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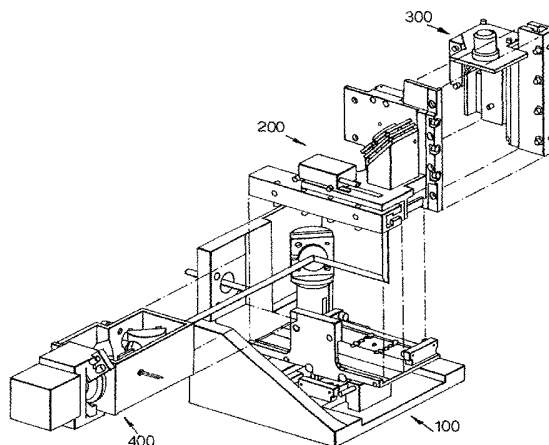
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(54) Title: COMPACT LINEAR SCANNER SYSTEM



(57) **Abstract:** The invention provides a compact, linear XYZ-scanner system, including an X-axis unit mounted on a chassis member and including an X-axis motor means fixedly attached to the chassis and adapted to drive a slide linearly guided by first guide means; an X-mirror mount moving together with the X-axis unit; a Y-axis unit mounted on a first bracket that moves together with the X-axis unit and including Y-axis motor means fixedly attached to the first bracket and adapted to drive a slide linearly guided by second guide means; a Y-mirror mount moving together with the Y-axis unit; a Z-axis unit mounted on a second bracket that moves together with the Y-axis unit and including Z-axis motor means fixedly attached to the second bracket and adapted to drive a slide linearly guided by third guide means, and a lens mount carrying a focusing lens and moving together with the Z-axis unit; wherein a light beam emitted by a light source and impinging on the X-mirror is reflected in an XY-plane onto the Y-mirror and thence, in an YZ-plane into the focusing lens, and wherein, by selectively actuating the motor means, the focal point of the light beam focused by the focusing lens can be moved to any point within a three-dimensional coordinate system.



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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

COMPACT LINEAR SCANNER SYSTEM

Field of the Invention

The present invention relates to a compact linear scanner system.

Background of the Invention

Computer-controlled scanning systems have found uses in many different fields, such as in certain types of surgery, in the application of microscopic markings on precious stones, in the micro-machining of hard or tough materials, and many more.

Most scanning systems used today operate by the well-known galvanometric, or galvo, principle, based on the relative rotary movement produced between a coil and a system of magnets, which is imparted to a mirror, thus causing a light or laser beam to scan the object. While galvo systems are mechanically relatively simple and, because of the small masses involved, permit high accelerations and speeds, their serious disadvantage is the curved field resulting from the slewing sweep of the beam as deflected by the galvo mirror. To correct the curved field, galvo systems require special optics (F- θ optics), which are very expensive. Further limitations of the galvo system and its optics reside in the existence of a minimum focal length (about 70 mm), below which distortions dominate, as well as the need for special galvo mirrors.

While known linear scanners do not suffer from the above-mentioned drawbacks, they are cumbersome, bulky and location-bound pieces of equipment, which restricts their usefulness.

Disclosure of the Invention

It is thus one of the objects of the present invention to provide a highly accurate, linear XYZ-scanner system that uses standard, off-the-shelf optical components and that, being highly compacted, is comparable in size and weight to galvo-based XY-scanners with similar ranges of movement.

It is a further object of the present invention to provide a scanner system that can be used both with laser and ordinary light, for a variety of purposes.

According to the present invention, the above objects are achieved by providing a compact, linear XYZ-scanner system, comprising an X-axis unit mounted on a chassis member and including an X-axis motor means fixedly attached to said chassis and adapted to drive a slide linearly guided by first guide means; an X-mirror mount moving together with said X-axis unit; a Y-axis unit mounted on a first bracket that moves together with said X-axis unit and including Y-axis motor means fixedly attached to said first bracket and adapted to drive a slide linearly guided by second guide means; a Y-mirror mount moving together with said Y-axis unit; a Z-axis unit mounted on a second bracket that moves together with said Y-axis unit and including Z-axis motor means fixedly attached to said second bracket and adapted to drive a slide linearly guided by third guide means, and a lens mount carrying a focusing lens and moving together with said Z-axis unit; wherein a light beam emitted by a light source and impinging on said X-mirror is reflected in an XY-plane onto said Y-mirror and thence, in an YZ-plane into said focusing lens, and wherein, by selectively actuating said motor means, the focal point of the light beam focused by said focusing lens can be moved to any point within a three-dimensional coordinate system.

Brief Description of the Drawings

The invention will now be described in connection with certain preferred embodiments with reference to the following illustrative figures so that it may be more fully understood.

With specific reference now to the figures in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

- Fig. 1 is an exploded, perspective view of the scanner system according to the present invention, showing the four units of the system;
- Fig. 2 is an exploded view of the X-axis unit;
- Fig. 3 illustrates the fully assembled X-axis unit;
- Fig. 4 is an exploded view of the Y-axis unit in its position above the XY-bracket of the assembled X-axis unit;
- Fig. 5 illustrates the fully assembled X-axis and Y-axis units;
- Fig. 6 is an exploded view of the Z-axis unit in relation to the fully assembled X-axis and Y-axis units;
- Fig. 7 illustrates an optional camera unit in its relation to the fully assembled X-axis, Y-axis and Z-axis units;
- Fig. 8 schematically illustrates the optical path of the system, including the optical components, and
- Fig. 9 illustrates the manner in which the scanner system according to the invention is used to cover larger volumes.

Detailed Description

Referring now to the drawings, there are seen in Fig. 1 three units of the system: the X-axis unit 100, the Y-axis unit 200 and the Z-axis unit 300. The fourth unit shown is a camera unit 400, which is optional.

Fig. 2 illustrates X-axis unit 100, showing a chassis member 102, to the bottom of which is fixedly attached stator 104 of a linear motor 106. Such motors are commercially available and can be, e.g., of the electromagnetic, piezo-ceramic, or even the lead-screw type. To runner 108 of motor 106 is connected a vertical, rib-like member 113, downwardly projecting from the XY-bracket 114, i.e., the bracket that moves along the X-axis and carries the Y-axis unit 200 (Fig. 4). Bracket 114 has a horizontal member 116 and a vertical member 118. To horizontal member 116 is fixedly attached a slide 110, riding on a guide rail 112 mounted on the bottom surface of chassis member 102. Horizontal member 116 carries a post 120, to which is attached a block 122 mounting X-mirror 124. Block 122 is rendered elastically

deformable by the provision of two slots 126, 126', whereby, with the aid of adjusting screws (not shown), mirror 124 can be tilted about two mutually perpendicular axes.

Also seen in Fig. 2 is a linear encoder read head 128, fixedly attached to chassis member 102 and cooperating with an encoder scale strip (not shown) attached to rib-like member 113. Further seen are two mechanical stops 130, 132 limiting the X-motion of slide 110 and fixedly attached to chassis member 102. Bore 134 in the rear wall of chassis member 102 serves as the entrance opening for a laser beam, as seen in Fig. 1, and holes 136 serve for the attachment of camera unit 400.

Fig. 3 shows the fully assembled X-axis unit.

Fig. 4 is an exploded view of Y-axis unit 200 in its position above XY-bracket 114 of the assembled X-axis unit. It will be appreciated that, both functionally and structurally, Y-axis unit 200 is largely an analogue of X-axis unit 100. Linear motor 204, including its stator 206 and runner 208, is mounted on horizontal member 116 of XY-bracket 114, as is guide rail 212 on which rides slide 210. To the latter is fixedly attached YZ-bracket 214, the horizontal member 216 of which carries post 220, complete with Y-mirror 224 and mirror mount 226.

Vertical member 218 of YZ-bracket 214 serves for the attachment of Z-axis unit 300, as shown in Fig. 6. Also seen is linear encoder read head 228, which, in assembly, is attached to vertical XY-bracket member 118. It will be understood that, due to the nature of the exploded view, encoder 228 appears to be below YZ-bracket 214, while in assembly it is obviously located above bracket 214, as seen in the illustration of the fully assembled X-axis and Y-axis units 100 and 200 of Fig. 5.

Fig. 6 is an exploded view of Z-axis unit 300, shown in its relation to the fully assembled X-axis and Y-axis units 100 and 200. Linear motor 304 is mounted on Y-bracket member 218 (Figs. 4 and 5), as is guide rail 312. For purely technical reasons, the Z-bracket is designed in two parts: the vertical, channel-shaped member 318, and the plate-shaped horizontal member 316. In assembly, both parts 316 and 318 are joined by screws. Member 318 is connected to motor runner 308 with one of its flanges, and to slide 310 with its web. Also shown is focusing lens 338, the focal length of which is not limited by considerations of distortion-free imaging.

The kinematic hierarchy of the system is as follows: linear motor 104 moves all three units; linear motor 204 moves the Y-axis and Z-axis units 200 and 300, and linear motor 304 moves only the Z-axis unit 300.

Fig. 7 illustrates an optional camera unit 400 and its position relative to units 100, 200 and 300, shown fully assembled. Unit 400, which is attachable to chassis member 102 at its upper left-hand corner, comprises a camera system 440, advantageously of the CCD type, a spacer 442 which accommodates the imaging optics and a mirror housing 444, in which a beam splitter 446 and a dichroic mirror 448 are mounted. Also seen are an LED light source 450, used to illuminate the scanned object, and a laser beam LB, which enters the system through bore 134 (Fig. 1). Further shown is an additional, annular light source 352, which can be slipped over focusing lens 338 and is intended to provide diffuse light.

Fig. 8 is a schematic representation of the light path of the scanning system according to the invention, including the optional camera system 400. A laser beam LB from a laser source outside the system impinges on dichroic mirror 448, is reflected at 90° in the X-direction, impinges on X-mirror 124 and is reflected at 90° in the XY-plane, hitting Y-mirror 224, whence it is reflected upwards in the YZ-plane into focusing lens 338, to be focused onto the object scanned. Clearly, by selectively actuating any or all of the linear motors, the object-side focal point of lens 338 can be moved to any point of a three-dimensional coordinate system.

Illumination required for the imaging process is supplied by LED 450, the light of which (dashed line) impinges on beam splitter 446, which reflects it right into the optical axis via dichroic mirror 448. Mirror 448 reflects light of the wavelength of laser beam LB, but passes ordinary light. This light, reflected from the scanned object, is collected and collimated by focusing lens 338 and returned along the optical path, passing dichroic mirror 448 and beam splitter 446, and reaching the objective of the CCD camera system. The camera unit, added to the scanner system, provides an integrated scanner/camera system.

XYZ-motion control is provided by a *per se* known motion controller system and based on the position information provided by linear encoders 128, 228, 328. Also required are a CPU, a frame grabber and a monitor (not shown).

The compactness of the scanner according to the invention is the result of the interlinking, indeed, the extensive mechanical integration of units 100, 200 and 300, producing a "close packing" effect. Due to this effect, a scanner according to the invention, covering a three-dimensional coordinate system of, e.g., 100 x 100 x 100 mm, weighs less than 15 kg and has physical dimensions of less than 200 x 200 x 250 mm. A scanner according to the invention, covering a 3-D-coordinate system of 50 x 50 x 50 mm, weighs less than 6 kg and measures 140 x 150 x 170 mm.

The above-described scanner is suitable for a variety of purposes, using a laser beam or an ordinary light beam, to scan a three-dimensional surface. In a different configuration (including the camera unit), it can be used for viewing an object illuminated either by an external source or by an internal source via the optical system of the scanner; for 3-D measurement, tracing, viewing (as through a microscope), or for pick-and-place applications.

Scanners according to the present invention can cover 3-D coordinate systems of 50 x 50 x 50 mm and 100 x 100 x 100 mm with an accuracy of a few microns and a repeatability of 0.1 microns, and still constitute convenient, cost-efficient packages.

Attempts to build devices that will cover larger volumes produce systems that are bulky, heavy and very expensive. This limitation can however be circumvented by the following simple and cost-effective strategy, elucidated with the aid of Fig. 9, which basically shows the four principal units of the system, the X-axis unit 100, the Y-axis unit 200, the Z-axis unit 300, and the camera unit 400. Further seen is an X-, or XY, or XYZ-motion worktable 500, on which the workpiece (not shown) is positioned.

The following describes the strategy employed:

The camera system 440 is an integral part of the scanner and views the workpiece at any given moment with an accuracy determined by the optical design

and camera design. This accuracy can be of the order of a few microns without resorting to any extraordinary optical design. The workpiece will be positioned on a motion system 500 (such as a conveyor) or a XY-or XYZ-motion system. Standard repeatability and resolution for these systems (0.01-0.1 mm and even up to 0.5 mm) is sufficient. Special accuracy is not required. When one 50 X 50 mm segment is completed by the scanner, the motion system 500 will advance somewhat less than 50mm, in order to bring the next segment into position. The connection between each segment to the next, maintaining the high accuracy and repeatability required by the user, is kept by image processing techniques.

The system will be programmed to identify a repeating element or any known feature at the edge of each segment or even create a feature using laser marking techniques. When the motion positions the next segment under the scanner, the scanner moves to the area where that element is expected to be (known to within 0.01-0.5

It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrated embodiments and that the present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

CLAIMS:

1. A compact, linear XYZ-scanner system, comprising:
 - an X-axis unit mounted on a chassis member and including an X-axis motor means fixedly attached to said chassis and adapted to drive a slide linearly guided by first guide means;
 - an X-mirror mount moving together with said X-axis unit;
 - a Y-axis unit mounted on a first bracket that moves together with said X-axis unit and including Y-axis motor means fixedly attached to said first bracket and adapted to drive a slide linearly guided by second guide means;
 - a Y-mirror mount moving together with said Y-axis unit;
 - a Z-axis unit mounted on a second bracket that moves together with said Y-axis unit and including Z-axis motor means fixedly attached to said second bracket and adapted to drive a slide linearly guided by third guide means, and
 - a lens mount carrying a focusing lens and moving together with said Z-axis unit;

wherein a light beam emitted by a light source and impinging on said X-mirror is reflected in an XY-plane onto said Y-mirror and thence, in an YZ-plane into said focusing lens, and

wherein, by selectively actuating said motor means, the focal point of the light beam focused by said focusing lens can be moved to any point within a three-dimensional coordinate system.
2. The scanner system as claimed in claim 1, wherein said light beam is a laser beam and said light source is a laser source.
3. The scanner system as claimed in claim 1, further comprising camera means attachable to said chassis member and including a light source producing a beam for illuminating the object of the scanning operation.
4. The scanner system as claimed in claim 3, further comprising a first beam splitter for reflecting said illuminating beam into said light beam.
5. The scanner system as claimed in claim 2, further comprising a second beam splitter interposed between said first beam splitter and said X-mirror, being a dichroic

beam splitter passing light of the wavelength of said illuminating beam, but reflecting light of the wavelength of said laser beam.

6. The scanner system as claimed in claim 1, further comprising linear encoders for each of said axes, each encoder consisting of a read head and a scale strip.

7. The scanner system as claimed in claim 1, wherein said three units are integrated to ensure that the movements of said units take place in three different, mutually perpendicular directions.

8. The scanner system as claimed in claim 6, wherein the read head is the stationary component of said linear encoders and is fixedly attached to a member of the X-axis unit.

9. The scanner system as claimed in claim 1, wherein each of said slides is provided with two stops defining the limits of their travel.

10. The scanner system as claimed in claim 1, further comprising a worktable adapted to carry out a linear movement along at least one axis, facilitating the extension of the coordinate systems coverable by said scanner system.

11. The scanner system as claimed in claim 10, wherein the scanner system is oriented relative to said worktable with the focusing lens facing said worktable.

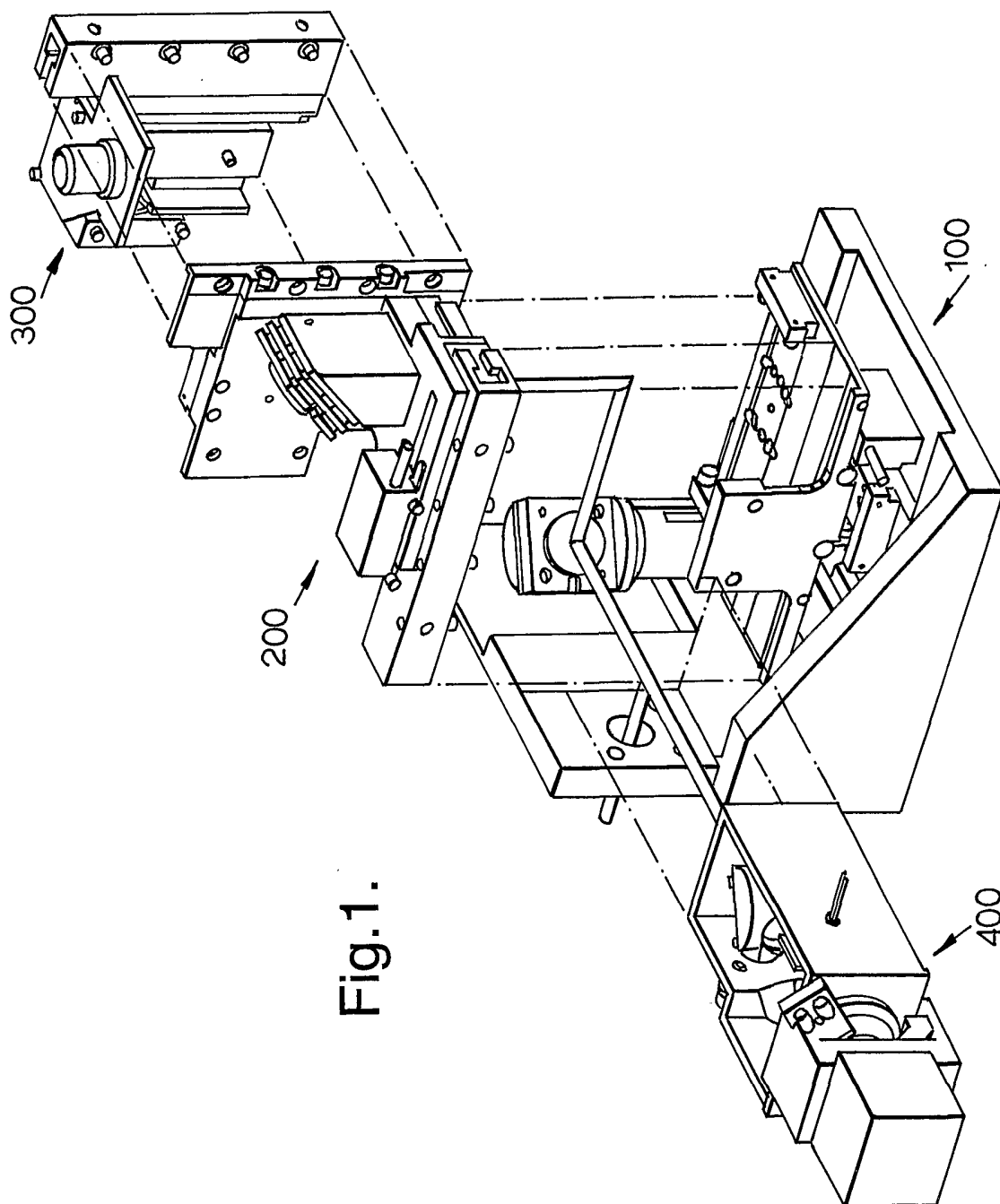


Fig.1.

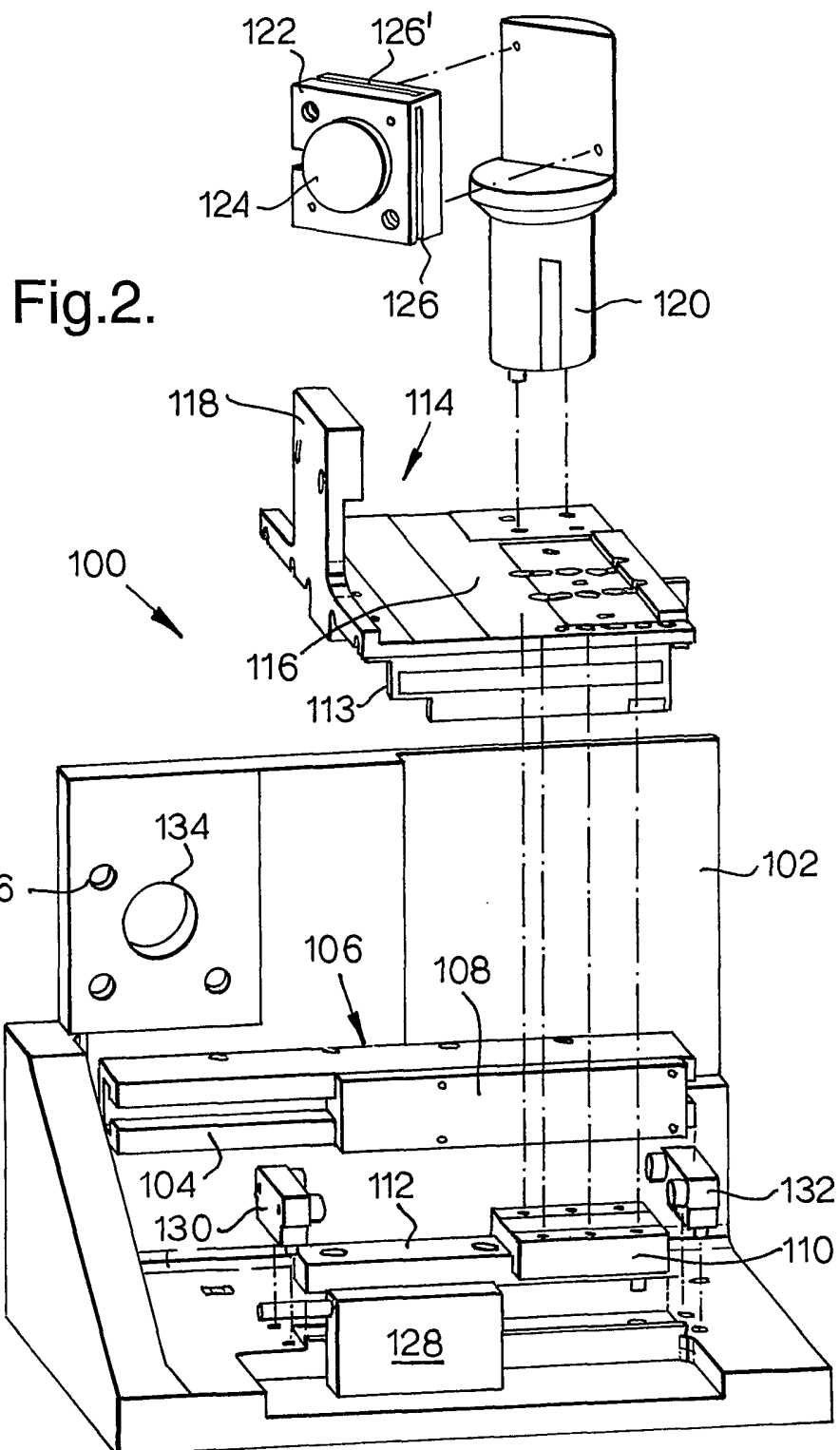


Fig.3.

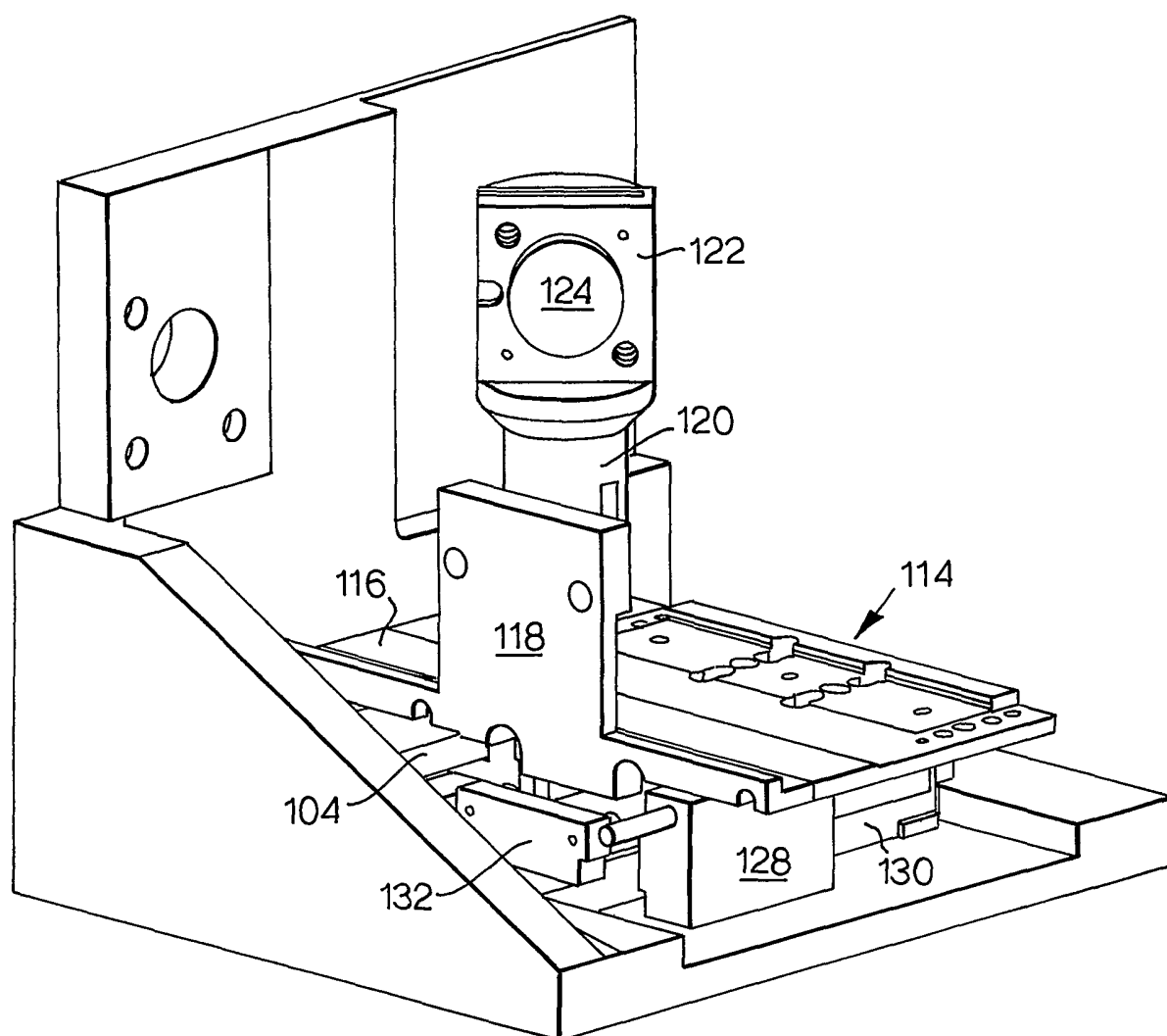
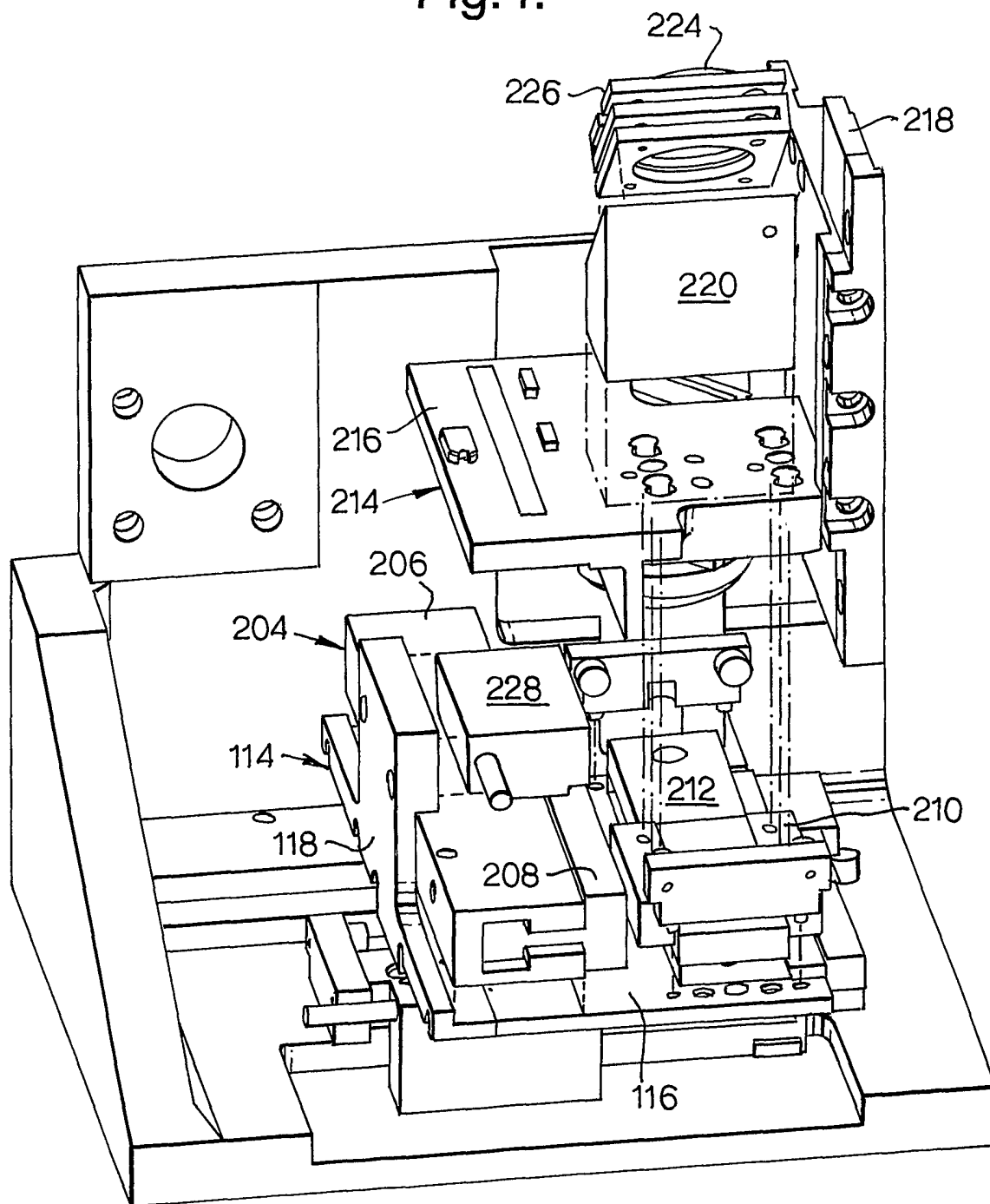


Fig.4.



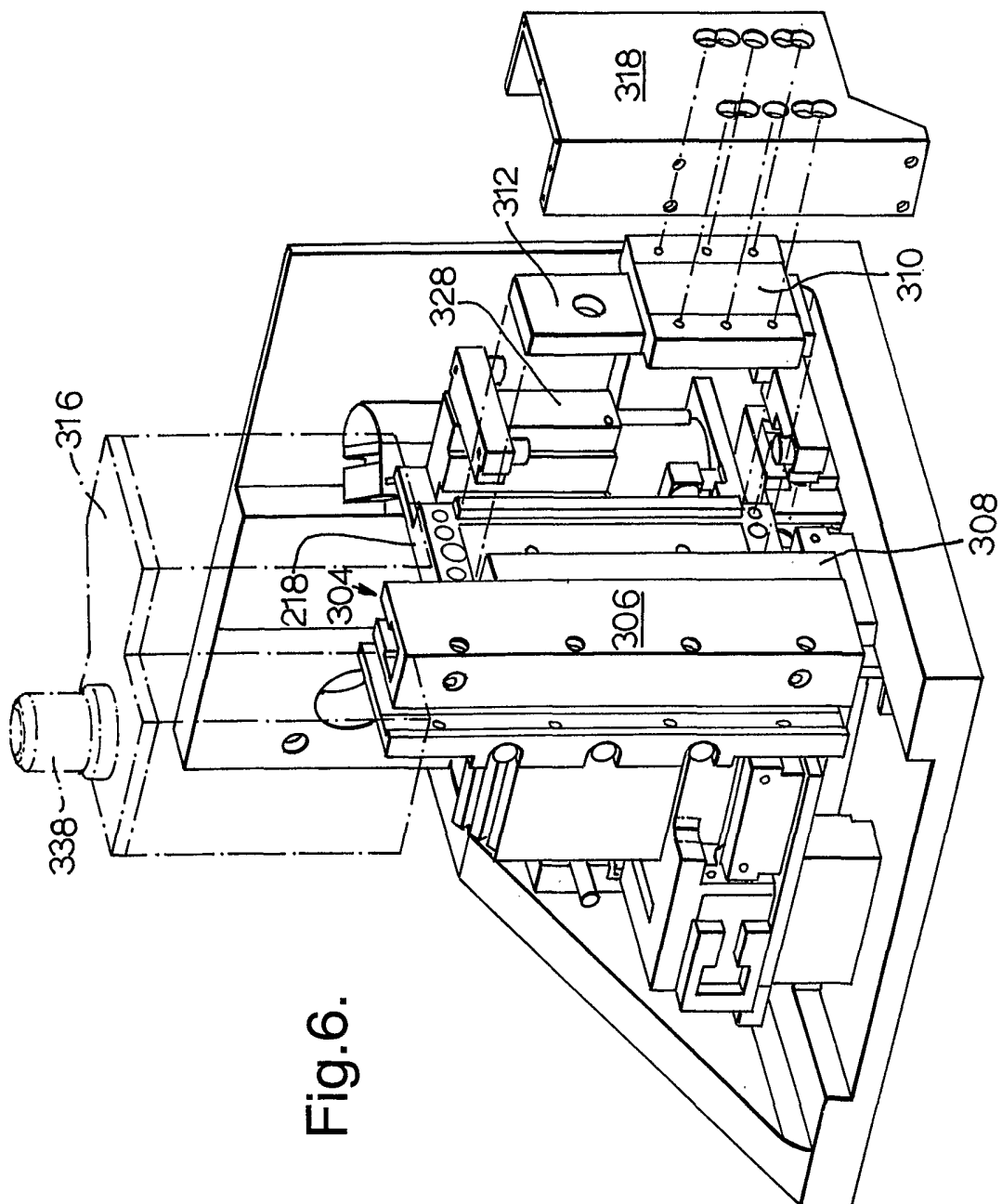


Fig. 6.

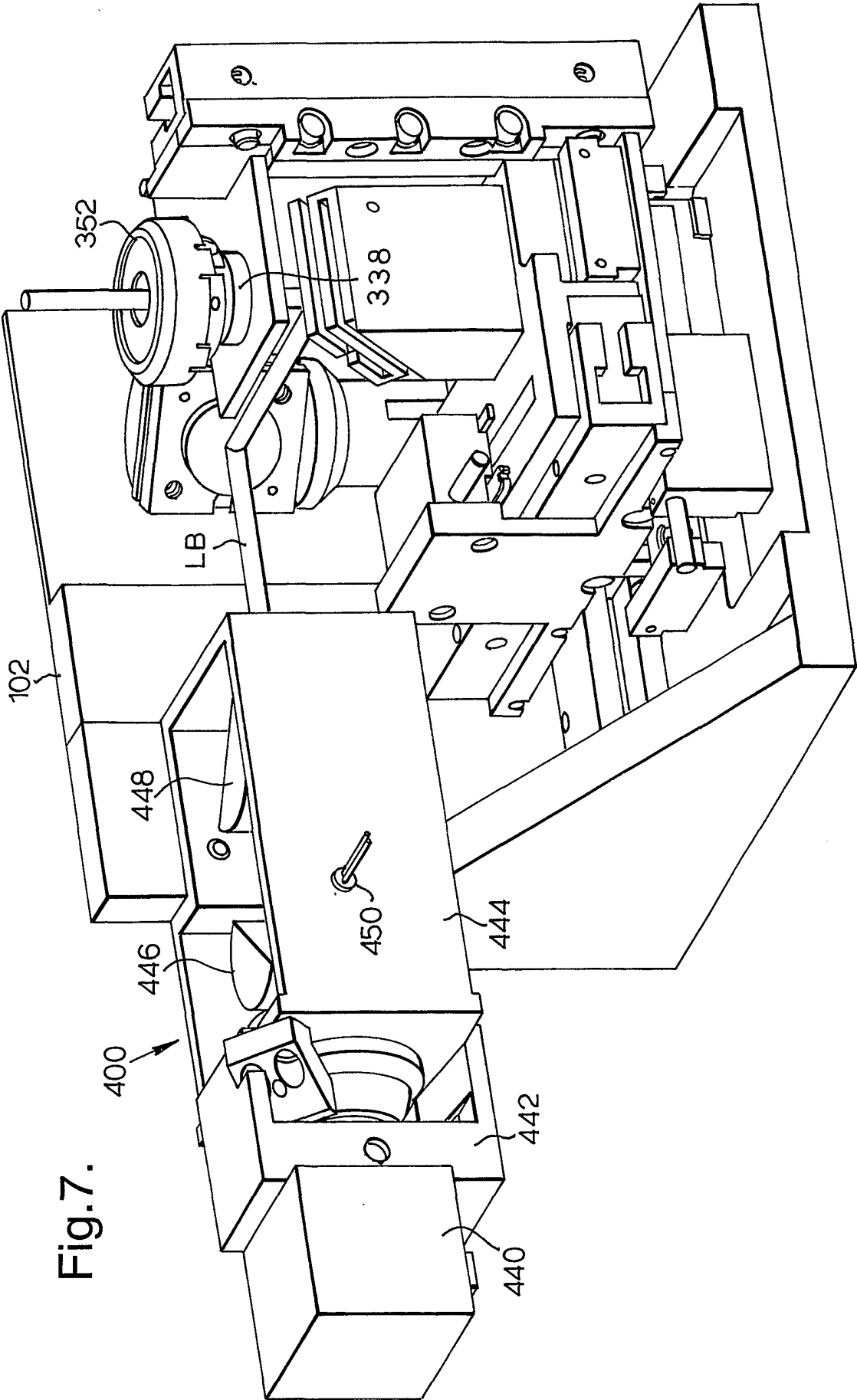


Fig.7.

Fig.8.

