

Description

Introductory part of the description for the Contracting States: DE GB

The invention relates to an electro-optical device for scanning an information disc without mechanical contact, which device comprises a movable optical system comprising at least one optical element, elongate supporting means which movably support the optical system, and an electromagnetic actuator comprising first actuator means and second actuator means which cooperate electromagnetically with each other via an air gap for moving the optical system in a controlled manner.

Such an electro-optical device is described in European Patent Application 0 092 997 to be considered under Art 54/3 in the Contracting States DE and GB. That electro-optical device is intended for use with a servo drive for reading out data from a recording surface of a rotating optical disc by means of a radiation beam which is emitted by a laser and which is concentrated to form a radiation spot. The servo drive moves the entirety of the electro-optical device electromagnetically.

The optical system comprises the objective of the electro-optical device. The flexible supporting means comprise two sets of flat leaf springs, which are spaced from one another, which extend at least substantially parallel to one another. The leaf springs of one of said sets are connected to the frame and are flexible in a first direction, the leaf springs of the other of said sets are connected with the leaf springs of the first mentioned set, are flexible in a second direction perpendicular to the first direction and are connected to the moving optical system. Here "frame" is to be understood to mean the housing of an integrated optical pick-up which comprises the optical system, which pick-up can be mounted entirely on a servo drive.

The electro-optical device describes in said EP patent application is provided with permanent magnets, elements of magnetically susceptible material and electromagnetic means so as to move the objective by means of magnetic pull forces in the first and second direction in order to focus the radiation spot on the information structure of the optical disc and to follow a track of the disc, respectively, whereby the leaf springs are also pretensioned by the magnetic means in their longitudinal directions.

In order to enable all the tracks on the disc to be followed in the radial direction also by means of the optical system the whole drive is driven, which means that the movements of the drive must be transmitted to the optical system via leaf springs. Therefore, the leaf springs have to satisfy conflicting requirements. The focussing movements not only require energy for accelerating and decelerating the mass of the optical system but also energy for the deflection of the springs. In order to minimize the thermal dissipation in the actuator means and the dimensioning of the amplifiers in the servo system which

controls the focussing movements of the optical system, weak leaf springs should be used. For transmitting the radial movements to the optical system, however, the leaf springs should be as stiff as possible. This means that for the focussing movements the leaf springs must be weak but in a direction transverse thereto, they must be stiff, which requirements can be met partly by making the leaf springs thin but sufficiently wide. Another requirement is that the leaf springs must have a minimal mass and must not be in resonance for the frequencies of movement of the optical system.

Another electro-optical device of this type defined in the opening paragraph is known from European Patent Application 0 077 581 (herewith incorporated by reference). That electro-optical device is intended for use with a swinging-arm device for writing and/or reading recording tracks in a recording surface of a rotating optical disc by means of a radiation beam which is emitted by a laser and which is concentrated to form a radiation spot. (European Patent Application 0 074 313, herewith incorporated by reference). The optical system comprises a plurality of lenses which, in combination with some lenses which are rigidly connected to the frame, constitute the objective of the electro-optical device. The flexible supporting means comprise two flat leaf springs, which are spaced from one another, and which each have one end connected to the moving optical system, the other end being rigidly secured to the frame. Here "frame" is to be understood to mean the housing of an integrated optical pick-up which comprises the optical system, which pick-up can be mounted entirely in the swinging arm of said swinging-arm device.

The optical system is supported by the leaf springs so as to be movable back and forth along the optical axis of the system in order to keep the radiation spot constantly focused on the information structure of the optical disc. In order to enable the tracks on the disc to be followed in the radial direction also by means of the optical system the whole swinging arm is driven, which means that the pivotal movements of the swinging arm must be transmitted to the optical system via the leaf springs. Therefore, the leaf springs have to satisfy the same conflicting requirements as already described.

It is the object of the invention to provide an electro-optical device of the type specified in the opening paragraph, which device meets said conflicting requirements imposed on the supporting means in a more efficient manner.

To this end an electro-optical device according to the invention comprises a movable optical system comprising at least one optical element, elongate supporting means which movably support the optical system, and which comprise at least one wire having a low resistance to bending, an electromagnetic actuator comprising first actuator means and second actuator means which cooperate electromagnetically with each other via an air gap for moving the optical system

in a controlled manner, a magnetic pretensioning device comprising first pretensioning means and second pretensioning means, which first and second pretensioning means cooperate magnetically with one another *via* an air gap and pretension said supporting means in their longitudinal direction.

The significance of the invention is such that it enables an entirely new generation of electro-optical devices of the type specified in the opening paragraph to be developed. The pretensioning device can provide an adequate resistance to movements in the transverse direction. The magnetic pretensioning device may be considered to form part of the supporting means which support the optical system movably on the frame. The force-displacement characteristic of the supporting means may be influenced by the choice of the magnetic pretensioning means, enabling a more linear characteristic to be obtained.

As described in the afore-mentioned European Patent Application 0 077 581, the movable optical system may comprise for example, a lens system with an optical axis. The term "lens system" is to be understood herein to mean an optical system comprising at least a single lens. When a lens system is supported by means of wires having a low resistance to bending, it may be necessary to make provisions which preclude tilting of the system about an axis perpendicular to the optical axis. In an embodiment of the invention which is advantageous in this respect the supporting means comprise two pairs of wires which extend at least substantially transversely of the optical axis, a first pair extending near a first end of the lens system and a second pair near a second end of the lens system, and the wires of each pair are disposed at an angle to one another. The resistance to tilting presented by the supporting means is the result of the fact that, because the wires are disposed at an angle to each other and hence have to describe different arcs during tilting of the optical system, the optical system can be tilted only if a tilting torque of such a magnitude is exerted that the torque limit necessary to overcome the pretensioning stresses in the wires is exceeded.

The above embodiment may have the further characteristic features: the first pair of wires meet at a first point of attachment, the second pair of wires meet at a second point of attachment and the first and the second point of attachment are spaced from each other and are situated on a pivotal axis of the lens system, which axis extends parallel to the optical axis of the lens system. Thus, also if two wires are used on each side, only two points of attachment for the wires are required. Moreover, the lens system moves along an arc of circle, which permits the stationary part of the device to be optimized in respect of production engineering. A further advantage is that in comparison with parallel wires the present arrangement results in a higher resistance to undesired pivotal movements of the lens system about axes which intersect and are perpendicular

to the optical axis and the pivotal axis. This will be explained more fully hereinafter.

The known swinging-arm device described in the afore-mentioned European Patent Application 0 077 581 requires the use of an expensive supporting arrangement for the swinging arm and, in addition, a supporting arrangement for supporting the lens system on the swinging arm. The steps described in the last-mentioned Patent Application enable a swinging-arm device to be obtained which occur in every revolution by means of only one servo-system, referred to as a "single-stage servo system". This means that the lens system is not controlled separately in a radial direction relative to the swinging arm. The entire swinging arm is incorporated in a servo loop for rapid tracking. The dynamic bandwidth of the swinging-arm device must comply with stringent requirements, which can be met only with difficulty.

The invention enables the known swinging arm device to be replaced completely by an electro-optical device having a very high bandwidth and a smaller number of parts. For this purpose another embodiment of the invention is used which has in addition to the features of the last-mentioned embodiment the characteristic features that the lens system is pivotable about the pivotal axis along an arc whose chord has a length which is at least equal to the radial dimension of the annular information area of the information disc to be read, and that the first actuator means extend along an arc whose centre of curvature is situated on the pivotal axis, and cooperate with the second actuator means *via* an air gap which is at least substantially constant regardless of the pivotal position of the lens system. This embodiment of the invention, by means of which a rotating optical disc can be scanned completely without the use of a further servo-controlled radially movable device, comprises only one moving part in the form of a lens system which is supported by wires which are pretensioned in a manner which requires no contact with the wires.

The invention may also be used to advantage in electrooptical devices of a different type, for example, as described in United States Patent Specification 4,021,101 (herewith incorporated by reference). In this known electro-optical device, the lens system is moved back and forth along the optical axis by means of a moving coil arranged in an annular air gap of a permanent-magnetic stator. For following the track of a rotating optical disc this known device may be used in combination with one or two pivotal mirrors, which respectively serve for following the track with the radiation spot in a radial direction and for providing compensation for timing errors by moving the radiation spot in a tangential direction. This known device can be improved in a manner such that the pivotal mirrors may be dispensed with by utilising an embodiment of the invention which is characterized in that the supporting means comprise at least three wires of equal length, which wires extend parallel to and are spaced from the

optical axis. The wires may be arranged for example on the underside of the lens system, so that the pretensioning means load the lens system in an upward direction, opposing the force of gravity. The lens system which is thus loaded in an upward direction can be moved not only along the optical axis but also in directions perpendicular to the optical axis with high frequency using suitable electro-magnetic actuator means.

It has been found that for rapidly mounting the wires in an electro-optical device in accordance with the invention, it may be of advantage to employ wires, which form part of the supporting means, and all form sections of a single uninterrupted length of wire. In this way the manipulation of separate lengths of wire is not required during assembly.

In order to obtain a wire which has a very low resistance to bending but which is nevertheless sufficiently strong, an embodiment of the invention may be used which has the characteristic feature that the wire comprises a plurality of separate fibres. In this respect it may be interesting if the wires comprise at least fibres of a first type and of a second type, the first type of fibres being made of a material which is suitable for the transmission of information signals and the second type of fibres being made of a material which has a higher modulus of elasticity than the first material. This is of particular interest if the movable optical system also comprises electronic means or receives a light beam via an optical fibre.

It is essential that the wires have a very low elasticity in the longitudinal direction. Preferably, the wires comprise a material with a modulus of elasticity higher than that of steel. For example, the invention may be characterized in that said material is a hydrocarbon polymer. Excellent results have been obtained by the use of multi-fibre wires, made of an aromatic polyamide. Other suitable materials are, for example poly para-phenylene-terephthalate and an ultra-strong polythene fibre. An aromatic polyamide can combine a very high tensile strength with a specific mass which is five times as low as that of steel, and has a modulus of elasticity which is approximately one and a half times that of steel. This material is available in the form of fibres, which are suitable for manufacturing wires of the required thickness having an extremely low elasticity.

To attain the object of the invention another electrooptical device according to the invention comprises a movable optical system comprising a lens system with an optical axis, elongate supporting means which movably support the optical system, and which comprises two leaf springs which extend at least substantially perpendicular of the optical axis, a first spring extending near a first end of the lens system and a second spring near a second end of the lens system, which leaf springs have points of attachment which are spaced from each other and are

situated on a pivotal axis of the lens system, which axis extends parallel to the optical axis of the lens system, an electromagnetic actuator comprising first actuator means and second actuator means which cooperate electromagnetically with each other via an air gap for moving the optical system in a controlled manner, and a magnetic pretensioning device comprising first pretensioning means and second pretensioning means, which first and second pretensioning means cooperate magnetically with one another via an air gap and pretension said supporting means in their longitudinal direction. The pretensioning device can provide an adequate resistance to movements in the transverse direction even when thin leaf springs are employed. Preferably this device has further the characteristic feature that the leaf springs each have a recess to form two strips which extend at least substantially perpendicularly of the optical axis. Such an embodiment has a high resistance to undesired pivotal movements of the lens system about axes which intersect and are perpendicular to the optical axis and the pivotal axis.

It is to be noted that it is known from United States Patent Specification 4 092 529 to make use of a number of resilient wires or leaf springs so as to couple an optical element to a supporting member of an information detecting head intended for use in an apparatus for reading optically the information recorded on a record carrier. That publication gives further no relevant information about the inventive device.

Introductory part of the description for the Contracting States: CH FR IT LI SE

The invention relates to an electro-optical device for scanning an information disc without mechanical contact, which device comprises a movable optical system comprising at least one optical element, elongate supporting means which movably support the optical system, and an electromagnetic actuator comprising first actuator means and second actuator means which cooperate electromagnetically with each other via an air gap for moving the optical system in a controlled manner.

Electro-optical devices of this type are known in a variety of versions, for example from European Patent Application 0 077 581 (herewith incorporated by reference). The electro-optical device described therein is intended for use with a swinging-arm device for writing and/or reading recording tracks in a recording surface of a rotating optical disc by means of a radiation beam which is emitted by a laser and which is concentrated to form a radiation spot. (European Patent Application 0 074 131, herewith incorporated by reference). The optical system comprises a plurality of lenses which, in combination with some lenses which are rigidly connected to the frame, constitute the objective of the electro-optical device. The flexible supporting means comprise two flat leaf springs, which are spaced from one another, which extend at least substantially paral-

labeled to one another, and which each have one end connected to the moving optical system, the other end being rigidly secured to the frame. Here "frame" is to be understood to mean the housing of an integrated optical pick-up which comprises the optical system, which pick-up can be mounted entirely in the swinging arm of said swinging-arm device.

The optical system is supported by the leaf springs so as to be movable back and forth along the optical axis of the system in order to keep the radiation spot constantly focused on the information structure of the optical disc. In order to enable the tracks on the disc to be followed in the radial direction also by means of the optical system the whole swinging arm is driven, which means that the pivotal movements of the swinging arm must be transmitted to the optical system via the leaf springs have to satisfy conflicting requirements. The focusing movements not only require energy for accelerating and decelerating the mass of the optical system and of the annular magnet surrounding this system, but also energy for the deflection of the springs. In order to minimize the thermal dissipation in the actuator coil which is arranged on the frame and the dimensioning of the amplifiers in the servo system which controls the focusing movements of the optical system, weak leaf springs should be used. For transmitting the radial movements to the optical system, however, the leaf springs should be as stiff as possible. This means that for the focusing movements the leaf springs must be weak but in a direction transverse thereto, they must be stiff, which requirements can be met partly by making the leaf springs thin but sufficiently wide. Another requirement is that the leaf springs must have a minimal mass and must not be in resonance for the frequencies of movement of the optical system.

It is the object of the invention to provide an electrooptical device of the type specified in the opening paragraph, which device meets said conflicting requirements imposed on the supporting means in a more efficient manner.

The invention is characterized in that there is provided a magnetic pretensioning device comprising first pretensioning means and second pretensioning means, which first and second pretensioning means cooperate magnetically with one another via an air gap and pretension said supporting means in their longitudinal direction. The pretensioning device can provide an adequate resistance to movements in the transverse direction even when thin leaf springs are employed. The magnetic pretensioning device may be considered to form part of the supporting means which support the optical system movably on the frame. The force-displacement characteristic of the supporting means may be influenced by the choice of the magnetic pretensioning means, enabling a more linear characteristic to be obtained.

Preferably, an embodiment of the invention is used which is characterized in that the magnetic

pretensioning device comprises permanent-magnetic means, because permanent magnetic means require no power supply. However, in principle it is alternatively possible to utilize electromagnetic means or a combination of electromagnetic and permanent-magnetic means. An advantageous embodiment is characterized in that at least a part of the pretensioning means also form part of the actuator means. This part of the actuator means then performs two functions, so that only a few or no additional parts are required.

The significance of the invention is such that it enables an entirely new generation of electro-optical devices of the type specified in the opening paragraph to be developed. This new generation of electro-optical devices is characterized in that said flexible supporting means comprise at least one wire having a low resistance to bending.

As described in the afore-mentioned European Patent Application 0 077 581, the movable optical system may comprise for example, a lens system with an optical axis. The term "lens system" is to be understood herein to mean an optical system comprising at least a single lens. When a lens system is supported by means of wires having a low resistance to bending, it may be necessary to make provisions which preclude tilting of the system about an axis perpendicular to the optical axis. An embodiment of the invention which is advantageous in this respect is characterized in that the supporting means comprise two pairs of wires which extend at least substantially transversely of the optical axis, a first pair extending near a first end of the lens system and a second pair near a second end of the lens system, and the wires of each pair are disposed at an angle to one another. The resistance to tilting presented by the supporting means is the result of the fact that, because the wires are disposed at an angle to each other and hence have to describe different arcs during tilting of the optical system, the optical system can be tilted only if a tilting torque of such a magnitude is exerted that the torque limit necessary to overcome the pretensioning stresses in the wires is exceeded.

This embodiment may be further characterized in that the first pair of wires meet at a first point of attachment, the second pair of wires meet at a second point of attachment and the first and the second point of attachment are spaced from each other and are situated on a pivotal axis of the lens system, which axis extends parallel to the optical axis of the lens system. Thus, also if two wires are used on each side, only two points of attachment for the wires are required. Moreover, the lens system moves along an arc of circle, which permits the stationary part of the device to be optimized in respect of production engineering. A further advantage is that in comparison with parallel wires the present arrangement results in a higher resistance to undesired pivotal movements of the lens system about axes which intersect and are perpendicular to the optical axis and the pivotal axis.

With reference to the above paragraph an alternative embodiment comprising a lens system with an optical axis is characterized in that the supporting means comprises two leaf springs which extend at least substantially perpendicular of the optical axis, a first spring extending near a first end of the lens system and a second spring near a second end of the lens system. Preferably this embodiment is further characterized in that the leaf springs have points of attachment which are spaced from each other and are situated on a pivotal axis of the lens system, which axis extends parallel to the optical axis of the lens system, and/or the leaf springs each have a recess to form two strips which extend at least substantially perpendicularly of the optical axis.

The known swinging-arm device described in the afore-mentioned European Patent Application 0 077 581 requires the use of an expensive supporting arrangement for the swinging arm and, in addition, a supporting arrangement for supporting the lens system on the swinging arm. The steps described in the last-mentioned patent Application enable a swinging-arm device to be obtained which constantly follows radial oscillations of the track which occur in every revolution by means of only one servo-system, referred to as a "single-stage servo system". This means that the lens system is not controlled separately in a radial direction relative to the swinging arm. The swinging arm is incorporated in a servo loop for rapid tracking. The dynamic bandwidth of the swinging-arm device must comply with stringent requirements, which can be met only with difficulty.

The invention enables the known swinging arm device to be replaced completely by an electro-optical device having a very high bandwidth and a smaller number of parts. For this purpose an embodiment of the invention is used which has the characteristic features of one of the last-mentioned embodiments and which, in addition, is characterized in that the lens system is pivotable about the pivotal axis along an arc whose chord has a length which is at least equal to the radial dimension of the annular information area of the information disc to be read, and the first actuator means extend along an arc whose centre of curvature is situated on the pivotal axis, and cooperate with the second actuator means *via* an air gap which is at least substantially constant regardless of the pivotal position of the lens system.

This embodiment of the invention, by means of which a rotating optical disc can be scanned completely without the use of a further servo-controlled radially movable device, comprises only one moving part in the form of a lens system which is supported by wires which are pretensioned in a manner which requires no contact with the wires.

The invention may also be used to advantage in electrooptical devices of a different type, for example, as described in United States Patent Specification 4,021,101 (herewith incorporated by

reference). In this known electro-optical device, the lens system is moved back and forth along the optical axis by means of a moving coil arranged in an annular air gap of a permanent-magnetic stator. For following the track of a rotating optical disc this known device may be used in combination with one or two pivotal mirrors, which respectively serve for following the track with the radiation spot in a radial direction and for providing compensation for timing errors by moving the radiation spot in a tangential direction. This known device can be improved in a manner such that the pivotal mirrors may be dispensed with by utilising an embodiment of the invention which is characterized in that the supporting means comprise at least three wires of equal length, which wires extend parallel to and are spaced from the optical axis. The wires may be arranged for example on the underside of the lens system, so that the pretensioning means load the lens system in an upward direction, opposing the force of gravity. The lens system which is thus loaded in an upward direction can be moved not only along the optical axis but also in directions perpendicular to the optical axis with high frequency using suitable electro-magnetic actuator means.

It has been found that for rapidly mounting the wires in an electro-optical device in accordance with the invention, it may be of advantage to employ an embodiment which is characterized in that said wires, which form part of the supporting means, all form sections of a single uninterrupted length of wire. In this way the manipulation of separate lengths of wire is not required during assembly.

In order to obtain a wire which has a very low resistance to bending but which is nevertheless sufficiently strong, an embodiment of the invention may be used which is characterized in that the wire comprises a plurality of separate fibres. In this respect it may be interesting if the wires comprise at least fibres of a first type and of a second type, the first type of fibres being made of a material which is suitable for the transmission of information signals and the second type of fibres being made of a material which has a higher modulus of elasticity than the first material. This is of particular interest if the movable optical system also comprises electronic means or receives a light beam *via* an optical fibre.

It is essential that the wires have a very low elasticity in the longitudinal direction. Preferably, the wires comprise a material with a modulus of elasticity higher than that of steel. For example, the invention may be characterized in that said material is a hydrocarbon polymer. Excellent results have been obtained by the use of multi-fibre wires, made of an aromatic polyamide. Other and suitable materials are, for example poly para-phenylene-terephthalate and an ultra-strong polythene fibre. An aromatic polyamide can combine a very high tensile strength with a specific mass which is five times as low as that of steel,

and has a modulus of elasticity which is approximately one and a half times that of steel. This material is available in the form of fibres, which are suitable for manufacturing wires of the required thickness having an extremely low elasticity.

It is to be noted that it is known from United States patent Specification 4 092 529 to make use of a number of resilient wires or leaf springs so as to couple an optical element to a supporting member of an information detecting head intended for use in an apparatus for reading optically the information recorded on a record carrier. That publication gives further no relevant information about the inventive device.

Description of the drawings for the Contracting States: CH DE FR GB IT LI SE

Some embodiments of the invention will now be described in more detail, by way of example, with reference to the drawings, in which:

Fig. 1 is a sectional view, drawn to an enlarged scale and taken on the line I—I in Fig. 2, of an electro-optical device in which a moving lens system is suspended in pretensioned leaf springs.

Fig. 2 is a plan view of the device shown in Fig. 1.

Fig. 3 is a graph depicting the relationship between the axial displacement X of the moving lens system of the electro-optical device shown in Fig. 1 as a function of the axial force F required for this displacement.

Fig. 4 is an exploded perspective view, drawn to an enlarged scale, showing a moving lens system suspended in thin wires with a low resistance to bending as an alternative to a part of the electro-optical device shown in Fig. 1.

Fig. 5 is a plan view of an optical audio disc drawn to approximately full scale and showing in broken lines the outlines of some of the principal parts, situated underneath said disc of an embodiment of an electro-optical device in accordance with the invention which is capable of scanning the entire area of interest of the disc surface.

Fig. 6 is a plan view of the electro-optical device for use in combination with the optical disc shown in Fig. 5.

Fig. 7 is a sectional view of this electro-optical device taken on the line VII—VII in Fig. 6.

Fig. 8 is a front view of the electro-optical device shown in Figs. 6 and 7.

Fig. 9 is a sectional view, drawn to an enlarged scale of a third embodiment of the invention.

Fig. 10 is a plan view of the electro-optical device shown in Fig. 9.

Fig. 11 is an exploded perspective view showing some parts of the device shown in Figs. 9 and 10, to illustrate the coil arrangement used, and

Fig. 12 is a perspective view of a fourth embodiment of the invention intended for use with the optical disc of Fig. 5.

The electro-optical device shown in Figs. 1 and 2 is a modification of the device described in the aforementioned European Patent Application 0 077 581. The device serves for reading an

information disc 1 comprising a transparent substrate 2 whose upper surface is provided with an information pattern which is covered with a reflective layer 3. The disc may be, for example, an optical audio disc or video disc. The device comprises a frame 4 comprising a tube 4A and a unit 4B arranged on this tube. This unit supports a movable lens system 5 which constitutes the movable part of an objective. It comprises a lens 6, see Fig. 2, and some further lenses, not shown. The device also comprises two stationary lenses 7 and 8 and two beam-splitting prisms 9A and 9B. A semiconductor laser 10 emits a light beam 11 which is focused by the lens system to form a light spot 12 on the information surface of the disc 1. The light beam which has been reflected by the reflecting layer 3 and modulated by the information is reflected as a beam 13 towards a semiconductor diode system 14 by a reflecting surface between the beam-splitting prisms 9A and 9B.

The lens system 5 is movably connected to the frame 4A, B by flexible elongate supporting means which comprise leaf springs 15 and 16. For the controlled movement of the lens system there is provided an electromagnetic actuator 17 comprising first actuator means in the form of a coil 17A on the frame and second actuator means in the form of an annular magnet 17B on the lens system. These means cooperate electromagnetically with each other via an air gap 18. With the aid of the electromagnetic actuator the resiliently suspended optical lens system 5 can perform controlled movements along the optical axis 19 for focusing the light spot 12 on the information surface of the disc 1.

The leaf springs 15 and 16 are pretensioned, i.e., prestressed in tension, in their longitudinal directions by means of a magnetic pretensioning device comprising first pretensioning means in the form of an annular magnet 20 arranged on the frame and second pretensioning means in the form of the afore-mentioned annular magnet 17B arranged on the lens system. The two pretensioning means cooperate magnetically with each other via the air gap 18. The annular magnet 17B is magnetized axially in such a manner that on the upper and lower sides regions of south polarity S are formed and in the central portion a region of north polarity N is formed. The annular magnet 20 is magnetized in the longitudinal direction of the leaf springs 15 and 16. As is indicated by the letters N and S in Fig. 2, one side of the annular magnet 20 has a region of north polarity and the opposite side a region of south polarity. As a result of this, the side of north polarity exerts a repelling force on the annular magnet 17B and the side of the south polarity exerts an attracting force, which two forces provide the pretension in the leaf springs.

The annular magnet 20 is magnetized locally but the entire ring is made of magnetizable material, so that the entire ring magnetically cooperates with the annular magnet 17B. This influences the force to be exerted on the lens

system 5 for the purpose of focusing. This will be explained by means of Fig. 3. This Figure shows an XOF system of axes and three curves 21, 22 and 23. The curve 21 is a graph representing the relationship between a displacement X and the axial force F required for this displacement for deflecting the leaf springs 15 and 16. For small displacements the force 21 may be regarded as a straight line. The curve 23 graphically represents the relationship between the displacement X and the axial forces exerted on the movable system 5 by the magnetic cooperation of the annular magnet 20 with the annular magnet 17. The resulting electro magnetic force to which the movable lens system subjected by the actuator is represented by the resultant curve 22 obtained by the addition of the curves 21 and 22. This curve is substantially flatter than the curve 21, so that the axial forces required for focusing are smaller than in the absence of the annular magnet 20.

The device shown in Fig. 4 may serve as an alternative to the upper part of the device shown in Figs. 1 and 2. It comprises a unit 21 which can be arranged on the tube 4A. The device further comprises a movable lens system 22 with a lens 23, elongate flexible supporting means 24 and 25 and an electromagnetic actuator 26 comprising first actuator means 26A in the form of a focusing coil 26A1 and two tracking coils 26A2. There are also provided second actuator means in the form of two annular magnets 26B arranged on the lens system 21. The magnetic pretensioning device comprises first pretensioning means 27 comprising a plate 27A and two soft-iron strips 27B. The second pretensioning means, arranged on the lens system, comprise the annular magnets 26B.

The unit 21, which is made of a suitable nonmagnetizable material, such as aluminium or a plastics, comprises four upwardly extending limbs 28. The two tracking coils 26A2 are each mounted between two of these limbs, for example by means of a suitable adhesive. The coil 26A1 is mounted around the limbs 28 and is connected thereto by means of an adhesive also. The pretensioning device 27 is also secured by means of an adhesive.

The supporting means for the lens system comprise two pairs of wires, 24 and 25 which extend at least approximately perpendicularly of the optical axis 29 of the movable lens system 22. The first pair 24 extends near a first end of the lens system and the second pair 25 near the other or second end of this system. The two wires of each pair 24 or 25 make an angle α with each other. The first pair of wires 24 meet at a first point of attachment 30 and the second pair of wires 25 meet at a second point of attachment 31. These points of attachment are spaced from each other and are situated on a pivotal axis 32 of the lens system, which axis extends parallel to the optical axis 29 of the lens system 22. The unit 21 has a slot 34 in a wall portion 33. The slot extends parallel to the optical axis 29. The wires 24 and 25 extend through the slot and are secured to the wall portion 33 at the location of the points of attachment 30 and 31 by means of an adhesive.

The permanent magnets 26B are magnetized axially in such a manner that they face each other with like poles. Owing to the presence of the tracking coil 26A2 the objective is not only movable along the optical axis 29 but it can also perform electrically controlled pivotal movements about the pivotal axis 32. This is distinct from the device shown in Figs. 1 and 2, in which the lens system 5 is only capable of performing movements along the optical axis 19. This enables the device shown in Fig. 4 to be mounted in a swinging arm or in a slide which can be translated radially of the axis of rotation of an optical disc and which roughly follows the track to be scanned. Small deviations in the radial position of the track can be followed by correction movements of the lens system 22 about the pivotal axis 32.

The oblique arrangement of the wires 24 and 25 respectively relative to each other has an important additional advantage in comparison with wires which, in the same way as the leaf springs 15 and 16 in Figs. 1—2, extend parallel to each other in pairs. When the lens system 5 in Figs. 1—2 is tilted about the axis 84 which intersects the optical axis 19 at right angles thereto and which extends parallel to the leaf springs 15 and 16, the springs 15 and 16 are subjected to a bending load. When the lens system 22 shown in Fig. 4 is tilted about the corresponding axis 85, however, two of the four wires (one upper wire and one lower wire which does not extend parallel to this upper wire) are always subjected to tensile forces. This is because the vector of the movement of the point where the relevant wire is connected to the lens system does not extend perpendicularly to the wire. The other two wires would have to be subjected to a compressive force which is equal but opposite to the said tensile force. Since the wires are pretensioned the tensile force produced in two wires by the pretensioning means increases and that produced in the other two wires decreases. Since wires with a low resistance to bending cannot take up any compressive force the lens system can be tilted about the axis 85 when a tilting moment is exerted of such a magnitude that the tensile force in two of the wires has decreased to zero. The magnitude of this critical moment required depends on the magnitude of the pretensioning forces applied to the wires and the magnitude of the angle α . If the wires are parallel the required critical tilting moment is in principle zero, so that there is no resistance to tilting at all.

It will be evident from the foregoing that the device shown in Figs. 1—2 can be improved if the leaf springs 14 and 15 are not arranged in parallel but, for example, as is indicated in broken lines in Fig. 2 for two alternative springs 15'. At their ends which are remote from the lens system 5 these springs may be arranged so that they do not converge, as shown, but that they diverge.

The improvement in the resistance to tilting as explained in the foregoing can also be obtained in devices which, in contradistinction to the device in accordance with the invention, do not comprise pretensioning means. For example, the improve-

ment obtained in the device shown in Figs. 1—2 is maintained if the annular magnet 20 is dispensed with. Instead of leaf springs it is possible to use springs of a different, for example circular, cross-section. The resistance to tension and compression, however, is always higher than the resistance to bending, because of the comparatively large length of the supporting means in comparison with their thickness.

Figs. 5 to 8 show an important embodiment of the invention. This electro-optical device resembles the device shown in Fig. 4 with respect to the supporting arrangement for the lens system. However, in principle it is suitable both for radial tracking and for carrying out the required correction movements in a radial direction. It comprises a lens system 35 with an optical axis 36, and the supporting means for the lens system again comprise wires 37 and 38 arranged in pairs and extending transversely of the optical axis, the first pair 37 extending near a first end and the second pair 38 near a second end of the lens system 35. The wires of each pair make an angle β with each other. The first pair of wires 37 meet at a first point of attachment 39 on a column 40 of a frame 41. The second pair of wires 38 meet at a second point of attachment 42 on the column 40. These two points of attachment are spaced from each other on the pivotal axis 43 of the lens system, which axis extends parallel to the optical axis 36 of the lens system 35. It is not strictly necessary that the angles between the wires of the one pair and between the wires of the other pair are both β . Sometimes it may be advantageous or necessary to give these angles different values. In the present embodiment the lens system, in addition to the lens 44 and possible further lenses, also comprises a radiation source and all the other optical and opto-electronic parts necessary for concentrating and focusing a radiation beam 45 so as to form a radiation spot 46 and for receiving the reflected radiation modulated by the information on an optical disc 47 and converting this information into an electrical modulation. The lens system 35 may comprise for example the parts present in the device shown in Figs. 1—2. The lens system 35 may therefore be regarded as a moving integrated electro-optical scanning unit. It is pivotable about the pivotal axis 43 along an arc 48 whose chord 49, see Fig. 5, has a length which is at least equal to the radial dimension of the annular information area 50 of the information disc 47 to be read. The lens system thus is capable of moving along the entire path necessary for reading the information. The suspension by means of the wires 37, 38 is the only supporting arrangement which is required. This arrangement is capable of producing both the focusing movements along the optical axis 36 and the pivotal movements about the pivotal axis 43 for following the track on the disc.

The actuator means 51 comprise first actuator means 51A which are arranged on the frame 41 and extend along an arc whose centre of curvature is situated on the pivotal axis 43. Second

actuator means 51B cooperate with the first actuator means *via* an air gap 53 which is at least substantially constant regardless of the pivotal position of the lens system 35.

The first actuator means 51A comprise four arcuate soft-iron strips 51A1 to 51A4 and two soft-iron side plates 51A5 which extend radially with respect to the pivotal axis 43. The first actuator means further comprise two arcuate permanent magnets 51A6 and 51A7 which are magnetized radially with respect to the pivotal axis 43. The second actuator means 51B comprise two cross-wise arranged coils 51B1 and 51B2 on the lens system 35. The direction of magnetization of the magnets 51A6 and 51A7 is indicated in Figs. 6 and 7 by the letters N and S, symbolizing north polarity and south polarity respectively. The lens system 35 is driven along the optical axis 36 by energizing the two coils in phase. Pivotal movements about the pivotal axis 39 can be obtained by energizing the coils in phase opposition.

For the attachment of the wires 37 and 38 to the lens system 35 the latter is provided with four mounting studs 54. The wires are secured to these studs by means of a suitable adhesive. The column 40 of the frame is formed with slots on both ends, in which slots the wires are fixed also by means of an adhesive.

The magnetic pretensioning device comprises first pretensioning means in the form of the iron strip 51A2 on the frame, which strip forms part of the first actuator means, and second pretensioning means in the form of a permanent-magnetic plate 55 on the lens system 35. These means cooperate magnetically with each other *via* the air gap formed between them. Thus, the wires 37 and 39 are pretensioned in a longitudinal direction in a manner which requires no contact with the wires.

The embodiment of the invention shown in Figs. 9 and 10 is a modification of an electro-optical device described in United States Patent Specification 4,021,101 (herewith incorporated by reference). The frame comprises a base plate 56 which is provided with a cylindrical sleeve 57. The movable optical system comprises a lens system 58, which comprises only one optical element 59. This element is an aspherical lens which serves for focusing a light beam 60 to form a light spot 61 for scanning the information contained in an information surface 62 of an optical disc 63. The lens has an optical axis 61.

The lens system further comprises a mounting 64 for the lens 59. By means of four flexible wires 65 the system is movably supported on a support 66.

An electromagnetic actuator 67 comprises first actuator means 67A1 and 67A2 in the form of two permanent-magnetic rings which are axially magnetized in opposite directions, and second actuator means in the form of two pairs of coils 67B1 and 67B2 which cooperate with the rings *via* an annular air gap. The wires 65 are pretensioned by first and second pretensioning means which cooperate *via* an air gap and which comprise the annular magnet 67A1 and a ferromagnetic ring 68

arranged in a cap 69 and the annular magnet 67A1. With the aid of the actuator means the optical system 58 is movable along translation XX and ZZ, see Fig. 11. For focusing the light spot 61 on the information surface 62 the entire lens system is also bodily movable along the optical axis 70 along the axis YY in Fig. 11. For this purpose the support 66 is arranged in a cylindrical sleeve 71, which is axially slidable in the sleeve 57. The upper end of the sleeve 71 is provided with a flange 72 which carries an annular focusing coil 73. This coil is axially movable in an annular gap of a permanent-magnetic stator comprising an axially magnetized annular magnet 74, end plates 75 and 76 and a central portion 77.

The wires 65 have equal lengths and extend parallel to the optical axis 70. Movements of small amplitude in the XX direction and the ZZ direction may therefore be regarded as translations. By means of the electro-optical device shown in Figs. 9 and 10 the radiation spot 61 can be kept automatically in focus on the information surface 62, and by means of the lens system 58 it is also possible to perform the rapid correction movements in the XX and ZZ directions necessary for correcting the position relative to the track and for correcting timing errors in the track.

In addition to the permanent-magnetic pretensioning means 67A1 and 68 there are provided electromagnetic pretensioning means. These means comprise an annular pretensioning coil 82 and the two actuator magnets 67A1 and 67A2. The pretensioning coil 82 enables the wires 65 to be subjected to tensile forces whose magnitude depends on the applied current. The pretensioning coil is arranged in series with the focusing coil 73 and can be so dimensioned that no or hardly any variations occur in the tensile force in the wires 65 as a result of accelerated or decelerated movements of the lens system along the optical axis. Variations of the pretensioning forces in the wires as a result of varying inertial forces exerted on the wires by the lens system 58 are thus compensated for by opposite corrections of substantially the same magnitude. The result is that the pretension of the supporting means does not vary, or at least to a smaller extent, despite the fact that the lens system performs rapid focusing movements along the optical axis. This is an application of a principle which forms the subject of the Applicants European Patent Application no. 83 20 1437.7 EP-A-186 626 (herewith incorporated by reference), which has not yet been published.

In principle the ferromagnetic ring 68 may be dispensed with, the pretensioning forces in the wires then being generated exclusively by means of the electromagnetic pretensioning means. The pretensioning coil 82 may not then be arranged in series with the focusing coil without special steps. This is because the electric current to be applied to the pretensioning coil should comprise a d.c. component for generating a constant pretension in the wires 65 and a variable component, for generating the correction forces, which variable

component is superimposed on said d.c. component and which is a function of the current in the focusing coil.

In an embodiment of the invention in which the supporting means for the lens system comprise a plurality of wires, for example as in the embodiments shown in Figs. 4 to 11, it is sometimes possible to form all the wires by means of a single continuous length of wire. This may substantially simplify mounting of the wires. In Fig. 4 an attempt has been made to indicate how the wires 24 and 25 can be formed by means of a single length of wire 78 having ends 79 and 80. The wire 78 is arranged on the optical system 22 as indicated by the broken lines. The parts of the length of wire 78 which do not form part of the supporting means 24 and 25 are secured to the optical system 22 by means of a suitable adhesive. It has been found that in this way the wires 24 and 25 can be readily formed by means of a simple tool. The end portions of the wires 24 and the looped portion 81 at the location of the point of attachment 31 of the wires 25 are secured in the slot 34 in the wall portion 33 by means of an adhesive. In the embodiment shown in Figs. 5 to 8 the supporting means are constructed in the same way.

For an optimum flexibility the wires are made of a plurality of separate fibres. Some experience has been gained with the embodiment shown in Fig. 4 using wires manufactured from an aromatic polyamide, available from Du Pont de Nemours under the trade-name "KEVLAR.49". The diameter of the individual fibres is 12 microns and the length of wire 78 comprises ten such fibres. For the embodiments shown in the drawing it is not indicated how the electrical or optical signals can be transmitted between the movable part of the device and the stationary parts. Sometimes, as in the embodiment shown in Figs. 5 to 8, it is also necessary to apply electric power to the moving part of the device. The moving part of the device may be connected to the stationary parts in a conventional manner by means of moving wires or by means of a flexible foil with a pattern of electrical conductors. In the embodiment shown in Figs. 1 and 2, in which the supporting means comprise metal leaf springs 15 and 16, the coil 17B can be driven by signals applied via the springs. If the supporting means comprise wires with a plurality of fibres it is possible to employ fibres of a first type and a second type, the first type being made of a material suitable for transmitting information signals and the second type being made of a material which is less elastic than the first material. The first material may be, for example, a metal, for transmitting electric signals or an electric current, or an optical material for transmitting optical signals. The high elasticity of these materials has no function in supporting the optical system, because the supporting function is provided by the fibres of the second material.

Preferably, in embodiments of the invention in which the supporting means comprise wires, the wires are made of a material with a modulus of

elasticity higher than that of steel. Preferably, this material is, a hydrocarbon polymer such as the afore-mentioned "KEVLAR.49". Such materials exhibit practically no elasticity, so that a very reliable supporting arrangement for the optical system is obtained, which combines an extremely low mass of the supporting means with a very high flexibility thereof in the relevant direction of movement or the relevant directions of movement of the optical system.

The apparatus shown in Fig. 12 may be regarded as a modification to the embodiment shown in Figs. 5 to 8. The apparatus comprises a lens system 90 which comprises a lens 92 and further lenses, if required, a radiation source, not shown, and opto-electronic parts. This lens system 90 has an optical axis 94. The apparatus further comprises elongate supporting means comprising two leaf springs 96 and 98 which extend transversely of the optical axis 94. The leaf springs 96 and 98 each have a recess, 100 and 102 respectively, to form two strips 104 and 106, respectively, and they are made of a resilient material such as spring steel or a material comprising carbon fibres. One leaf spring 96 is secured to the upper end of the lens system 90 and the other leaf spring is secured to the lower end of the lens system 90. The two leaf springs 96 and 98 are secured to a rod 114 which forms part of a frame 102, shown schematically, by means of ball pivots 108 and 110.

The supporting means using the leaf springs 96 and 98 allows focussing movements of the lens system 90 along the optical axis 94 and tracking movements of the lens system 90 about a pivotal axis 116 which extends through the pivots 108 and 110.

The actuator means comprise first actuator means 118A which are mounted on the frame 102 and which have the shape of an arc whose centre of curvature is situated on the pivotal axis 116. The second actuator means 118B cooperate with the first actuator means *via* air gaps 120A and 120B. The first actuator means comprise an axially magnetized magnet 118A1 with two soft-iron side plates 118A2 and 118A3, and a radially magnetized magnet 118A4 with an iron member 118A5 and a closing plate 118A6. The direction of magnetization of the magnets 118A1 and 118A4 is indicated by the letters N and S symbolizing north and south polarity, respectively. The second actuator means 118B comprise a focussing coil 119B1 and a tracking coil 118B2.

The magnetic pretensioning device comprises first pretensioning means in the form of the focussing magnet 118A1 with the side plates 118A2 and 118A3 belonging to the first actuating means, and second pretensioning means in the form of a soft-iron plate 122 on the lens system 90. They cooperate magnetically with each other *via* said air gaps 120A, thereby axially pretensioning the leaf springs 96 and 98 in a contactless manner.

Within the scope of the invention as defined by the Claims various other embodiments are poss-

ible. The movable optical system need not comprise a lens system but may comprise, for example, a mirror or other optical elements. The pretensioning means need not comprise actuator means but may comprise exclusively means having no other function than pretensioning the supporting means.

Claims for the Contracting States: DE GB

1. An electro-optical device for scanning an information disc without mechanical contact, which device comprises:

- a movable optical system (22; 35; 58) comprising at least one optical element,
- elongate supporting means (24, 25; 37, 38; 65) which movably support the optical system, and which comprise at least one wire (24, 25; 37, 38; 65) having a low resistance to bending,
- an electromagnetic actuator (26; 51; 67) comprising first actuator means and second actuator means which cooperate electromagnetically with each other *via* an air gap for moving the optical system in a controlled manner,
- a magnetic pretensioning device comprising first pretensioning means (27; 51A6; 68, 82) and second pretensioning means (26B; 55; 67B1; B2), which first and second pretensioning means cooperate magnetically with one another *via* an air gap and pretension said supporting means in their longitudinal direction.

2. An electro-optical device as claimed in Claim 1, said optical system comprising a lens system, with an optical axis (29; 36), wherein,

- the supporting means comprise two pairs of wires which extend at least substantially perpendicularly of the optical axis (29; 36), a first pair (24; 27) extending near a first end of the lens system and a second pair (25; 38) near a second end of the lens system, and
- the wires of each pair are disposed at an angle (α ; α') to one another.

3. An electro-optical device as claimed in Claim 2,

- the first pair of wires meet at a first point of attachment (30; 39) the second pair of wires meet at a second point of attachment (31; 40), and
- the first and second points of attachment are spaced from each other and are situated on a pivotal axis (32; 40) of the lens system, which axis extends parallel to the optical axis of the lens system.

4. An electro-optical device as claimed in Claim 3, wherein

- the lens system is pivotable about the pivotal axis (40) along an arc whose chord has a length which is at least equal to the radial dimension of the annular information area of the information disc to be read, and
- the first actuator means extend along an arc whose centre of curvature is situated on the pivotal axis, and co-operate with the second actuator means *via* an airgap which is at least substantially constant regardless of the pivotal position of the lens system.



5. An electro-optical device as claimed in Claim 1, wherein the optical system comprises a lens system with an optical axis (70), and the supporting means comprise at least three wires (65) of equal length, which extend parallel to and are spaced from the optical axis.

6. An electro-optical device as claimed in Claim 1, comprising a plurality of wires which form part of the supporting means but which all form sections of a single uninterrupted length of wire (78).

7. An electro-optical device as claimed in Claim 1, wherein the wire comprises a plurality of separate fibres.

8. An electro-optical device as claimed in 7, wherein the wire comprises at least fibres of a first type and a second type, the first type of fibres being made of a material which is suitable for the transmission of information signals and the second type of fibres being made of material which has a higher modulus of elasticity than the first material.

9. An electro-optical device as claimed in Claim 1, wherein the wire comprises a material with a modulus of elasticity higher than that of steel.

10. An electro-optical device as claimed in Claim 9, wherein said material is a hydrocarbon polymer.

11. An electro-optical device for scanning an information disc without mechanical contact, which device comprises:

- a movable optical system (90) comprising a lens system with an optical axis (94),

- elongate supporting means which movably support the optical system, and which comprises two leaf springs (96; 98) which extend at least substantially perpendicular of the optical axis, a first spring extending near a first end of the lens system and a second spring near a second end of the lens system, which leaf springs have points of attachment which are spaced from each other and are situated on a pivotal axis (116) of the lens system, which axis extends parallel to the optical axis of the lens system,

- an electromagnetic actuator (118) comprising first actuator means and second actuator means which cooperate electromagnetically with each other *via* an air gap for moving the optical system in a controlled manner, and

- a magnetic pretensioning device comprising first pretensioning means (118A1) and second pretensioning means (122), which first and second pretensioning means cooperate magnetically with one another *via* an air gap and pretension said supporting means in their longitudinal direction.

12. An electro-optical device as claimed in Claim 11 wherein the leaf springs each have a recess (100, 102) to form two strips (104, 106) which extend at least substantially perpendicularly of the optical axis.

13. An electro-optical device as claimed in Claim 11 or 12, wherein the material of the leaf comprises carbon fibres.

Claims for the Contracting States: CH FR IT LI SE

1. An electro-optical device for scanning an information disc without mechanical contact, which device comprises:

- a movable optical system (5; 22; 35; 58; 90) comprising at least one optical element,

- elongate supporting means (15, 16; 24, 25; 37, 38; 65, 96, 98) which movably support the optical system, and

- an electromagnetic actuator (17; 26; 51; 67; 118) comprising first actuator means and second actuator means which cooperate electromagnetically with each other *via* an air gap for moving the optical system in a controlled manner, characterized in that there is provided a magnetic pretensioning device comprising first pretensioning means (20; 27; 51A6; 68, 82; 118A1) and second pretensioning means (17B; 26B; 55; 67B1; B2; 122), which first and second pretensioning means cooperate magnetically with one another *via* an air gap and pretension said supporting means in their longitudinal direction.

2. An electro-optical device as claimed in Claim 1, characterized in that the magnetic pretensioning device comprises permanent-magnetic means.

3. An electro-optical device as claimed in Claim 1, characterized in that at least a part of the pretensioning means also forms part of the actuator means.

4. An electro-optical device as claimed in Claim 1, characterized in that said supporting means comprise at least one wire (24, 25; 37, 38; 65) having a low resistance to bending.

5. An electro-optical device as claimed in Claim 4, said optical system comprising a lens system, with an optical axis (29; 36), characterized in that

- the supporting means comprise two pairs of wires which extend at least substantially perpendicularly of the optical axis (29; 36), a first pair (24; 27) extending near a first end of the lens system and a second pair (25; 38) near a second end of the lens system, and

- the wires of each pair are disposed at an angle (α ; α') to one another.

6. An electro-optical device as claimed in Claim 5, characterized in that

- the first pair of wires meet at a first point of attachment (30; 39)

- the second pair of wires meet at a second point of attachment (31; 40), and

- the first and second points of attachment are spaced from each other and are situated on a pivotal axis (32; 40) of the lens system, which axis extends parallel to the optical axis of the lens system.

7. An electro-optical device as claimed in Claim 1, 2, or 3 said optical system comprising a lens system with an optical axis (94) characterized in that

- the supporting means comprises two leaf springs (96; 98) which extend at least substantially perpendicular of the optical axis (94), a first spring extending near a first end of the lens



system and a second spring near a second end of the lens system.

8. An electro-optical device as claimed in Claim 7, characterized in that the leaf springs have points of attachment which are spaced from each other and are situated on a pivotal axis (116) of the lens system, which axis extends parallel to the optical axis of the lens system.

9. An electro-optical device as claimed in Claim 7 or 8 characterized in that the leaf springs each have a recess (100, 102) to form two strips (104, 106) which extend at least substantially perpendicularly of the optical axis.

10. An electro-optical device as claimed in Claim 6 or 8 characterized in that

- the lens system is pivotable about the pivotal axis along an arc whose chord has a length which is at least equal to the radial dimension of the annular information area of the information disc to be read, and

- the first actuator means extend along an arc whose centre of curvature is situated on the pivotal axis, and co-operate with the second actuator means via an airgap which is at least substantially constant regardless of the pivotal position of the lens system.

11. An electro-optical device as claimed in Claim 4, said optical system comprising a lens system with an optical axis (70), characterized in that the supporting means comprise at least three wires (65) of equal length, which wires extend parallel to and are spaced from the optical axis.

12. An electro-optical device as claimed in Claim 4, characterized in that there is provided a plurality of wires which form part of the supporting means but which all form sections of a single uninterrupted length of wire (78).

13. An electro-optical device as claimed in Claim 4, characterized in that the wire comprises a plurality of separate fibres.

14. An electro-optical device as claimed in Claim 13, characterized in that the wire comprises at least fibres of a first type and a second type, the first type of fibres being made of a material which is suitable for the transmission of information signals and the second type of fibres being made of material which has a higher modulus of elasticity than the first material.

15. An electro-optical device as claimed in Claim 4, characterized in that the wire comprises a material with a modulus of elasticity higher than that of steel.

16. An electro-optical device as claimed in Claim 15, characterized in that said material is a hydrocarbon polymer.

17. An electro-optical device as claimed in Claim 7, 8 or 9 characterized in that the material of the leaf springs comprises carbon fibres.

Patentansprüche für Vertragsstaaten: DE GB

1. Elektrooptische Anordnung zum Abtasten einer Informationsscheibe ohne mechanischen Kontakt, wobei diese Anordnung die folgenden Elemente aufweist:

- ein bewegliches optisches System (22; 35; 58) mit wenigstens einem optischen Element, - längliche Lagermittel (24; 25; 37, 38; 65), die das optische System beweglich unterstützen und wenigstens einen geschmeidigen Draht (24, 25; 37, 38; 65) aufweisen,

- ein elektromagnetisches Betätigungselement (26; 51; 67) mit ersten Betätigungsmitteln und zweiten Betätigungsmitteln, die über einen Luftspalt zum auf kontrollierte Art und Weise Bewegen des optischen Systems elektromagnetisch miteinander zusammenarbeiten,

- eine magnetische Vorspannanordnung mit ersten Vorspannmitteln (27; 51A6; 68. 82) und zweiten Vorspannmitteln (26B; 55; 67B1; B2), wobei diese ersten und zweiten Vorspannmittel über einen Luftspalt magnetisch miteinander zusammenarbeiten und die Lagermittel in der Längsrichtung vorspannen.

2. Elektrooptische Anordnung nach Anspruch 1, wobei das optische System ein Linsensystem aufweist mit einer optischen Achse (29; 36), dadurch gekennzeichnet, dass

- die Lagermittel zwei Drahtpaare aufweisen, die sich wenigstens im wesentlichen senkrecht zu der optischen Achse (29; 36) erstrecken, wobei ein erstes Paar (24; 27) sich in der Nähe eines ersten Endes des Linsensystems erstreckt und ein zweites Paar (25; 38) in der Nähe eines zweiten Endes des Linsensystems und

- die Drähte jedes Paares einen Winkel von (α ; α') miteinander einschließen.

3. Elektrooptische Anordnung nach Anspruch 2, dadurch gekennzeichnet, dass

- die Drähte des ersten Drahtpaares an einem ersten Befestigungspunkt (30; 39) zusammentreffen

- die Drähte des zweiten Drahtpaares an einem zweiten Befestigungspunkt (31; 40) zusammentreffen und

- der erste und zweite Befestigungspunkt in einem Abstand voneinander auf einer Schwenkachse (32; 40) des Linsensystems liegen, wobei diese Achse sich parallel zu der optischen Achse des Linsensystems erstreckt.

4. Elektrooptische Anordnung nach Anspruch 3, dadurch gekennzeichnet, dass

- das Linsensystem um die Schwenkachse (40) über einen Bogen schwenkbar ist, dessen Sehne eine Länge hat, die der radialen Abmessung des ringförmigen Informationsbereiches der auszulesenden Informationsscheibe wenigstens entspricht und

- die ersten Betätigungsmittel sich in einem Bogen erstrecken, dessen Krümmungsmitte auf der Schwenkachse liegt, und über einen Luftspalt, der wenigstens im wesentlichen konstant ist, ungeachtet der Schwenklage des Linsensystems, mit den zweiten Betätigungsmitteln zusammenarbeiten.

5. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass das optische System ein Linsensystem aufweist mit einer optischen Achse (70) und die Lagermittel wenigstens drei Drähte (65) gleicher Länge aufweisen, die



sich Parallel zu und in einem Abstand von der optischen Achse erstrecken.

6. Elektrooptische Anordnung nach Anspruch 1 einer Anzahl Drähte, die einen Teil der Lagermittel bilden, die aber alle einen Teil eines einzigen ununterbrochenen Drahtabschnittes (78) bilden.

7. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass der Draht eine Anzahl einzelner Fasern aufweist.

8. Elektrooptische Anordnung nach Anspruch 7, dadurch gekennzeichnet, dass der Draht wenigstens Fasern einer ersten Art und einer zweiten Art aufweist, wobei die Fasern der ersten Art aus einem Werkstoff hergestellt sind, der sich zur Übertragung von Informationssignalen eignet und die Fasern der zweiten Art aus einem Werkstoff hergestellt sind, der einen höheren Elastizitätsmodul aufweist als der erste Werkstoff.

9. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass der Draht einen Werkstoff aufweist mit, einem Elastizitätsmodul, der höher ist als der von Stahl.

10. Elektrooptische Anordnung nach Anspruch 9, dadurch gekennzeichnet, dass der genannte Werkstoff ein Kohlenwasserstoffpolymer ist.

11. Elektrooptische Anordnung zum Abtasten einer Informationsscheibe ohne mechanischen Kontakt, wobei diese Anordnung die folgenden Elemente aufweist:

- ein bewegliches optisches System (90) mit einem Linsensystem mit einer optischen Achse (94),
- längliche Lagermittel, die das optische System beweglich unterstützen und zwei Blattfedern (96; 98) aufweisen, die sich wenigstens im wesentlichen senkrecht zu der optischen Achse erstrecken, wobei eine erste Feder sich in der Nähe eines ersten Endes des Linsensystems erstreckt und eine zweite Feder sich in der Nähe eines zweiten Endes des Linsensystems erstreckt, wobei die Blattfedern in einem Abstand voneinander und auf einer Schwenkachse (116) des Linsensystems liegende Befestigungspunkte haben, wobei diese Achse sich Parallel zu der optischen Achse des Linsensystems erstreckt,

- ein elektromagnetisches Betätigungselement (118) mit ersten Betätigungsmitteln und zweiten Betätigungsmitteln, die über einen Luftspalt zum auf kontrollierte Art und Weise Bewegen des optischen Systems miteinander zusammenarbeiten und

- eine magnetische Vorspannvorrichtung mit ersten Vorspannmitteln (118A1) und zweiten Vorspannmitteln (122), die über einen Luftspalt magnetisch miteinander zusammenarbeiten und die Lagermittel in der Längsrichtung vorspannen.

12. Elektrooptische Anordnung nach Anspruch 11, dadurch gekennzeichnet, dass die Blattfedern je eine Ausnehmung (100, 102) zum Bilden zweier Streifen (104, 106) aufweisen, die sich wenigstens im wesentlichen senkrecht zu der optischen Achse erstrecken.

13. Elektrooptische Anordnung nach Anspruch 11 oder 12, dadurch gekennzeichnet, dass das Material der Blattfeder Kohlenstofffasern aufweist.

Patentansprüche für die Vertragsstaaten: CH FR IT LI SE

1. Elektrooptische Anordnung zum Abtasten einer Informationsscheibe ohne mechanischen Kontakt, wobei diese Anordnung die folgenden Elemente aufweist:

- ein bewegliches optisches System (5; 22; 35; 58; 90) mit wenigstens einem optischen Element,
- längliche Lagermittel (15, 16; 24; 25; 37, 38; 65, 96, 98), die das optische System beweglich unterstützen und

- ein elektromagnetisches Betätigungselement (17; 26; 51; 67; 118) mit ersten Betätigungsmitteln und zweiten Betätigungsmitteln, die über einen Luftspalt zum auf kontrollierte Art und Weise Bewegen des optischen Systems elektromagnetisch miteinander zusammenarbeiten. dadurch gekennzeichnet, dass eine magnetische Vorspannanordnung mit ersten Vorspannmitteln (20; 27; 51A6; 68, 82; 118A1) und zweiten Vorspannmitteln (17B; 26B; 55; 67B1; 82; 122) vorgesehen ist, wobei diese ersten und zweiten Vorspannmittel über einen Luftspalt magnetisch miteinander zusammenarbeiten und die Lagermittel in der Längsrichtung vorspannen.

2. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass die magnetische Vorspannanordnung Dauermagnetmittel aufweist.

3. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass wenigstens ein Teil der Vorspannmittel ebenfalls einen Teil der Betätigungsmittel bildet.

4. Elektrooptische Anordnung nach Anspruch 1, dadurch gekennzeichnet, dass die Lagermittel wenigstens einen Draht (24, 25; 37, 38; 65) mit einem geringen Biegezustand aufweisen.

5. Elektrooptische Anordnung nach Anspruch 4, wobei das optische System ein Linsensystem aufweist mit einer optischen Achse (29; 36), dadurch gekennzeichnet, dass

- die Lagermittel zwei Drahtpaare aufweisen, die sich wenigstens im wesentlichen senkrecht zu der optischen Achse (29; 36) erstrecken, wobei ein erstes Paar (24; 27) sich in der Nähe eines ersten Endes des Linsensystems und ein zweites Paar (25; 38) in der Nähe eines zweiten Endes des Linsensystems erstreckt und

- die Drähte jedes Paares einen Winkel von (α ; α') miteinander einschliessen.

6. Elektrooptische Anordnung nach Anspruch 5, dadurch gekennzeichnet, dass

- die Drähte des ersten Drahtpaares an einem ersten Befestigungspunkt (30; 39) zusammentreffen

- die Drähte des zweiten Drahtpaares an einem zweiten Befestigungspunkt (31; 40) zusammentreffen und

- der erste und zweite Befestigungspunkt in einem Abstand voneinander auf einer Schwenkachse (32; 40) des Linsensystems liegen, wobei diese Achse sich parallel zu der optischen Achse des Linsensystems erstreckt.

7. Elektrooptische Anordnung nach Anspruch 1,



2 oder 3, wobei das optische System ein Linsensystem mit einer optischen Achse (94) aufweist, dadurch gekennzeichnet, dass die Lagermittel zwei Blattfedern (96; 98) aufweisen, die sich wenigstens im wesentlichen senkrecht zu der optischen Achse (94) erstrecken, wobei eine erste Feder sich in der Nähe eines ersten Endes des Linsensystems erstreckt und eine zweite Feder sich in der Nähe eines zweiten Endes des Linsensystems erstreckt.

8. Elektrooptische Anordnung nach Anspruch 7, dadurch gekennzeichnet, dass die Blattfedern Befestigungspunkte haben, die in einem Abstand voneinander liegen und auf einer Schwenkachse (116) des Linsensystems liegen, wobei diese Achse sich parallel zu der optischen Achse des Linsensystems erstreckt.

9. Elektrooptische Anordnung nach Anspruch 7 oder 8, dadurch gekennzeichnet, dass die Blattfedern je eine Ausnehmung (100, 102) aufweisen zum Bilden zweier Streifen (104, 106), die sich wenigstens im wesentlichen senkrecht zu der optischen Achse erstrecken.

10. Elektrooptische Anordnung nach Anspruch 6 oder 8, dadurch gekennzeichnet, dass

- das Linsensystem um die Schwenkachse über einen Bogen schwenkbar ist, dessen Sehne eine Länge hat, die der radialen Abmessung des ringförmigen Informationsbereiches der auszulesenden Informationsscheibe wenigstens entspricht und

- die ersten Betätigungsmittel sich in einem Bogen erstrecken, dessen Krümmungsmitte auf der Schwenkachse liegt, und über einen Luftspalt, der wenigstens im wesentlichen konstant ist, ungeachtet der Schwenklage des Linsensystems, mit den zweiten Betätigungsmitteln zusammenarbeiten.

11. Elektrooptische Anordnung nach Anspruch 4, wobei das optische System ein Linsensystem aufweist mit einer optischen Achse (70), dadurch gekennzeichnet, dass die Lagermittel wenigstens drei Drähte (65) gleicher Länge aufweisen, die sich parallel zu und in einem Abstand von der optischen Achse erstrecken.

12. Elektrooptische Anordnung nach Anspruch 4, dadurch gekennzeichnet, dass eine Anzahl Drähte vorgesehen sind, die einen Teil der Lagermittel bilden, die aber alle einen Teil eines einzigen ununterbrochenen Drahtabschnittes (78) bilden.

13. Elektrooptische Anordnung nach Anspruch 4, dadurch gekennzeichnet, dass der Draht eine Anzahl einzelner Fasern aufweist.

14. Elektrooptische Anordnung nach Anspruch 13, dadurch gekennzeichnet, dass der Draht wenigstens Fasern einer ersten Art und einer zweiten Art aufweist, wobei die Fasern der ersten Art aus einem Werkstoff hergestellt sind, der sich zur Übertragung von Informationssignalen eignet und die Fasern der zweiten Art aus einem Werkstoff hergestellt sind, der einen höheren Elastizitätsmodul aufweist als der erste Werkstoff.

15. Elektrooptische Anordnung nach Anspruch 4, dadurch gekennzeichnet, dass der Draht einen

Werkstoff aufweist mit einem Elastizitätsmodul, der höher ist als der von Stahl.

16. Elektrooptische Anordnung nach Anspruch 15, dadurch gekennzeichnet, dass der genannte Werkstoff ein Kohlenwasserstoffpolymer ist.

17. Elektrooptische Anordnung nach Anspruch 7, 8 oder 9, dadurch gekennzeichnet, dass der Werkstoff der Blattfedern Kohlefasern aufweist.

10 Revendications pour les Etats Contractants: DE GB

1. Dispositif électro-optique pour explorer un disque d'information sans contact mécanique, dispositif comportant:

- un système optique mobile (22; 35; 58) muni d'au moins un élément optique,
- des moyens d'appui allongés (24, 25; 37; 38; 65) supportant de façon mobile le système optique et comportant au moins un fil (24, 25; 37, 38; 65) ayant une faible résistance à la flexion,
- un actionneur électromagnétique (26; 51; 67) comportant de premiers et de seconds moyens d'actionnement coopérant par voie électromagnétique à travers un entrefer pour imprimer au système optique des mouvements commandés,
- un dispositif de pré-tension magnétique comportant de premiers moyens de pré-tension (27; 51A6; 68, 82) et de seconds moyens de pré-tension (26B; 55, 67B1; B2) coopérant magnétiquement à travers un entrefer et soumettant lesdits moyens d'appui à une pré-tension dans leur sens longitudinal.

2. Dispositif électro-optique selon la revendication 1, ledit système optique comportant un système de lentilles ayant un axe optique (29; 36), dans lequel

- les moyens d'appui comportent deux paires de fils s'étendant au moins sensiblement perpendiculairement à l'axe optique (29; 36), une première paire (24; 27) s'étendant près d'une première extrémité du système de lentilles et une seconde paire (25; 38) près d'une seconde extrémité du système de lentilles et
- les fils de chaque paire font un angle (α , α') l'un avec l'autre.

3. Dispositif électro-optique selon la revendication 2, dans lequel

- les fils de la première paire se rencontrent en un premier point de fixation (30; 39)
- les fils de la seconde paire se rencontrent en un second point de fixation (31; 40) et
- les premier et second points de fixation sont séparés par une distance et sont situés sur un axe de pivotement (32; 40) du système de lentilles, axe qui est parallèle à l'axe optique du système de lentilles.

4. Dispositif électro-optique selon la revendication 3, dans lequel

- le système de lentilles peut pivoter autour de l'axe de pivotement (40) suivant un arc dont la corde a une longueur au moins égale à la dimension radiale de la zone d'information annulaire du disque d'information à lire et
- les premiers moyens d'actionnement s'étendent



suivant un arc dont le centre de courbure est situé sur l'axe de pivotement, et coopèrent avec les ~~se~~ ^{des} moyens d'actionnement à travers un entrefer qui est au moins sensiblement constant, quelle que soit la position de pivotement du système de lentilles.

5. Dispositif électro-optique selon la revendication 1, dans lequel le système optique comporte un système de lentilles ayant un axe optique (70) et les moyens de support comportent au moins trois fils (65) ayant des longueurs égales et s'étendant parallèlement à l'axe optique tout en étant séparés par une distance de celui-ci.

6. Dispositif électro-optique selon la revendication 1, comportant une pluralité de fils faisant partie des moyens d'appui mais formant tous des portions d'un seul bout de fil ininterrompu (78).

7. Dispositif électro-optique selon la revendication 1, dans lequel le fil comporte une pluralité de fibres séparées.

8. Dispositif électro-optique selon la revendication 7, dans lequel le fil comporte au moins des fibres d'un premier type et d'un second type, le premier type de fibre étant en matériau convenant pour la transmission de signaux d'information et le second type de fibre étant en matériau ayant un module d'élasticité plus élevé que le premier matériau.

9. Dispositif électro-optique selon la revendication 1, dans laquelle le fil comporte un matériau ayant un module d'élasticité plus élevé que celui de l'acier.

10. Dispositif électro-optique selon la revendication 9, dans lequel ledit matériau est un hydrocarbure polymérique.

11. Dispositif électro-optique pour explorer un disque d'information sans contact mécanique, dispositif comportant:

- un système optique mobile (90) comportant un système de lentilles ayant un axe optique (94),
- des moyens d'appui allongés supportant de façon mobile le système optique et comportant deux ressorts-lames (96; 98) s'étendant au moins sensiblement perpendiculairement à l'axe optique, un premier ressort s'étendant près d'une première extrémité du système de lentilles et un second ressort près d'une seconde extrémité du système de lentilles, ressorts-lames qui ont des points de fixation séparés par une distance et situés sur un axe de pivotement (116) du système de lentilles, axe qui est parallèle à l'axe optique du système de lentilles,
- un actionneur électro-magnétique (118) comportant de premiers moyens d'actionnement et de seconds moyens d'actionnement coopérant électro-magnétiquement à travers un entrefer pour imprimer au système optique des mouvements commandés et
- un dispositif de pré-tension magnétique comportant de premiers moyens de pré-tension (118A1) et de seconds moyens de pré-tension (122) coopérant magnétiquement à travers un entrefer et soumettant lesdits moyens d'appui à une pré-tension dans leur sens longitudinal.

12. Dispositif électro-optique selon la revendication 11, dans lequel les ressorts-lames présentent chacun un évidement (100, 102) de façon à former deux bandes (104, 106) s'étendant au moins sensiblement perpendiculairement à l'axe optique.

13. Dispositif électro-optique selon la revendication 11 ou 12, dans lequel le matériau des ressorts-lames comporte des fibres de carbone.

Revendications pour les Etats Contractants: CH FR IT LI SE

1. Dispositif électro-optique pour explorer un disque d'information sans contact mécanique, dispositif comportant:

- un système optique mobile (5; 22; 35; 58; 90) muni d'au moins un élément optique,
- des moyens d'appui allongés (15; 16; 24, 25; 37, 38; 65, 96, 98) supportant de façon mobile le système optique et
- un actionneur électromagnétique (17; 26; 51; 67; 118) comportant de premiers et de seconds moyens d'actionnement coopérant par voie électromagnétique à travers un entrefer pour imprimer au système optique des mouvements commandés, caractérisé en ce qu'il est prévu un dispositif de pré-tension magnétique comportant de premiers moyens de pré-tension (20; 27; 51A6; 68, 82; 118A1) et de seconds moyens de pré-tension (17B; 26B; 55; 67B1; B2; 122), coopérant magnétiquement à travers un entrefer et soumettant lesdits moyens d'appui à une pré-tension dans leur sens longitudinal.

2. Dispositif électro-optique selon la revendication 1, caractérisé en ce que le dispositif de pré-tension magnétique comporte des moyens à aimantation permanente.

3. Dispositif électro-optique selon la revendication 1, caractérisé en ce qu'au moins une partie des moyens de pré-tension appartient également aux moyens d'actionnement.

4. Dispositif électro-optique selon la revendication 1, caractérisé en ce que lesdits moyens d'appui comportent au moins un fil (24, 25; 37, 38; 65) ayant une faible résistance à la flexion.

5. Dispositif électro-optique selon la revendication 4, ledit système optique comportant un système de lentilles ayant un axe optique (29; 36) caractérisé en ce que

- les moyens d'appui comportent deux paires de fils s'étendant au moins sensiblement perpendiculairement à l'axe optique (29; 36), une première paire (24; 27) s'étendant près d'une première extrémité du système de lentilles et une seconde paire (25; 38) près d'une seconde extrémité du système de lentilles et
- les fils de chaque paire font un angle (α ; α') l'un avec l'autre.

6. Dispositif électro-optique selon la revendication 5, caractérisé en ce que

- les fils de la première paire se rencontrent en un premier point de fixation (30; 39),
- les fils de la seconde paire se rencontrent en un second point de fixation (31; 40) et
- les premier et second points de fixation sont



séparés par une distance donnée et sont situés sur un axe de pivotement (42; 40) du système de lentilles, axe qui est parallèle à l'axe optique du système de lentilles.

7. Dispositif électro-optique selon la revendication 1, 2 ou 3, ledit système optique comportant un système de lentilles ayant un axe optique (94), caractérisé en ce que

- les moyens d'appui comportent deux ressorts-lames (96; 98) s'étendant au moins sensiblement perpendiculairement à l'axe optique (94), un premier ressort s'étendant près d'une première extrémité du système de lentilles et un second ressort près d'une seconde extrémité du système de lentilles.

8. Dispositif électro-optique selon la revendication 7, caractérisé en ce que les ressorts-lames ont des points de fixation séparés par une distance et situés sur un axe de pivotement (116) du système de lentilles, axe qui est parallèle à l'axe optique du système de lentilles.

9. Dispositif électro-optique selon la revendication 7 ou 8, caractérisé en ce que les ressorts-lames présentent chacun un évidement (100, 102) de façon à former deux bandes (104, 106) s'étendant au moins sensiblement perpendiculairement à l'axe optique.

10. Dispositif électro-optique selon les revendications 6 ou 8, caractérisé en ce que

- le système de lentilles peut pivoter autour de l'axe de pivotement suivant un arc dont la corde a une longueur au moins égale à la dimension radiale de la zone d'information annulaire du disque d'information à lire et les premiers moyens d'actionnement s'étendent suivant un arc dont le centre de courbure est situé sur l'axe de pivotement et coopèrent avec les seconds moyens d'actionnement à travers un entrefer qui

est au moins sensiblement constant, quelle que soit la position de pivotement du système de lentilles.

11. Dispositif électro-optique selon la revendication 4, ledit système optique comportant un système de lentilles ayant un axe optique (70), caractérisé en ce que les moyens d'appui comportent au moins trois fils (65) ayant des longueurs égales, fils qui s'étendent parallèlement à l'axe optique tout en étant séparés par une distance de celui-ci.

12. Dispositif électro-optique selon la revendication 4, caractérisé en ce qu'il est prévu une pluralité de fils faisant partie des moyens d'appui mais formant tous des portions d'un seul bout de fil ininterrompu (78).

13. Dispositif électro-optique selon la revendication 4, caractérisé en ce que le fil comporte une pluralité de fibres séparées.

14. Dispositif électro-optique selon la revendication 13, caractérisé en ce que le fil comporte au moins des fibres d'un premier type et d'un second type, le premier type de fibre étant en matériau convenant pour la transmission de signaux d'information et le second type de fibre étant en matériau ayant un module d'élasticité plus élevé que le premier matériau.

15. Dispositif électro-optique selon la revendication 4, caractérisé en ce que le fil est constitué par un matériau ayant un module d'élasticité plus élevé que celui de l'acier.

16. Dispositif électro-optique selon la revendication 15, caractérisé en ce que ledit matériau est un hydrocarbure polymérique.

17. Dispositif électro-optique selon la revendication 7, 8 ou 9, caractérisé en ce que le matériau des ressorts-lames est constitué par des fibres de carbone.

