte-objectif (72) est au moins partiellement en matériau ferromagnétique et
- toutes les bobines d'actionnement et toutes les bobines de lévitation (81, 82, 85) sont montées rigidement sur le châssis (73, 76) et coopèrent magnétiquement avec des parties ferromagnétiques du porte-objectif. 45

4. Appareil opto-électronique selon la revendication 3, caractérisé en ce que 50

- le porte-objectif (72) comporte une bague de montage ferromagnétique, concentrique avec l'axe optique (z) de l'objectif (74), 55
- pour des mouvements suivant tous les degrés de liberté de l'objectif, sauf pour des mouvements rotatifs autour de l'axe optique, sont disposées sur le châssis une pluralité de bobines (81, 82) situées sur des faces axiale- 60

ment opposées de la bague de montage (72) et exerçant sur la bague de montage des composantes de force magnétique axialement opposées, et une pluralité de bobines (85) situées sur des faces diamétralement opposées de la bague de montage (72) et exerçant sur la bague de montage des composantes de force magnétique diamétralement opposées, bobines qui font fonction de bobines d'actionnement, de bobines de lévitation ou à la fois de bobines d'actionnement et de bobines de lévitation.

5. Appareil opto-électronique selon la revendication 1, caractérisé en ce que le dispositif de mesure de la position de l'objectif comporte au moins:

a) deux éléments capacitifs (90L—87; 88—91L) disposés en série et comportant des plaques stationnaires (90L, 91L) en matériau conducteur de l'électricité placées en vis-à-vis sur le châssis et des plaques mobiles (87, 88) en matériau conducteur de l'électricité placées en vis-à-vis sur le porte-objectif,

b) une source de courant alternatif à haute fréquence (a),

c) un circuit de différence de tension couplé inductivement à la source de courant alternatif à haute fréquence et relié aux deux éléments capacitifs et

d) des moyens pour appliquer le signal de sortie (S_i) du circuit de différence de tension au circuit de réglage de la lévitation.

6. Appareil opto-électronique selon la revendication 1, caractérisé en ce qu'il est muni d'un dispositif opto-électronique de mesure de la position de l'objectif, dispositif qui comporte:

a) une source de rayonnement (44) placée sur le châssis (10) et servant à émettre un faisceau de rayonnement vers le porte-objectif (11),

b) un système de détection sensible aux rayonnements placé sur le châssis et comportant une pluralité de détecteurs (47, 48) qui sont divisés chacun en au moins deux sous-détecteurs, les lignes de séparation entre les sous-détecteurs étant parallèles,

c) un élément optique (43) de division de faisceau placé sur le porte-objectif et servant à diviser en sous-faisceaux (45A, B) le faisceau de rayonnement (45) émis par la source de rayonnement en direction du système de détection sensible aux rayonnements, la répartition du rayonnement sur les sous-détecteurs étant déterminée par la position de l'élément optique, et par conséquent, du porte-objectif par rapport au châssis et.

d) circuit électronique servant à fournir des signaux d'erreur de position et muni d'entrées qui sont reliées chacune à part à un sous-détecteur du système de détection.

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