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(54) **DETECTION SYSTEM FOR ATOMIC FORCE MICROSCOPES**

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(51) **Int. Cl.^{7}** **G01B 5/28**
(52) **U.S. Cl.** **73/105**
(58) **Field of Search** 73/105; 250/306, 250/307

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(57) **ABSTRACT**

A scanning probe microscope is provided with a piezoceramic tube to carry the sensitive probe at its free end to translationally move the probe in the X and Y directions. Large stationary surfaces can then be scanned by probe tip motion. The tube is also capable of movement in the Z direction so that the tip can follow the contours of the surface. Optical detection means track the motion of the probe tip and generate signals corresponding to and representative of surface contours. In one mode of operation, the signals are used in a feed back loop to keep constant the spacing between the tip and the surface, in which case the error or control signals represent the contours.

58 Claims, 2 Drawing Sheets

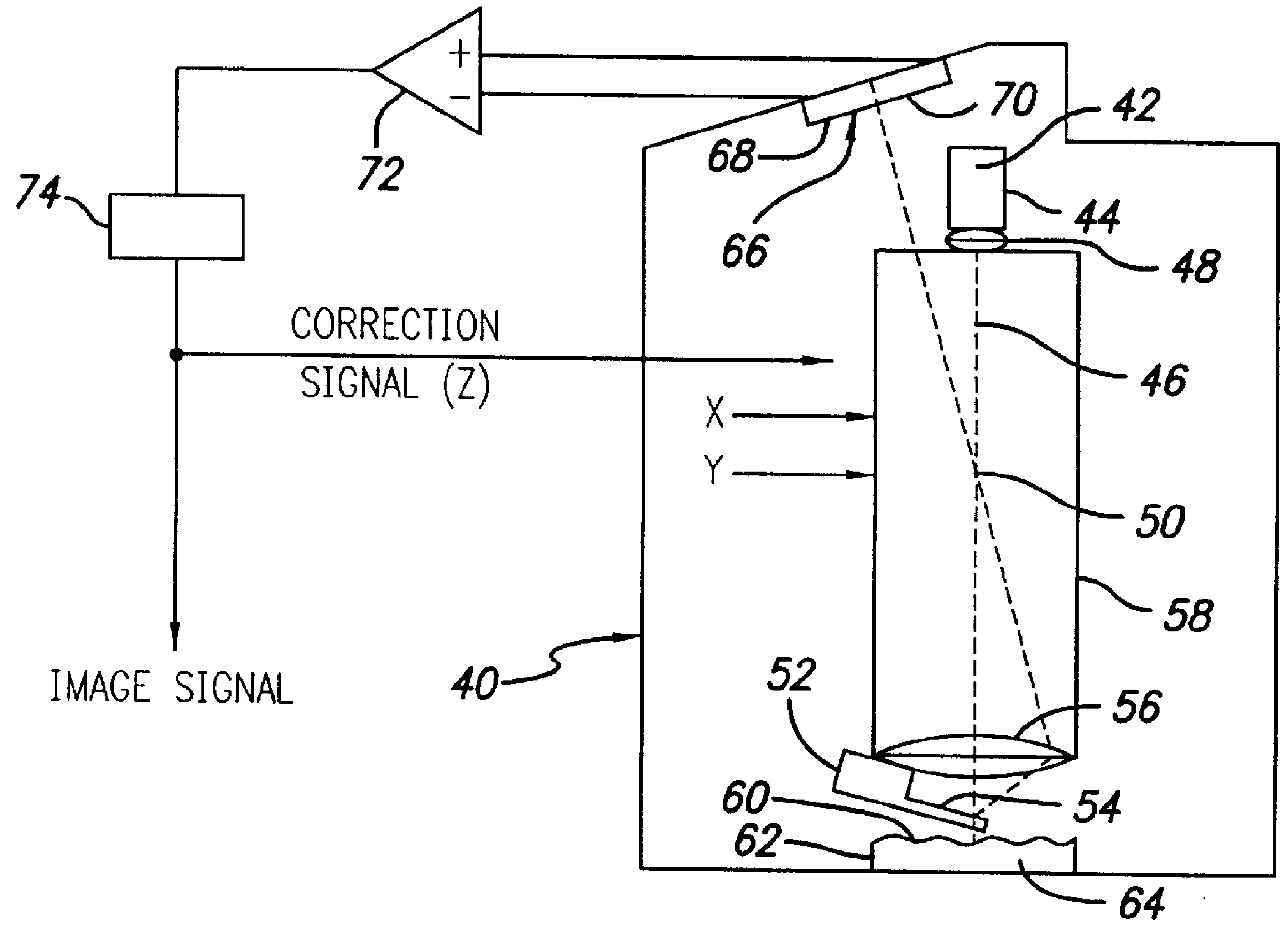


FIG. 1

PRIOR ART

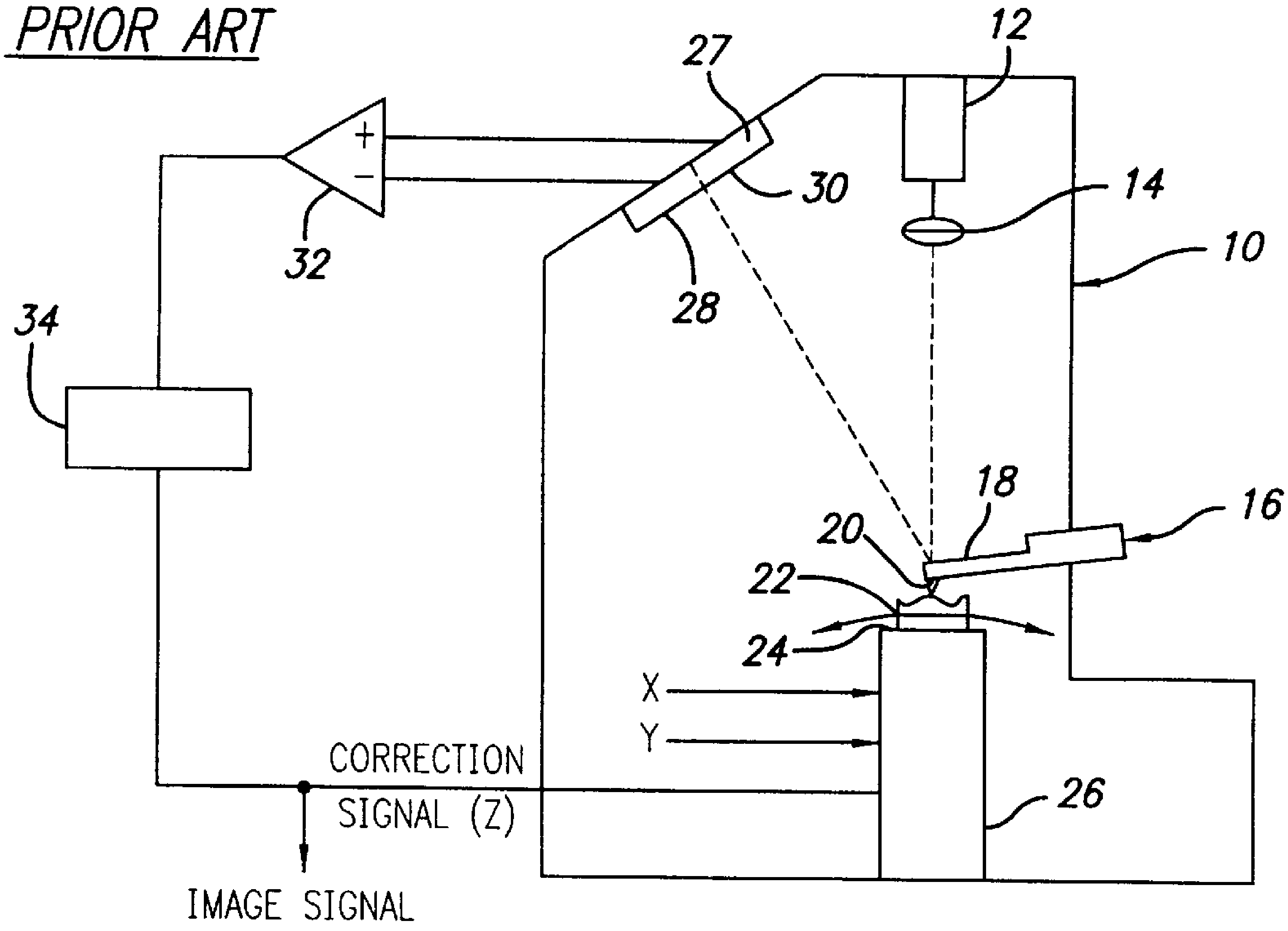


FIG. 2

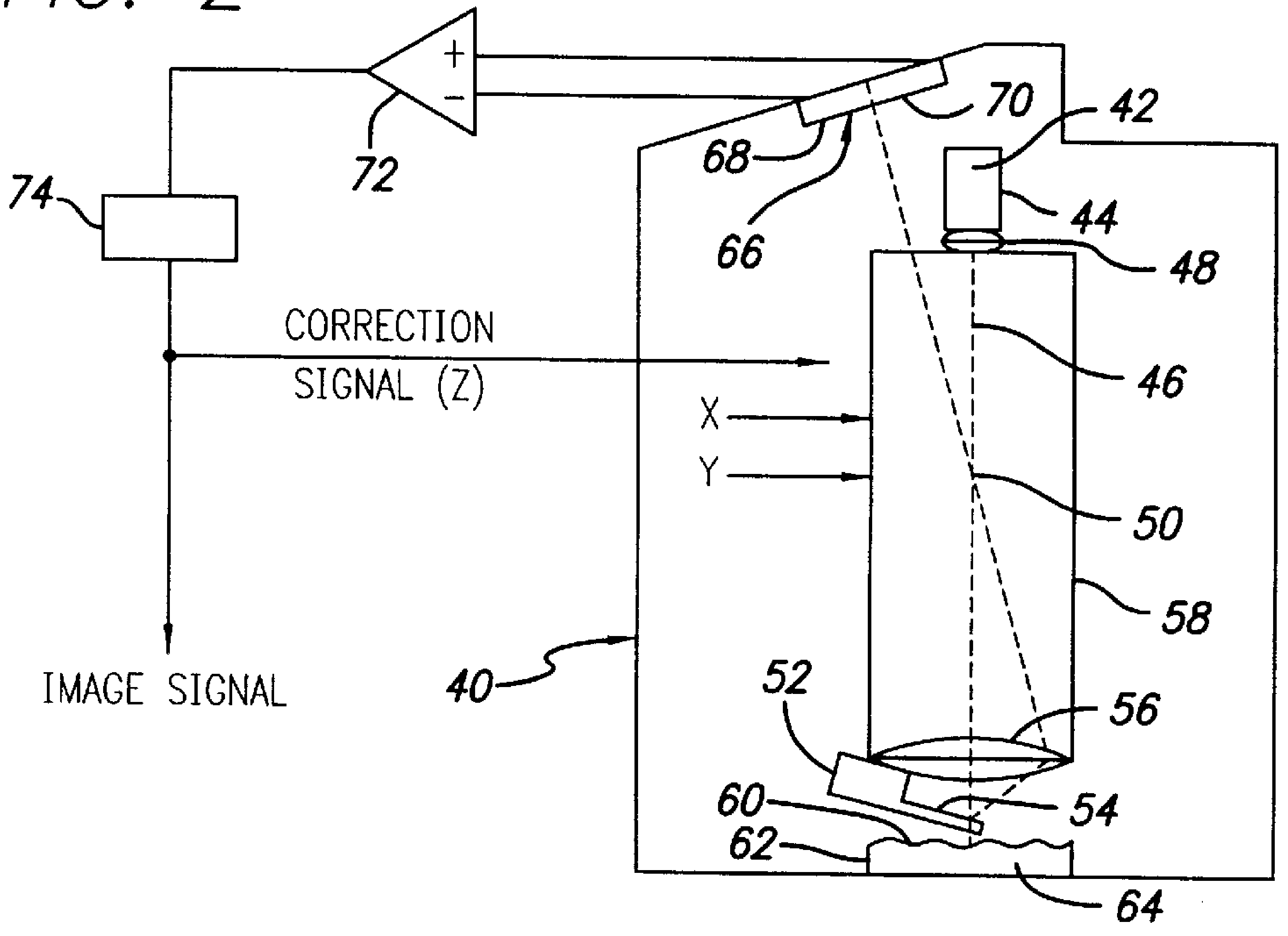
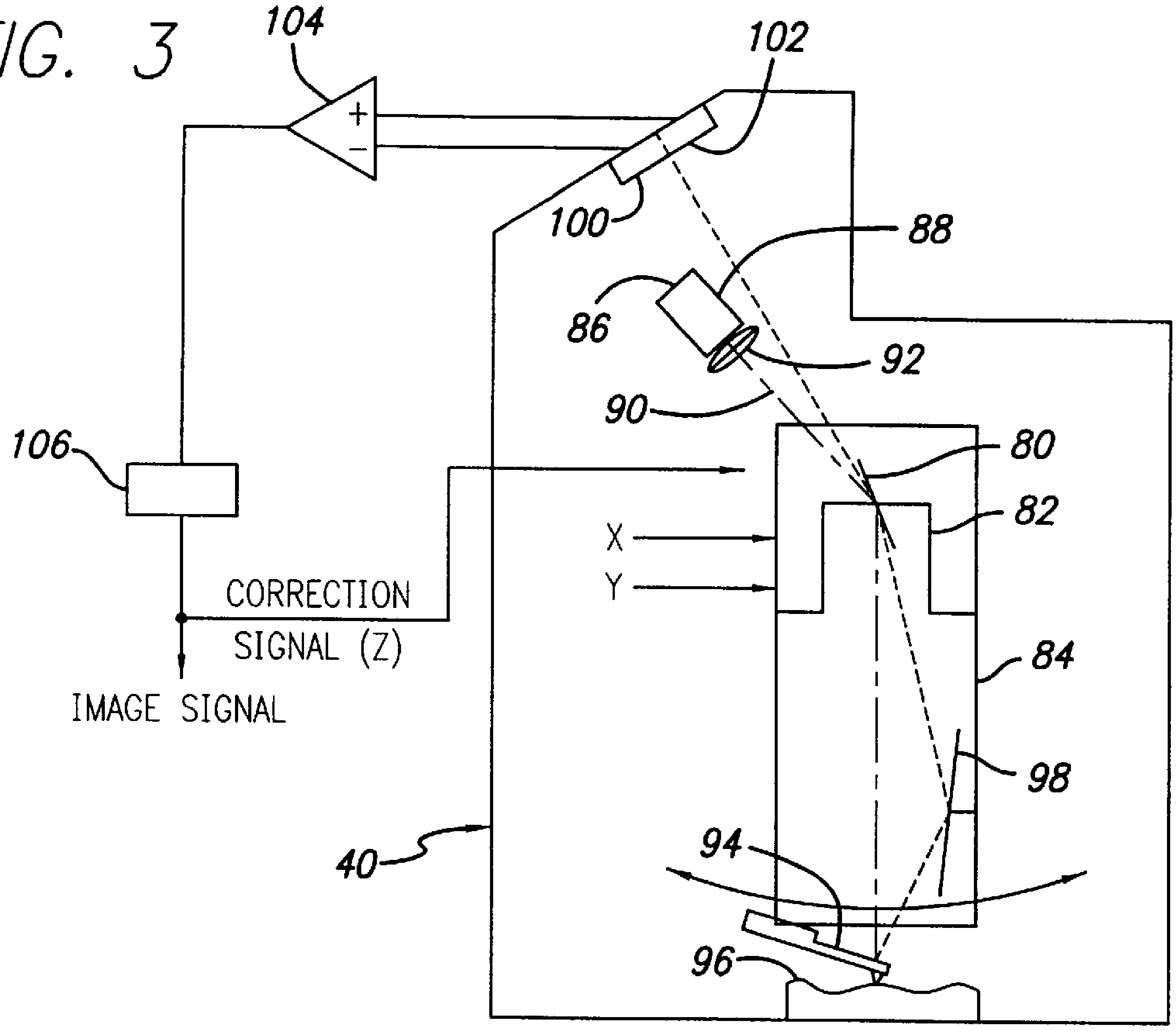


FIG. 3


104
102
+
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SIGNAL (Z)
IMAGE SIGNAL
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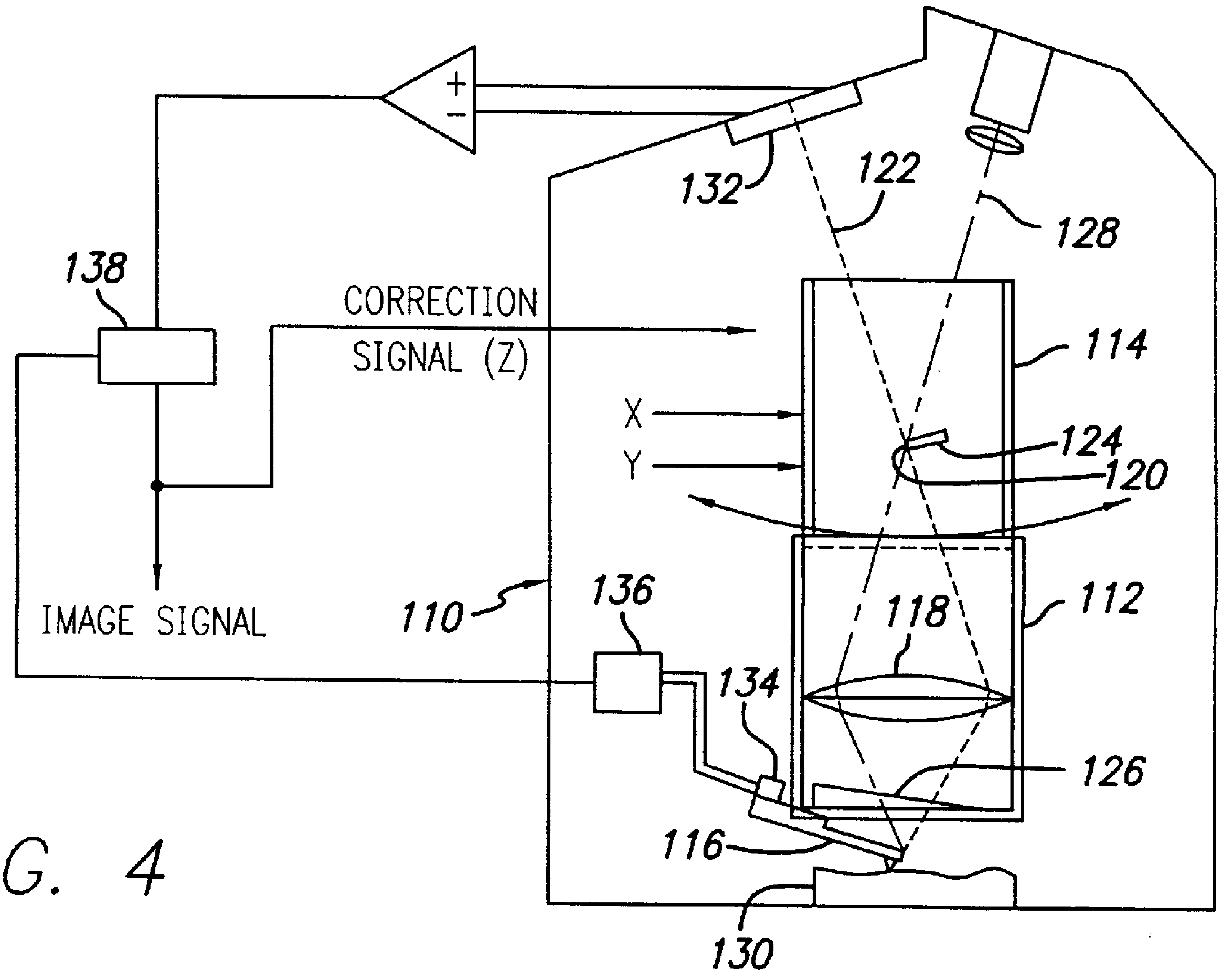
96


+
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132
122
128
138
CORRECTION
SIGNAL (Z)
114
X
Y
124
120
IMAGE SIGNAL
110
136
118
112
134
126
116
130

FIG. 4

DETECTION SYSTEM FOR ATOMIC FORCE MICROSCOPES

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

The present invention relates to scanning probe microscopes and, more specifically to scanning force microscopes, sometimes referred to as atomic force microscopes.

BACKGROUND OF THE INVENTION

Scanning force microscopes (SFM), sometimes referred to as atomic force microscopes (AFM) are used to investigate the surfaces of matter in the micrometer, nanometer, and sub-Angstrom scale. Such microscopes operate by positioning a probe, consisting of a cantilever arm with a sharp tip located orthogonally on one end of the cantilever arm, in, or nearly in, contact with the surface to be profiled or otherwise examined.

The cantilever arm has such a small spring constant that typically one nanonewton of force will cause a noticeable deflection. The cantilever arm deflects due to natural forces present between the tip and the sample. The probe may be either attracted to the surface or repelled by the surface depending on the forces at work. When relative motion in the X and Y directions exists between the probe and the sample surface, the cantilever arm will bend as topographical features of the sample move under the tip.

Typical prior art is described in U.S. Pat. Nos. 4,724,318 and 4,800,274. In these patents, microscopes are described in which the detection of cantilever arm bending is accomplished by a second probe which is suspended over the first probe. The second probe detects changes in a tunneling current flowing from the first probe to the second probe. Measurable changes in this tunneling current result when the distance between the first probe and the second probe changes as the cantilever portion of the first probe moves up and down in response to the presence of topographical features of the sample moving under the first probe tip.

Subsequent patents of the prior art describe optical detectors which use only a first probe and use either light interference or light beam deflection (optical lever) to detect the bending of the probe cantilever arm due to the interaction of the forces between the surface and probe tip. The interference method is described by Y. Martin, et al, in the publication, J. Appl. Phys. 61,4723, (1987).

The optical lever method is described by O. Marti, B. Drake, and P. K. Hansma, in the publication Appl. Phys. Letters 51,484 (1984). Further, U. S. Pat. Nos. 4,935,634 and 5,025,658 describe optical detection schemes in which a sample is moved in a rastered motion under the probe.

The optical lever method of detecting the probe deflection utilizes a narrow beam of light directed toward the probe. Probe deflections caused by the changing topography of the sample surface result in changes in the angle of the reflected light beam. This change is detected by means of photodiodes. The light source may be a laser device. A pair of photo-diodes are placed in close proximity to each other and form a bicell.

As the reflected light from the probe shines on the diodes, and as the probe cantilever arm moves up or down, the proportion of the light on each of the photo-diodes will change. This change is used to determine the amount of bending of the cantilever arm, thus indicating a change in the relative distance or force between the probe tip and the surface being examined.

The prior art also teaches that the sample, whose surface is to be examined, may be attached to a motion controlling device, typically a piezoelectric cylinder, the end of which moves the sample back and forth in both the X and Y directions in a rastering motion underneath the probe. Further, using the signals generated by the photo-diodes, the device moving the sample in X and Y may also control the Z direction, or height.

The photo-diode signals are typically subtracted to create a difference signal. The set-point value will then establish a constant probe deflection value. The subtraction of the difference signal from the set-point value results in an error signal. This signal is routed through feedback conditioning means to create a correction signal.

The feedback conditioning means may be either an analog circuit or a digital circuit using computing means such as is described by Hanselmann in "Implementation of Digital Controllers—A Survey" Automatica, Vol. 23 No 1, 1987. Digital control also is described in U.S. Pat. No. 4,889,988 dated Dec. 26, 1989, reissued as U.S. Pat. No. RE 34,331 on Aug. 3, 1993.

The correction signal is, in turn, routed to the motion control device such that the control device keeps the cantilever arm at a constant bend angle. Consequently, the force between the probe tip and the sample surface remains essentially constant even though the topography of the sample is changing under the probe tip.

Stated differently, the probe cantilever arm is maintained at a constant deflection. The correction signal is then an indication of the surface profile. The correction signal may also be filtered or conditioned to produce a second signal which can enhance certain surface profile features.

The prior art thus described provides X and Y raster signals and a Z signal indicating the surface profile. These three signals are sufficient to give surface topographical information. Persons skilled in the art recognize that the signals thus generated can be digitized and displayed by a computer with the topography displayed in various representations.

Certain distortions in the image can be corrected in computer software. Software algorithms can be employed to correct curvature in the image caused by the arc traced by the probe as it swings from side to side instead of traversing the surface of the sample in a flat plane, as would be the ideal case.

The prior art system thus described has several shortcomings. Since the sample is moved, and as each sample may have a different mass, it may be necessary to change the feedback loop parameters, or the raster speed, or both with changes of sample in order to preserve loop stability. Also the motion producing device has only limited available force to move the sample. Therefore, large samples can only be examined when cut or broken into smaller fragments.

It would, therefore, be desirable to have the probe move over the sample in a rastering fashion, rather than moving the sample under the probe. As the probe moves in X and Y directions, it will be deflected in the Z (vertical) direction as it passes over the surface features. With prior art beam deflection (optical lever) systems this is not possible, since the raster motion of the probe moves the probe away from (out of) the light path thereby depriving the photo-diodes of information representing the signal. The feedback loop is also isolated from the optical information relating to the probe motion.

Although it is possible to make the light spot so large that the probe can always remain inside the circle of light, even when the probe is rastered, reflections from the sample surface will interfere with the portion of light reflected from the probe. Moreover, the light energy density inside the circle must be constant. With a large light spot, the intensity of reflected light may be so low as to require image intensifiers at the photodiode.

In variations of the prior art, the cantilevered portion of the probe may be intentionally excited into resonance by signals to the motion controller. In this case, as the probe tip is brought near the surface, the resonance changes and this change is used to generate a signal which controls the feedback loop to the motion controller.

This form of the prior art has advantages since the topology of the surface may be measured with less lateral force on the tip. Consequently, with some samples, the resultant image is a more accurate representation of the surface. The reduced lateral force results from the fact that the tip is momentarily pulled away from the surface during one half of the oscillatory cycle. Should the tip encounter a steep vertical feature on the sample surface, it does not experience as much lateral force since it is further away from the surface.

SUMMARY OF THE INVENTION

According to the present invention a scanning force microscope utilizes means for steering the light beam to follow the raster motion of the probe. Means are provided to correct for the aberrations that would otherwise appear in the image signal due to the changing incident angle of the light beam on the probe. In one variation of the present invention a non-moving image of the moving probe is produced by optical components of the device used to steer the light beam.

The means for steering the light beam may include a less combined with a motion controller. The motion controller is preferably in the shape of a cylindrical piezo-ceramic tube and means for moving the tube may reside inside the tube. A lens is positioned inside the tube such that the light beam is directed toward the moving cantilever arm. The means for steering the light beam may also include a mirror combined with the motion controller such that the light beam is directed toward the moving cantilever arm.

The path of the beam, as it is reflected back from the probe, is controlled such that an image of the probe is formed at a separate location. The lens focuses the incoming light beam on or nearly on the probe. The reflected light in this case is reflected at twice the incident angle of the incoming light beam.

The lens diameter is large enough so that the reflected light beam passes through the edge of the lens and is refracted and refocused. Additionally, if the reflected light is focused at or near a special position inside the tube, the image of the probe does not appear to move or to substantially move in the lateral direction, even though the probe itself is moving laterally.

This special position is determined by calculating the arc shaped by the piezo-ceramic tube when its tip is deflected from the rest position. Next, a tangent to the arc is drawn such that it touches the arc at the probe point. A similar tangent when the tip is deflected to a different point is then calculated. The intersection point of the two tangents indicates the position where the optical steering system should create an image of the probe.

Directing the light beam to follow the movement of the probe results in a change in the position of the light spot on the photo-diodes. Ordinarily such a change results from the change in the deflection angle of the probe as it follows changes in the Z value of the surface features. The changes in photo-diode output resulting from a change in Z are interpreted as the Z value for the subsequent image generation.

Since a change also results from the light beam following the X and Y motion of the probe, it follows that there can be a false value which is added to the resulting image. This change of photo-diode output due to the changing angle of the laser beam, however, is very small compared to the change in probe angle caused by the relative motion between the sample surface features and the probe.

Further, even the small amount of image distortion caused by the X and Y motion of the light beam as it follows the probe can be corrected. Means for correcting this aberration may be a computer and software algorithm which processes the aberrated signal after that signal is generated by the photo-diodes. This software algorithm utilizes the known X and Y raster signal values and the Z value reported by the feedback system. The algorithm makes a correction in the image value for Z.

Since the angle causing the distortion for any particular X and Y value is known, the apparent change in Z due to the change in reflection angle caused by the displacement in X or Y can be calculated. The result can be added to or subtracted from the apparent Z value to give a true Z value.

The advantages of the present invention and its variations are most evident when changing from one sample to another sample with a different mass. Since the mechanical parameters of the feedback loop remain essentially constant in the present invention, it is not necessary to experiment with new feedback loop parameters for each sample change. Further, the force microscope may now be used to image samples of virtually any size without the need to cut or break the samples into the small low mass size that can be translated or rastered by the prior art devices.

The novel features which are characteristic of the invention, both as to structure and method of operation thereof, together with further objects and advantages thereof, will be understood from the following description, considered in connection with the accompanying drawings, in which the preferred embodiment of the invention is illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only, and they are not intended as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a simplified diagram of a prior art microscope using a laser beam deflection system;

FIG. **2** is a diagram of a scanning microscope system according to the present invention;

FIG. **3** shows an alternative embodiment of a microscope system according to the present invention; and

FIG. **4** shows a second alternative embodiment of a microscope system according to the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to FIG. **1**, a scanning force microscope system **10** according to the prior art is shown. As seen, a light source **12** which may be a laser, directs its light to a lens **14**. The light beam is focussed on a probe **16** which takes the form of a lever **18**. The lever **18** is mounted such that it does not move in the lateral or X and Y directions but is capable of motion in the vertical or Z direction. The lever **18** has a pointed tip **20** on the side facing a sample **22**.

The sample **22** is mounted on a free end **24** of a piezo-electric element **26** which, in this embodiment, has a cylindrical shape and is capable of motion in the vertical or Z direction. The focussed light beam reflects from the free end of the lever **18** and is directed to a photo-diode bicell **27** which includes a first photo-element **28** and a second photo-element **30**. These photo-elements may be photo diodes.

Probe motion in the vertical or Z direction is detected when the reflected light beam moves from one photo-element **28** to the other element **30**. Signals from the photo-detector elements **28,30** are applied to a differential amplifier **32** to form a difference signal which is applied to a feedback system **34**.

The feedback system **34** generates a correction signal which is applied to the piezo-electric element **26** to cause it to expand or contract in the Z direction in a predetermined manner in order to maintain a desired spacing or force between the probe tip **20** and the sample **22**. The correction signal sent to the piezo-element **26** may also be used as an indication or representation of the surface topography of the sample **22**.

The present invention is described with reference to FIG. **2**. A force microscope system **40** includes a light source **42**, preferably a laser **44**. The laser **44** output beam **46** is directed through a lens **48**. The lens **48** allows the beam to be focused at or near a point **50** where the reflected light intersects with the directed light.

The light beam **46** diverges after it passes point **50** and is further directed through a second lens **56** which focuses the light on or near a probe **52** which has a scanning tip and a lever **54** with a reflective upper surface. The second lens **56** is mounted in a scanning element **58**, the free end of which is capable of translational motion substantially in the X-Y plane as well as motion in the vertical or Z direction.

The returning beam is then returned to point **50** which has been chosen to be the location where an image of the probe **52** is formed. Point **50** is further chosen to be located at a point where the image of the probe **52** does not appear to move in either the X or the Y direction even though the probe **52** and the second lens **56** can move in both the X and Y direction. This point is the point where tangents to the arc traced by the bending axis of the scanning element **58**, intersect when such tangents are drawn from the point where the scanning element **58** axis and the lever **54** intersect.

The scanning element **58** is in the form of a cylinder which "bends" relative to a central axis under the influence of applied X and Y raster signals. The probe **52** is attached at the "free" end of the scanning element **58** and is consequently "rastered" over the surface **60** of a sample **62** by the bending motion of the scanning element **58**. The lens **56** also moves as a result of its attachment to the scanning element **58**.

The sample **62** is fixed to a base **64** and need not move. The light beam **46** is reflected off the reflective surface of the lever **54** and is directed back through the edge of the correcting lens **56**. The lens **56** directs the light beam **46** to refocus at or near point **50** which subsequently begins to diverge.

Light beam **46** then proceeds to impinge upon a detector **66** which is comprised of photo-detector elements **68**, **70**. The signals from the photo-detectors **68**, **70** are subtracted from each other in a difference amplifier **72**. A difference signal is formed which is in turn applied to a feedback circuit **74**. After proper conditioning, a correction signal is generated which drives the scanning element **58** in the Z direction to maintain proper distance and/or force between the tip of lever **54** and the sample surface **60**.

FIG. **3** Shows an alternative embodiment of the present invention which utilizes an upper mirror to permit off axis placement of a light source. In this embodiment, a first mirror **80** is mounted to a structure **82** which is mounted to a scanning device **84**. Scanning device **84** is a piezo-electric cylinder which bends relative to a central axis under the influence of applied X and Y raster signals thereby moving the free end in the X and Y directions. The scanning device **84** can also be made to move in the vertical or Z direction, as well.

A light source **86**, preferably a laser **88**, creates a light beam **90** which is directed through a lens **92**. Lens **92** focuses the beam **90** at or near the reflective upper surface of a probe lever **94**. Probe lever **94** is mounted to the free end of the scanning device **84**.

Mirror **80** is located in a specified position within the structure **82** such that it does not (or nearly does not) translate in directions X and Y with the bending of the scanning device **84**. However, mirror **80** rotates as the scanning device **84** bends. As a result of this rotation, the beam **90** moves in such a fashion as to follow the probe lever **94** as it translates in directions X and Y over a sample **96** which is rigidly attached to a base (not shown).

The reflected light beam returns from the probe lever **94** at a reflected angle which is equal to the incident angle of the light beam on the probe lever **94**. This reflected beam strikes a mirror **98** which is attached to the scanning element **84**. In this manner the reflected beam returns to the upper first mirror **80** and is then directed to the photo-diodes **100** and **102**.

Photo-diode signals are sent to difference amplifier **104**. The difference signal output is applied to feedback element **106** whose output signal may be considered a correction signal for the Z motion of the scanning element **84**. Alternatively, this signal may be used as the image signal corresponding to the Z displacement of the probe lever **94**. The secondary mirror **98** may be replaced by an optical wedge to produce the same effect by refracting light back toward the upper mirror **80**.

FIG. **4** shows a second alternative embodiment of a scanning force microscope **110** according to the present invention. In this embodiment, an extender **112**, which in itself does not distort under the raster signals X and Y or under the Z signal, is attached to a scanning device **114**. The extender **[110]** *112* serves two purposes. It extends the X and Y motion range of a probe lever **116** which is mounted to the free end of the extender **[110]** *112* and it is a support for a lens **118**.

In this way, the lens **118** and the probe lever **116** rotate about a fixed point **120** as the scanning device **114** moves in the X and Y directions.

As in other embodiments a reflected beam **122** forms an image **124** of the probe lever **116** at a point which does not appear to move in the X and Y directions, notwithstanding that the probe lever **116** moves in the X and Y directions. In this embodiment, a wedge shaped optical element **126** has *been* added to offset and rotate the incoming light beam **128** as well as the light beam **122** which is reflected from the probe lever **116**. This rotation compensates for the angle from the horizontal at which probe lever **116** may be mounted. Such an angle is convenient in order to prevent points of the probe lever **116** other than the tip from touching the sample **130** surface. By positioning light beam **128** on one side of the lens **118**, the optical element **126** can be eliminated.

As will be appreciated by those skilled in the art, this rastered probe scanning force microscope **110** can be placed on large structural samples **130** and can then be used to image various areas of the surface of large objects such as mirrors, lenses, and structural members, by scanning locally at selected locations to investigate the surface features with the probe lever **116**.

The rastered probe force microscope **110** can be mounted on a support structure (not shown) which, in turn, can rest on the sample **130** and can be moved around over the sample **130**. By this method, composite mosaic images can be created from the surface of very large samples.

In further variations of the present invention, four or more photo-diodes **132** can be employed such that twisting or torque applied to the probe lever **116** can be detected, as well as any vertical deflection of the probe lever **116**, as described above.

The present invention may also be used with means *134, 136, 138* for exciting a probe into vibration at or near its resonant mode such that, as the probe nears the sample surface, changes in the resonant parameters (such as amplitude or phase) may be detected and used as a signal to control the Z displacement of the scanning device.

Others skilled in the art may devise different and alternative embodiments of the present invention. Accordingly, the scope of the invention should be limited only by the claims presented below.

What is claimed as new is:

1. A scanning force microscope device comprising in combination:

a. a sensing probe having a substantially reflective surface on one side and a scanning tip on the opposite side, said tip adapted to be positioned adjacent a surface to be scanned;

b. illuminating means positionally decoupled from said sensing probe and independent of probe motion for generating a radiant energy beam and for applying said beam to said reflective surface;

c. position control means coupled to said sensing probe for moving said scanning tip substantially parallel to a surface to be scanned in a predetermined pattern and for moving said scanning tip orthogonal to the surface to follow the contours of the surface;

d. beam positioning means adapted to receive said radiant energy beam from said illuminating means for directing said radiant energy beam to said reflective surface to follow said sensing probe through lateral motion of said probe; and

e. detector means adapted to receive the energy beam reflected from said reflective surface *through said position control means* and operable in response to movement of said reflected energy beam corresponding to position changes of said sensing probe relative to the surface to be scanned to produce a motion representing signal corresponding to tip movement following the contours of the scanned surface,

whereby tip motion in a direction orthogonal to scanning motion results in a series of electrical signals corresponding to and representative of the surface contours of the scanned surface. [surface.]

2. The microscope device of claim **1** wherein said illuminating means include a laser.

3. The microscope device of claim **1** wherein said illuminating means include a lens for focussing said energy beam to said reflective surface.

4. The microscope device of claim **3** wherein said lens narrowly focuses said radiant energy beam at said scanning probe reflective surface.

5. The microscope device of claim **1** wherein said detecting means are comprised of at least two photodetecting cells.

6. The microscope device of claim **1** further including compensating means for correcting for errors at said detection means resulting from lateral movement of said reflective surface.

7. The microscope device of claim **6** wherein said compensating means include a lens and further include computer means employing software algorithms operable in response to applied detector means signals for compensating for errors arising from scanning tip lateral movement.

[**8**. The microscope device of claim **1** wherein said beam positioning means include a directing lens and lens moving means independent of said position control means for moving said lens in coordination with tip motion.]

9. The microscope device of claim **1** wherein said beam positioning means include a directing mirror and mirror moving means independent of said positioning means for moving said mirror in coordination with tip motion.

10. In a scanning force microscope having a sensitive probe with a tip mounted for movement in response to relative vertical distance changes between the sensing tip and a sample surface as the tip moves laterally with respect to the sample surface, apparatus for sensing the vertical movement of the tip relative to the surface being scanned and for creating a signal representative of such vertical movement comprising:

a. a reflective surface carried by the sensitive probe tip;

b. an energy source positionally decoupled from lateral movement of the sensitive probe tip for emitting a radiant energy beam including [focussing] *focusing* means for applying said beam to said reflective surface;

c. control means for moving the sensitive probe tip laterally in a raster fashion over the surface of a sample to be scanned and including beam directing means for causing said radiant energy beam to follow the motion of the probe tip;

d. driving means for moving the sensitive probe tip in a vertical direction towards and away from the surface of the sample to be examined; and

e. detection means positioned to receive said energy beam *through said control means* after reflection from said reflective surface for signalling changes in the beam position, said changes corresponding to and representative of vertical displacement of the sensitive probe tip during raster motion over the sample surface.

11. In a scanning force microscope having a sensitive probe with a tip mounted for movement in response to relative vertical distance changes between the sensing tip and a sample surface as the tip moves laterally with respect to the sample surface, apparatus for sensing the vertical movement of the tip relative to the surface being scanned and for creating a signal representative of such vertical movement comprising:

f. a reflective surface carried by the sensitive probe tip;

g. an energy source for emitting a radiant energy beam including directing means for applying said beam to said reflective surface;

h. control means for moving the sensitive probe tip laterally in a raster fashion over the surface of a sample to be scanned and including beam directing means for causing said radiant energy beam to follow the motion of the probe tip;

i. driving means for moving the sensitive probe tip in a vertical direction towards and away from the surface of the sample to be examined;

j. means for creating an image of said probe in space at a point in space such that said image does not appear to move when said probe is moved; and

k. detection means positioned to receive said energy beam after reflection from said reflective surface for signalling changes in the beam position, said changes corresponding to and representative of vertical displacement of the sensitive probe tip during raster motion over the sample surface.

12. The microscope device of claim **11** further including compensating means including computer means responsive to the raster location of the sensitive probe tip relative to the sample surface and the distance between said energy source, said control means, the sensitive probe tip and said detection means for correcting beam positional errors.

13. The microscope device of claim **11** wherein said energy source is a laser.

14. The microscope device of claim **11** wherein said detecting means include at least two photodetecting cells.

15. In a scanning force microscope having a sensitive probe with a tip mounted for movement in response to relative vertical distance changes between the sensing tip and a sample surface as the tip moves laterally with respect to the sample surface, apparatus for sensing the vertical movement of the tip relative to the surface being scanned and for creating a signal representative of such vertical movement comprising:

a. a reflective surface carried by the sensitive probe tip;

b. an energy source for emitting a radiant energy beam including directing means for applying said beam to said reflective surface;

c. control means for moving the sensitive probe tip laterally in a raster fashion over the surface of a sample to be scanned and including beam directing means for causing said radiant energy beam to follow the motion of the probe tip;

d. driving means for moving the sensitive probe tip in a vertical direction towards and away from the surface of the sample to be examined;

e. detection means positioned to receive said energy beam after reflection from said reflective surface for signalling changes in the beam position, said changes corresponding to and representative of vertical displacement of the sensitive probe tip during raster motion over the sample surface; and

f. a lens system attached to a deformable ceramic transducer having an axis to create an image of the probe substantially at a selected point along the axis of said transducer at which the probe image appears to be stationary, notwithstanding lateral movement of the probe.

16. The microscope device of claim **15** wherein said deformable transducer is a cylinder.

17. The microscope device of claim **15** wherein said selected point is the midpoint of the transducer axis.

18. The microscope device of claim **15** further including a mirror system attached to a deformable ceramic transducer having an axis to create an image of the probe substantially at a selected point along the axis of said transducer at which the probe image appears to be stationary, notwithstanding lateral movement of the probe.

19. In a scanning force microscope having a sensitive probe tip mounted for vertical movement in response to relative force changes between the tip and a sample surface as a function of the relative lateral motion of the tip over the sample surface, apparatus for sensing vertical movement of the tip and for creating signals representative of such tip movement corresponding to sample surface contours as a function of lateral position comprising:

a. a reflective surface carried by the sensitive probe tip;

b. a light source for emitting a radiant energy beam;

c. directing means for applying said beam to said reflective surface;

d. scanning means for moving the sensitive probe tip in a raster fashion over the sample surface in a plane substantially parallel to the sample surface;

e. deploying means for moving the sensitive probe tip in a vertical direction relative to the sample surface;

f. steering means for moving said light beam in coordination with the raster motion of the sensitive probe tip; and

g. detection means isolated from and independent of probe tip movement responsive to the light beam reflected from said reflective surface *through said scanning means* for signalling changes in light beam position resulting from movement of the sensitive probe tip,

whereby detection mean output signals correspond to and are representative of the vertical motion of the sensitive probe tip and represent the contours of a scanned surface.

20. In a scanning force microscope having a sensitive probe tip mounted for vertical movement in response to relative force changes between the tip and a sample surface as a function of the relative lateral motion of the tip over the sample surface, apparatus for sensing vertical movement of the tip and for creating signals representative of such tip movement corresponding to sample surface contours as a function of lateral position comprising:

a. a reflective surface carried by the sensitive probe tip;

b. a light source for emitting a radiant energy beam;

c. directing means for applying said beam to said reflective surface;

d. scanning means for moving the sensitive probe tip in a raster fashion over the sample surface in a plane substantially parallel to the sample surface;

e. deploying means for moving the sensitive probe tip in a vertical direction relative to the sample surface;

f. steering means for moving said light beam in coordination with the raster motion of the sensitive probe tip;

g. detection means responsive to the light beam reflected from said reflective surface for signalling changes in light beam position resulting from movement of the sensitive probe tip; and

h. means for creating an image of said probe in space at a point in space such that said image does not appear to move when said probe is moved, whereby detection mean output signals correspond to and are representative of the vertical motion of the sensitive probe tip and represent the contours of a scanned surface.

21. The microscope device of claim **20** including a lens system attached to a deformable ceramic transducer having an axis, said lens system creating said image of the probe substantially at a selected point along the axis of said transducer at which point said probe image appears to be stationary, notwithstanding lateral movement of the probe.

22. The microscope device of claim **20** wherein said energy source is a laser.

23. The microscope device of claim **20** wherein said detecting means include at least two photodetecting cells.

24. The scanning force microscope of claim **20**, wherein said steering means include mirror elements.

25. The scanning force microscope of claim **20**, wherein said steering means include lens elements.

26. The scanning force microscope of claim **20**, wherein said steering means include mirror elements and lens elements to direct said light beam from said light source to said reflective surface of the sensitive probe tip.

27. A scanning force microscope comprising:

- *a. a reflective sensing probe;*
- *b. means for scanning the sensing probe in relationship to a surface to be scanned;*
- *c. a radiant energy source for applying an energy beam to the sensing probe during scanning;*
- *d. a detector responsive to the radiant energy beam reflected from the sensing probe during scanning for determining information related to the surface to be scanned, and*
- *e. optical means for maintaining a first focal point in the radiant energy beam fixed with respect to the radiant energy source or the detector and a second focal point fixed with respect to the sensing probe.*

28. The scanning force microscope of claim 27, wherein the first focal point is fixed with respect to the radiant energy source.

29. The scanning force microscope of claim 27, wherein the first focal point is fixed with respect to the detector.

30. The scanning force microscope of claim 27, wherein the first focal point is fixed with respect to both the detector and the radiant energy source.

31. The scanning force microscope of claim 30, wherein the optical means further comprises:

means for guiding the radiant energy beam through the first focal point to the second focal point for reflection by the sensing probe and for guiding the reflected radiant energy beam from the sensing probe back through the first focal point to the detector.

32. The scanning force microscope of claim 31, further comprising:

means for exciting the probe into vibration at or near its resonance mode; and

means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected.

33. The scanning force microscope of claim 32, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detecting changes in the resonant parameters of the vibration.

34. The scanning force microscope of claim 32, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detection changes in the amplitude of the vibration.

35. The scanning force microscope of claim 32, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detecting changes in the phase of the vibration.

36. The scanning force microscope of claim 27, further comprising:

means for exciting the probe into vibration at or near its resonance mode; and

means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected.

37. The scanning force microscope of claim 36, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detecting changes in the resonant parameters of the vibration.

38. The scanning force microscope of claim 36, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detection changes in the amplitude of the vibration.

39. The scanning force microscope of claim 36, wherein the means for detecting changes in the sensing probe vibration further comprises:

means for detecting changes in the phase of the vibration.

40. A scanning force microscope for determining information about a surface to be scanned, comprising:

- *a. a sensing probe;*
- *b. means for moving the sensing probe in relationship to the surface to be scanned;*
- *c. means for exciting the probe into vibration at or near the probe's resonance mode; and*
- *d. means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected, including means for detecting changes in the resonant parameters of the vibration.*

41. A scanning force microscope for determining information about a surface to be scanned, comprising:

- *a. a sensing probe;*
- *b. means for moving the sensing probe in relationship to the surface to be scanned;*
- *c. means for exciting the probe into vibration at or near the probe's resonance mode; and*
- *d. means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected, including means for detecting changes in the amplitude of the vibration.*

42. A scanning force microscope for determining information about a surface to be scanned, comprising:

- *a. a sensing probe;*
- *b. means for moving the sensing probe in relationship to the surface to be scanned;*
- *c. means for exciting the probe into vibration at or near the probe's resonance mode; and*
- *d. means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected, including means for detecting changes in the phase of the vibration.*

43. A scanning force microscope for determining information about a surface to be scanned, comprising:

- *a. a sensing probe;*
- *b. means for scanning the sensing probe in relationship to the surface to be scanned;*
- *c. means for exciting the probe into vibration at or near the probe's resonance mode;*
- *d. means for detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected;*
- *e. a light source for applying light to said sensing probe.*

44. The invention of claim 43, further comprising:

means for detecting light reflected from said sensing probe.

45. A method for determining information from a surface to be scanned comprising the steps of:

- *a. scanning a reflective sensing probe in relationship to the surface to be scanned;*

c. applying an energy beam from an energy source to the sensing probe during scanning;

d. determining information related to the surface to be scanned by applying a portion of the energy beam reflected by the sensing probe to a detector; and

d. during scanning, maintaining a first focal point in the energy beam fixed with respect to the energy source or the detector and a second focal point fixed with respect to the sensing probe.

46. The invention of claim 45, wherein the step of maintaining the first focal point further comprises the step of:

maintaining the first focal point fixed with respect to the radiant energy source.

47. The invention of claim 45, wherein the step of maintaining the first focal point further comprises the step of:

maintaining the first focal point fixed with respect to the detector.

48. The invention of claim 45, wherein the step of maintaining the first focal point further comprises the step of:

maintaining the first focal point fixed with respect to the detector and energy source.

49. The invention of claim 48, further comprising the steps of:

guiding the radiant energy beam through the first focal point to the second focal point for reflection by the sensing probe; and

guiding the reflected radiant energy beam from the sensing probe back through the first focal point to the detector.

50. The invention of claim 49, further comprising the steps of:

exciting the probe into vibration at or near its resonance mode; and

detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected.

51. The invention of claim 50, wherein the step of detecting changes in the sensing probe vibration further comprises the step of:

detecting changes in the resonant parameters of the vibration.

52. The invention of claim 50, wherein the step of detecting changes in the sensing probe vibration further comprises the step of:

detecting changes in the amplitude of the vibration.

53. The invention of claim 50, wherein the step of detecting changes in the sensing probe vibration further comprises:

detecting changes in the phase of the vibration.

54. The invention of claim 50, further comprising the step of:

exciting the probe into vibration at or near its resonance mode; and

detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected.

55. The invention of claim 54, wherein the step of detecting changes in the sensing probe vibration further comprises the step of:

detecting changes in the resonant parameters of the vibration.

56. The invention of claim 54, wherein the step of detecting changes in the sensing probe vibration further comprises the step of:

detecting changes in the amplitude of the vibration.

57. The invention of claim 54, wherein the step of detecting changes in the sensing probe vibration further comprises the step of:

detecting changes in the phase of the vibration.

58. A method for determining information about a surface to be scanned, comprising the steps of:

moving a sensing probe in relationship to the surface to be scanned including the steps of: mounting the sensing probe adjacent a moving end of a motion generation, supporting the motion generator adjacent a fixed end thereof, and providing an optical path between the fixed and moving ends;

exciting the probe into vibration at or near the probe's resonance mode; and

detecting changes in the sensing probe vibration resulting from proximity of the sensing probe to the surface to be detected; and

mounting a light source in said optical path mounted adjacent said fixed end to apply light to the sensing probe.

59. The invention of claim 58, further comprising the step of:

detecting light reflected from said sensing probe.

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