## Description

The invention relates to an optical device comprising: a frame; an axially movable objective with an optical axis; a parallel guide for the axial guidance of the objective being connected to said frame; and an electromagnetic actuating device for axially moving said objective, which device comprises first actuating means connected to said objective and second actuating means arranged on said frame, which first and second actuating means co-operate axially with each other in an air gap with a magnetic field which is oriented transversely of the optical axis.

Such optical devices are used in increasing numbers, in particular as focussing devices for focussing a light beam on an optical disk. An optical focussing device for an optical disk player is known from GB—A—2 064 848. The known optical device has an electromagnetic actuating device of which the direct actuating means comprise a coil which is connected to the objective and of which the second actuating means consist of magnetic yokes and a circular magnet, the magnetic yokes and the circular magnet being firmly secured to the frame. The objective is guided by an upper and a lower diaphragm which are secured to said frame.

In the present Application, "frame" is to be understood to mean that part of the device on which the guide arrangement for the axial guidance of the objective is connected. *Via* the air gap the second actuating means which are arranged on that frame exert magnetic forces on the first actuating means.

Since in general the objective has a mass which is not negligible, and in some cases, for example in video-disk players the objective has to move fairly rapidly along its optical axis, the said forces are substantial. As a result of this, the reactive forces exerted on the second actuating means are also substantial. Therefore, the frame may be subject to mechanical vibrations and transmit these to the frame with which the objective is connected. This is undesirable because the frame transmits these vibrations via the guide arrangement to the objective because the guide arrangement is connected with the frame. These vibrations of the objective, which may be amplified in a certain range of frequency cause a lateral movement of the objective, which causes an undesired displacement of the spot of the light beam on the optical disc and may cause great track following deviations. Furthermore other optical devices arranged in the light path and mounted on the frame may be set in vibration, which may give rise to cross-talk between the various optical devices.

The invention aims at providing an optical device of the type mentioned in the opening paragraph in which the vibrations transmitted to the defined frame are reduced and is characterized in that axially resilient damping means are interposed between said frame and said second actuating means, for damping the axial forces exerted on the frame by the said part of the second actuating means. Thus, in the device in accordance with the invention the second actuating means are arranged on said frame *via* said axially resilient damping means. Surprisingly, axial movements of the second actuating means relative to the frame and consequently relative to the objective do not disturb the focussing movement of the objective. This is because the second actuating means do not transmit vibrations to the objective. An embodiment of the invention which is of interest in this respect is characterized in that said frame is provided with a parallel guide for the axial guidance of said second actuating means. This ensures that the second actuating means cannot inadvertently perform movements other than axial movements.

In optical devices it is advantageous to use an embodiment of the invention which is characterized in that the parallel guide for the objective comprises a bearing bush rigidly secured to the frame and made of a non-magnetizable material. When said bearing bush is rigidly secured to said frame the axially moving second actuating means cannot exert variable frictional forces on the objective. However, it is then important that the stationary bearing bush be made of a non-magnetizable material because otherwise substantial variable radial forces would inevitably be exerted on the moving second actuating means. Indeed, the bearing bush is disposed near the comparatively strong permanent magnet so that the slightest deviation in the position of the bearing bush from the magnetic centre of the annular magnet gives rise to substantial radial forces.

An interesting embodiment of the invention uses damping means made of butyl rubber. In addition to resilient properties this type of rubber has excellent damping properties and moreover it can be formed easily into any desired shape.

It is advantageous to modify the afore-mentioned known focussing device with an embodiment of the invention which is characterized in that the second actuating means are entirely resiliently supported on the frame and the resilient damping means comprise: leaf-spring means connected to the second actuating means and to the frame and rubber isolating means between the frame and the leaf-spring means. A suitable embodiment is characterized in that the leaf-spring means comprise a single integrally formed leaf-spring member which comprises a plurality of leaf springs which extend along or substantially tangentially to a circle concentric with the axis of the objective and which are separated from the remainder of said member by punched-out slots.

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

Figure 1 is a sectional view of an optical focussing device (taken on the line I—I in Figure 2),

Figure 2 is a plan view of the focussing device shown in Figure 1,

Figure 3 is a sectional view of another focussing device (taken on the line III—III in Figure 4),

Figure 4 is a plan view of the focussing device shown in Figure 3, and

Figure 5 is a sectional view of a part of the optical focussing device shown in Figures 3 and 4, taken on the line V—V in Figure 4.

Figures 1 and 2 show an optical focussing device for a video-disk player, which device is a modification of the optical focussing device known from the aforementioned United States Patent Specification 4,021,101.

An objective 1 with an optical axis 2 is axially movable in order to focus a light beam 3 onto a rotary video disk 4. The objective is actuated by means of an electro-magnetic actuating device which comprises first actuating means, comprising an annular coil 5 which is connected to the objective 1, and second actuating means which co-operate axially with the coil 5 in an air gap 6 with a permanent-magnetic field which is oriented transversely of the optical axis 2. The second actuating means comprise an axially magnetized annular permanent magnet 7 which is arranged concentrically around the objective, and a soft-iron yoke comprising pole-pieces 8 and 9 disposed on opposite sides of the annular magnet and a soft-iron sleeve 10 which is connected to the pole-piece 8 and which is spaced from the other pole-piece 9 by the annular air gap 6.

The objective is fixed in a mount 11. The parallel guide for axially guiding the objective, comprises a bearing bush 12, the mount 11 having an accurate axially sliding fit in the bush. The bearing bush is integral with a frame plate 13 by which the device is secured to a carriage 14 of the video-disk player by means of four bolts 15. The frame plate 13 and the bearing bush 12 are made of a non-magnetic material, for example aluminium or a copper alloy.

Between the frame 13 and the second actuating means — which as already stated comprise the annular magnet 7, the pole-pieces 8 and 9 and the sleeve 10 — there are interposed damping means in the form of a layer of foam rubber 16. This layer is slightly resilient in the axial direction and also has damping properties. Suitably, the layer is made of butyl rubber, which has excellent damping properties. The axial forces exerted on the frame by the second actuating means are damped by the layer of foam rubber. The pole piece 8, the layer of foam rubber 16, and the frame 13 may be connected rigidly to each other, for example, by gluing. This counteracts radial displacements of the annular magnet 7 and the soft-iron yoke.

The optical focussing device shown in Figures 3 to 5 is also a modification of an optical focussing device known from the aforementioned United States Patent Specification 4,021,101. The objective 21 is axially movable along an optical axis 22 by means of an annular coil 23. The objective is mounted in a bearing bush 24 which is rigidly connected to a frame 25. This frame is capable of performing radial translational movements relative to an axis of rotation of a video disk 26. For this purpose the frame 27 of the video-disk player in which the optical focussing device is used comprises two guide rods 28 and 29.

In addition to the focussing device two further electro-dynamically controlled optical devices are secured to the frame 25, namely two pivotable mirrors 30 and 31. These mirrors are arranged in such a way that a light beam emitted by a laser and directed parallel with the guide rods 28 and 29 is first reflected by the mirror 30 and subsequently by the mirror 31, after which it is focussed onto the video disk 26 by the objective 21. In the drawing the laser beam is not shown and the objective 21 is shown in its rest position, *i.e.* its lowermost position.

As in the device shown in Figures 1 and 2, the second actuating means, which are arranged on the frame of the focussing device comprise an axially magnetized annular magnet 32, a pole-piece 33, a pole-piece 34 and a sleeve 35 which is spaced from the pole-piece 33 by an annular air gap 36. In the air gap 36 a radially oriented permanent-magnetic field exists, which permits the coil 23 to be actuated axially. The second actuating means, consisting of the annular magnet 32 with the soft-iron yoke, are entirely resiliently supported on the frame by resilient damping means which comprise four leaf springs 37A to 37D, which are connected to the second actuating means and to the frame, and a plurality of butyl-rubber rings 38, see in particular Figure 5. By the use of accurately identical rings a substantially equal damping is obtained at the four corners. This avoids problems due to asymmetrical damping. The leaf springs 37A to 37D form parts of a single integrally formed leaf-spring member 37. The leaf springs extend along or substantially tangentially, to a circle concentric with the axis 2 and are spaced from the remainder of the leaf-spring member 37 by punched-out slots 39A to 39D.

As already stated the two embodiments shown are modifications to a known optical focussing device. However, the same principles may be applied to other optical devices. Furthermore, the invention may be used to advantage in other focussing devices which differ from the focussing devices shown in the drawing as regards the parallel guide of the objective and the construction of the actuating means. For example, it is possible to use the invention in focussing devices in which the parallel guide for the objective comprises not a slide-bearing arrangement but a resilient objective-suspension (see for example the article "Control Mechanisms in the Philips 'VLP' Record Player" by P. J. M. Janssen and P. E Day, 1973, no. 7, pages 190 to 193). Alternatively, an electro-dynamic parallel guide may be used, for this see EP—A1—0070070 which has not been published previously. These two references also describe other constructions of the actuating means. In the focussing device described in the first-mentioned reference the first actuating means are disposed on the underside of the device, whilst the second reference shows and

describes a number of different devices with actuating means of an entirely different construction. Alternatively, the first actuating means may comprise permanent-magnetic parts and the second actuating means may comprise one or more coils. Instead of permanent-magnetic means electro-magnetic means may be employed.

It has been found that in a focussing device as shown in Figures 3 to 5 the tolerance of the device to vertical oscillations of the position of the video track on the disk increases substantially, namely by a factor of at least 10. The mass of the objective is approximately 7.5 grammes, the permanent magnet plus the yoke having a mass which is about six to ten times greater. The maximum acceleration of the objective during operation in a video disc player is approximately 100 m/sec$^2$, so that reactive forces of approximately 0.75N are exerted on the second actuating means. The magnetic field in the air gap is homogeneous within an axial range of 3 to 4 mm. The amplitude of the objective movement at low frequencies is 0.5 to 1.5 mm, the amplitudes decreasing at higher frequencies.

The bandwidth of the automatic focussing control loop in an optical video-disk player is approximately 5 kHz. The movements of the objective produce a certain sound pressure in a frequency range to which the human ear is very sensitive. Depending on the construction the invention may have the additional advantage that the sound pressure is reduced by the movements of the second actuating means. If the objective and the second actuating means move in opposite directions, the sound pressures will also be opposed to each other and will consequently cancel each other at least partly.

**Claims**

1. An optical device comprising:
— a frame;
— an axially movable objective with an optical axis,
— a parallel guide arrangement for the axial guidance of said objective being connected to said frame; and
— an electromagnetic actuating device for axially moving the objective, which device comprises first actuating means connected to said objective and second actuating means arranged on said frame, which first and second actuating means axially co-operate with each other in an air gap with a magnetic field which is oriented transversely of the optical axis, characterized in that axially resilient damping means are interposed between said frame and said second actuating means, for damping the axial forces exerted on said frame by the said second actuating means.

2. An optical device as claimed in Claim 1, characterized in that said frame is provided with a parallel guide for the axial guidance of said second actuating means.

3. An optical device as claimed in Claim 1, of the type in which, characterized in that the parallel guide for the objective comprises a bearing bush rigidly secured to the frame and made of a non-magnetizable material.

4. An optical device as claimed in Claim 1, characterized in that the damping means are made of butyl rubber.

5. An optical device as claimed in Claim 1, of the type in which the second actuating means comprise:
— an axially magnetized annular permanent magnet which is arranged concentrically around the objective and
— a soft-iron yoke comprising pole-pieces disposed on opposite sides of the annular magnet and a soft-iron sleeve which is connected to one of the pole-pieces and which is spaced from the other pole-piece by an annular gap, the first actuating means comprising an annular coil which moves in the annular gap of said soft-iron yoke,
characterized in that
— the second actuating means are entirely resiliently supported on the frame, and
— the resilient damping means comprise:
— leaf-spring means connected to the second actuating means and to the frame, and
— rubber isolating means between the frame and the leaf-spring means.

6. An optical device as claimed in Claim 5, characterized in that the leaf-spring means comprise a single integrally formed leaf-spring member which comprises a plurality of leaf springs which extend along or substantially tangentially to a circle concentric with the axis of the objective and which are separated from the remainder of said member by punched-out slots.

**Patentansprüche**

1. Optische Vorrichtung mit:
— einem Gestell,
— einem axial beweglichen Objektiv mit einer optischen Achse,
— einer Parallelführung zur axialen Führung des genannten Objektivs, die mit dem genannten Gestell verbunden ist, sowie
— einer elektromagnetischen Antriebsvorrichtung für das Objektiv mit ersten, mit dem genannten Objektiv verbundenen und zweiten auf dem genannten Gestell angeordneten Antriebsmitteln, die einem Luftspalt mit einem quer zu der optischen Achse gerichteten Magnetfeld axial miteinander zusammenarbeiten, dadurch gekennzeichnet, dass in axialer Richtung federnde Dämpfungsmittel zwischen dem genannten Gestell und den genannten zweiten Antriebsmitteln vorhanden sind zum Dämpfen der von den genannten zweiten Antriebsmitteln auf das Gestell ausgeübten axialen Kräfte.

2. Optische Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass das genannte Gestell mit einer Parallelführung zu axialen Führung der genannten zweiten Antriebsmittel.

describes a number of different devices with actuating means of an entirely different construction. Alternatively, the first actuating means may comprise permanent-magnetic parts and the second actuating means may comprise one or more coils. Instead of permanent-magnetic means electro-magnetic means may be employed.

It has been found that in a focussing device as shown in Figures 3 to 5 the tolerance of the device to vertical oscillations of the position of the video track on the disk increases substantially, namely by a factor of at least 10. The mass of the objective is approximately 7.5 grammes, the permanent magnet plus the yoke having a mass which is about six to ten times greater. The maximum acceleration of the objective during operation in a video disc player is approximately 100 m/sec$^2$, so that reactive forces of approximately 0.75N are exerted on the second actuating means. The magnetic field in the air gap is homogeneous within an axial range of 3 to 4 mm. The amplitude of the objective movement at low frequencies is 0.5 to 1.5 mm, the amplitudes decreasing at higher frequencies.

The bandwidth of the automatic focussing control loop in an optical video-disk player is approximately 5 kHz. The movements of the objective produce a certain sound pressure in a frequency range to which the human ear is very sensitive. Depending on the construction the invention may have the additional advantage that the sound pressure is reduced by the movements of the second actuating means. If the objective and the second actuating means move in opposite directions, the sound pressures will also be opposed to each other and will consequently cancel each other at least partly.

**Claims**

1. An optical device comprising:
— a frame;
— an axially movable objective with an optical axis,
— a parallel guide arrangement for the axial guidance of said objective being connected to said frame; and
— an electromagnetic actuating device for axially moving the objective, which device comprises first actuating means connected to said objective and second actuating means arranged on said frame, which first and second actuating means axially co-operate with each other in an air gap with a magnetic field which is oriented transversely of the optical axis, characterized in that axially resilient damping means are interposed between said frame and said second actuating means, for damping the axial forces exerted on said frame by the said second actuating means.

2. An optical device as claimed in Claim 1, characterized in that said frame is provided with a parallel guide for the axial guidance of said second actuating means.

3. An optical device as claimed in Claim 1, of the type in which, characterized in that the parallel guide for the objective comprises a bearing bush rigidly secured to the frame and made of a non-magnetizable material.

4. An optical device as claimed in Claim 1, characterized in that the damping means are made of butyl rubber.

5. An optical device as claimed in Claim 1, of the type in which the second actuating means comprise:
— an axially magnetized annular permanent magnet which is arranged concentrically around the objective and
— a soft-iron yoke comprising pole-pieces disposed on opposite sides of the annular magnet and a soft-iron sleeve which is connected to one of the pole-pieces and which is spaced from the other pole-piece by an annular gap, the first actuating means comprising an annular coil which moves in the annular gap of said soft-iron yoke,
characterized in that
— the second actuating means are entirely resiliently supported on the frame, and
— the resilient damping means comprise:
— leaf-spring means connected to the second actuating means and to the frame, and
— rubber isolating means between the frame and the leaf-spring means.

6. An optical device as claimed in Claim 5, characterized in that the leaf-spring means comprise a single integrally formed leaf-spring member which comprises a plurality of leaf springs which extend along or substantially tangentially to a circle concentric with the axis of the objective and which are separated from the remainder of said member by punched-out slots.

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1. Optische Vorrichtung mit:
— einem Gestell,
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— einer elektromagnetischen Antriebsvorrichtung für das Objektiv mit ersten, mit dem genannten Objektiv verbundenen und zweiten auf dem genannten Gestell angeordneten Antriebsmitteln, die einem Luftspalt mit einem quer zu der optischen Achse gerichteten Magnetfeld axial miteinander zusammenarbeiten, dadurch gekennzeichnet, dass in axialer Richtung federnde Dämpfungsmittel zwischen dem genannten Gestell und den genannten zweiten Antriebsmitteln vorhanden sind zum Dämpfen der von den genannten zweiten Antriebsmitteln auf das Gestell ausgeübten axialen Kräfte.

2. Optische Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass das genannte Gestell mit einer Parallelführung zu axialen Führung der genannten zweiten Antriebsmittel.



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3. Optische Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass die Parallelführung für das Objektiv eine Lagerbüchse aufweist, die ortsfest auf dem Gestell angeordnet ist und aus einem nicht-magnetisierbaren Material besteht.

4. Optische Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, dass die Dämfpungsmittel aus Butylkautschuk bestehen.

5. Optische Vorrichtung nach Anspruch 1, von dem Typ, bei dem die zweiten Antriebsmittel aus den folgenden Elementen bestehen:

— einem axial magnetisierten ringförmigen Dauermagneten, der konzentrisch um das Objektiv angeordnet ist und

— einem Weicheisenjoch mit Schliessplatten auf beiden Seiten des Ringmagneten und mit einer Weicheisenhülse, die mit einer der Schliessplatten verbunden und durch einen ringförmigen Spalt von der anderen Schliessplatte getrennt ist und wobei die ersten Antriebsmittel eine ringförmige Spule aufweisen, die sich in dem ringförmigen Spalt des genannten Weicheisenjoches bewegt, dadurch gekennzeichnet, dass

— die zweiten Antriebsmittel völlig von dem Gestell federnd unterstützt werden und

— dass die federnden Dämfpungsmittel die folgenden Elemente aufweisen:

— Blattfedermittel, die mit den zweiten Antriebsmitteln sowie mit dem Gestell verbunden sind und

— aus Gummi bestehende Isoliermittel zwischen dem Gestell und den Blattfedermitteln.

6. Optische Vorrichtung nach Anspruch 5, dadurch gekennzeichnet, dass die Blattfedermittel aus einem einzigen integral hergestellten Blattfederelement bestehen mit einer Anzahl durch ausgestanzte Schlitze von dem übrigen Teil getrennter einzelner im wesentlichen tangentiell gerichteter Blattfedern.

**Revendications**

1. Dispositif optique comportant:

— un châssis;

— un objectif mobile dans le sens axial et ayant un axe optique,

— un guidage parallèle servant à guider ledit objectif dans le sens axial et réuni audit châssis et

— un dispositif de commande électromagnétique servant à déplacer l'objectif dans le sens axial, dispositif de commande comportant de premiers moyens de commande réunis audit objectif et de seconds moyens de commande disposés sur ledit châssis, premiers et seconds moyens de commande qui coopèrent axialement dans un entrefer ayant un champ magnétique orienté perpendiculairement à l'axe optique, caractérisé en ce que des moyens d'amortissement élastiques dans le sens axial sont interposés entre ledit châssis et lesdits seconds moyens de commande pour amortir les forces axiales qu'exercent lesdits seconds moyens de commande sur ledit châssis.

2. Dispositif optique selon la revendication 1, caractérisé en ce que ledit châssis est muni d'un guide parallèle pour guider lesdits seconds moyens de commande dans le sens axial.

3. Dispositif optique selon la revendication 1, caractérisé en ce que le guide parallèle pour l'objectif comporte un coussinet solidement fixé au châssis et fait en matériau non aimantable.

4. Dispositif optique selon la revendication 1, caractérisé en ce que les moyens d'amortissement sont en caoutchouc butyle.

5. Dispositif optique selon la revendication 1, du type dans lequel les seconds moyens de commande comportent:

— un aimant permanent annulaire aimanté dans le sens axial et disposé concentriquement autour de l'objectif et

— une culasse en fer doux comportant, d'une part, des épanouissements polaires disposés sur des faces opposées de l'aimant annulaire et, d'autre part, un manchon en fer doux réuni à l'un des épanouissements polaires et séparé de l'autre épanouissement polaire par un entrefer, les premiers moyens de commande comportant une bobine annulaire se déplaçant dans l'entrefer annulaire de ladite culasse en fer doux,

caractérisé en ce que

— les seconds moyens de commande sont supportés entièrement élastiquement par le châssis et

— les moyens d'amortissement élastiques comportent:

— des moyens à ressorts-lame réunis aux seconds moyens de commande et au châssis et

— des moyens d'isolation en caoutchouc placés entre le châssis et les moyens à ressorts-lame.

6. Dispositif optique selon la revendication 5, caractérisé en ce que les moyens à ressorts-lame comportent un organe à ressorts-lame d'une seule pièce comportant une pluralité de ressorts-lame s'étendant suivant un cercle concentrique avec l'axe de l'objectif ou sensiblement tangentiellement à ce cercle et séparés du reste dudit organe par des fentes pratiquées par découpage.



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