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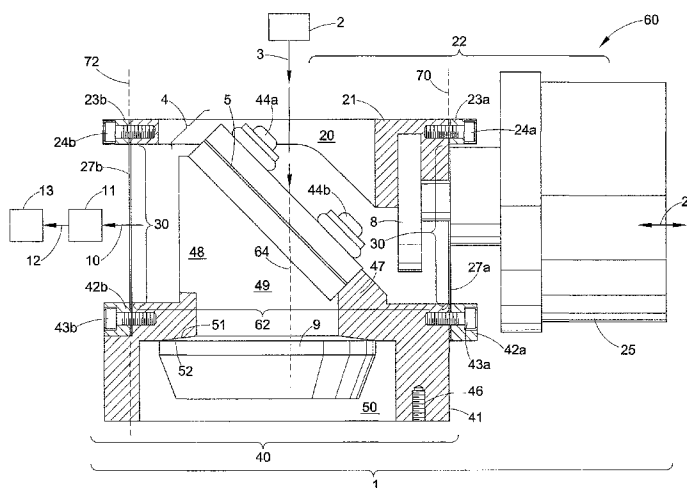
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[Continued on next page]

(54) Title: INTERFEROMETER MAINTAINING OPTICAL RELATIONSHIP BETWEEN ELEMENTS



(57) Abstract: An interferometer (1) for Fourier transform infrared spectroscopy includes a fixed assembly (40) including a housing (41), a beam splitter (4), and a mirror (9) fixedly positioned relative to each other. A movable assembly (22) includes a housing (21), a mirror (8), and a motor coil (25), fixedly positioned relative to each other. A first flat spring (27a) has an opening for providing an unobstructed optical path of radiation therethrough. A first end of the first flat spring is secured to the fixed assembly and a second end of the first flat spring is secured to the movable assembly for providing movement of the movable assembly relative to the fixed assembly via the first flat spring. An optical relationship between the beam splitter, the mirror of the fixed assembly, and the mirror of the movable assembly is maintained independent of a distance between the movable assembly and the fixed assembly.

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INTERFEROMETER MAINTAINING OPTICAL RELATIONSHIP BETWEEN ELEMENTS

Background

[0001] The present invention relates to interferometers. It finds particular application in conjunction with maintaining alignment of interferometers and will be described with particular reference thereto. It will be appreciated, however, that the invention is also amenable to other applications.

[0002] Michelson interferometers are known and have been used in many commercial applications. Also well known is that slight misalignment of the optical elements cause modulation changes that can significantly affect the performance of the interferometer. There have been numerous attempts in the design of commercial interferometers, Michelson interferometers included, to assure that either misalignments have been reduced, or that effects of misalignments have been reduced. Some of these attempts include passive means such as using cube corner mirrors, retro-mirrors, and/or other means to compensate undesirable effects. Others have used active means such as dynamic mirror alignment or active thermal control, among others. Alternatively, readily accessible adjustment mechanisms are made available to the user or maintainer of the interferometer that allows for periodic or necessary reestablishment of the relationships of the optical components to maintain an acceptable alignment condition.

[0003] The functioning of a Michelson interferometer is well known, based on the design of Michelson in 1891. Griffiths and deHaseth begin their book "Fourier Transform Infrared Spectroscopy" describing the operation of the Michelson interferometer. It is necessary to have a movable mirror that maintains its perpendicularity and flatness to a wave front while the mirror is moving or has moved to

a new position. Any short or long term change (commonly referred to as optical instability) in the perpendicularity or flatness of either the fixed or movable mirrors to the wave front may produce compromised results. Similar results occur if the beam splitter changes flatness or angle relative to the wave front. While the effects of mirror misalignment are described in the Griffiths and deHaseth book, the authors make little attempt to address the specifics of the underlying causes of optical instability or loss of modulation efficiency.

[0004] Historically, interferometers have been designed with significant mass and thermal capacity for the purposes of reducing the misalignment effects of mechanical, acoustic, and thermal disturbances. Obviously, instruments using massive interferometers are not easily portable, or even easily movable at best. More recently there have been instruments designed for portability and which are designed to maintain alignment. One such instrument, described by Korb, et al., (Applied Optics, 1 April 1996) and patented by Dybwad (US Patent No. 5,173,744) is reported to have been used for 3 years without the need for realignment. Unfortunately, the instrument and interferometer described therein requires the use of infrared transmitting prisms that require very stringent manufacturing tolerances, resulting in significant manufacturing costs.

[0005] More recently Simon et al. (US Patent No. 5,309,217) invented an interferometer using a pivot and retro-reflectors. Although the Simon et al. patent states the interferometer is stable, easily aligned, and a compact configuration, the invention presented in that patent requires a plurality of additional mirror surfaces and an increase in associated path length that significantly contributes to optical instability resulting from thermal change. Furthermore, the added optical elements and associated structure certainly challenge the use of the word "compact."

[0006] Flat spring/bearings have been used with interferometers. However, until now, such flat spring/bearings have required periodic realignment when significant temperature changes occur in the interferometer's operating environment. Although the means for realignment is typically achieved by means of an automatic alignment algorithm, actuated through precision stepper motors, the need for a realignment often

occurs at inopportune times, which causes significant user inconvenience and/or frustration. In addition, significant costs (both monetary and space) are incurred to effect realignments.

[0007] The present invention provides a new and improved compact and portable interferometer system that maintains a condition of substantially permanent alignment without the need for expensive prisms or additional expensive optical elements.

Summary

[0008] An interferometer for Fourier transform infrared spectroscopy includes a fixed assembly including a housing, a beam splitter, and a mirror fixedly positioned relative to each other. A movable assembly includes a housing, a mirror, and a motor coil, fixedly positioned relative to each other. A first flat spring has an opening for providing an unobstructed optical path of radiation therethrough. A first end of the first flat spring is secured to the fixed assembly and a second end of the first flat spring is secured to the movable assembly for providing movement of the movable assembly relative to the fixed assembly via the first flat spring. An optical relationship between the beam splitter and the mirror of the movable assembly is maintained independent of a distance between the movable assembly and the fixed assembly.

Brief Description of the Drawings

[0009] In the accompanying drawings which are incorporated in and constitute a part of the specification, embodiments of the invention are illustrated, which, together with a general description of the invention given above, and the detailed description given below, serve to exemplify the embodiments of this invention.

[0010] **FIGURE 1** illustrates a cross-sectional side elevational view of optical elements in a first embodiment of the present invention;

[0011] **FIGURE 2** illustrates a cross-section side elevational view of the first embodiment of the present invention;

[0012] **FIGURE 3** illustrates a front elevational view of spring pairs used in the first embodiment of the present invention; and

[0013] **FIGURE 4** illustrates an isometric cross-sectional view showing detail of a fixed mirror and mechanism for affixing it to a fixed interferometer housing.

Detailed Description of Illustrated Embodiment

[0014] With reference to **FIGURES 1 and 2**, optical elements, including a beam splitter **4**, a movable mirror **8**, and a fixed mirror **9**, in an interferometer **1** are illustrated according to a first embodiment of the present invention. Infrared radiation **3** from a source of infrared radiation **2** is directed to the beam splitter **4**, which includes a beam splitting surface **5**. In one embodiment, the interferometer is used for Fourier transform infrared (FTIR) spectroscopy. The infrared radiation **3** is split by the beam splitting surface **5** into a reflected portion **6a** and a transmitted portion **7a**. The reflected portion **6a** continues on to the movable mirror **8**, which reflects the reflected portion **6a** back onto itself as a reflected beam **6b** that returns to the beam splitting surface **5**. In a similar fashion, the transmitted portion **7a** continues on to a fixed mirror **9**, which reflects the transmitted portion **7a** back onto itself as a reflected beam **7b** that returns to beam splitting surface **5**. The reflected beams **6b**, **7b** are recombined at the beam splitting surface **5** and a portion of the reflected beams **6b**, **7b** is reflected as a recombined radiation beam **10**. The recombined radiation beam **10** then continues on to a sampling apparatus **11**. The sampling apparatus **11** modifies the recombined radiation beam **10** into a sample encoded radiation **12** as a function of a sample **11a** in the sampling apparatus **11**. The sample encoded radiation **12** continues on to a detection system **13**. The sample **11a** is identified as a function of the encoded radiation **12**.

[0015] When the respective optical distances from the beam splitting surface **5** to the mirrors **8**, **9** are substantially equal, the recombined radiation beam **10** remains in

phase, as there is no optical retardation. If the movable mirror **8** moves either closer to or further from the beam splitting surface **5**, but remains perpendicular to the reflected beam **6b** of the reflected portion **6a**, a retardation change is created. The retardation change modulates the recombined radiation beam **10**.

[0016] When using the interferometer **1** as part of a rapid scanning Fourier transform infrared (FTIR) system **60**, the movable mirror **8** is typically driven at a constant velocity so as to modulate the recombined radiation beam **10** in a known way that may subsequently be Fourier transformed to recover frequency information of the recombined radiation beam **10** and/or the sample encoded infrared radiation **12**.

[0017] If one or more of the optical elements including the beam splitter **4**, the movable mirror **8**, and/or the fixed mirror **9** change(s) position(s), or if the optical relationships change between the beam splitter **4**, the movable mirror **8**, and/or the fixed mirror **9**, some amount of modulation change occurs in the recombined radiation beam **10**. Such unintended changes in modulation produce unwanted effects and, therefore, are undesirable.

[0018] A fixed housing **41** acts as a structural member of a fixed housing assembly **40**. The fixed housing assembly **40** includes the beam splitter **4**, the fixed mirror **9**, clamps **42a**, **42b**, fasteners **43a**, **43b**, beam splitter fasteners **44a**, **44b**, and o-rings **45**. Multiple threaded holes **46** are provided for affixing the interferometer **1** to, for example, a frame, instrument housing, or base plate (not shown). A cavity **47** in the fixed housing **41** is provided to receive the beam splitter **4**. Holes **48**, **49** provide clearance for the recombined radiation **10** and the beam splitting radiation portions **7a**, **7b**.

[0019] The infrared radiation **3** from the source of infrared radiation **2** enters a movable housing **21** of the interferometer **1** via a through hole defined by a wall **20** in the movable housing **21**. The movable housing **21** is a structural member of a movable assembly generally noted by **22**, which includes clamp members **23a**, **23b**, fasteners **24a**, **24b**, the movable mirror **8**, and a motor coil assembly **25**. All components of the movable assembly **22** are rigidly fastened to the movable housing **21** to form a rigid unit

that moves together when actuated by an electromagnetic force **26** exerted on the motor coil assembly **25**. The electromagnetic force **26** is largely exerted either to the left or to the right as illustrated, depending on the polarity of the voltage exerted on the motor coil assembly **25**. The use of motor coils for driving movable mirrors of interferometers to achieve retardation (e.g., distance) between the fixed and movable assemblies **40**, **22**, respectively, is known in the art.

[0020] The movable assembly **22** is further rigidly affixed to flat spring/bearings **27a**, **27b** at each end of movable housing **21** via the clamp members **23a**, **23b** and the fasteners **24a**, **24b**. The two flat spring/bearings **27a**, **27b** are substantially the same size, shape, and thickness. Furthermore, when the spring/bearing **27a** is clamped by the clamp members **23a**, **42a** and the fasteners **24a**, **43a** to the movable housing **21** and the fixed housing **41**, and when the spring/bearing **27b** is clamped by the clamp members **23b**, **42b** and the fasteners **24b**, **43b** to the movable housing **21** and the fixed housing **41**, the spring/bearings **27a**, **27b** have substantially the same unrestricted active spring/bearing length **30**.

[0021] The clamp members **23a**, **23b**, **42a**, **42b** and the fasteners **24a**, **24b**, **43a**, **43b** act as a means to affix the flat springs/bearings **27a**, **27b** to the housings **21**, **41** while allowing movement between the movable and fixed assemblies **22**, **40**. In alternate embodiments, adhesives, braze solder, welding, epoxy, and extruded metal are used to affix the flat springs/bearings to the housings.

[0022] In the illustrated embodiment, the beam splitter **4**, the mirror **9** of the fixed assembly **40**, and the mirror **8** of the movable assembly **22** are positioned in a space between planes **70**, **72** containing the first and second flat springs **27a**, **27b** in their flat condition. The first and second flat springs **27a**, **27b** restrict movement of the movable assembly **22**. Because of the restricted movement, a plane containing the mirror **8** of the movable assembly **22** is parallel to all planes containing the mirror **8** of the movable assembly **22** at all retardations (e.g., distances) between the fixed and movable assemblies **40**, **22**, respectively, of interest so that the optical relationship between the beam splitter **4** and the mirror **8** of the movable assembly **22** remains substantially unchanged except for the retardation. In other words, the optical relationship between the beam splitter **4** and

the mirror **8** of the movable assembly **22** is maintained independent of a distance between the movable assembly **22** and the fixed assembly **40**.

[0023] The optical relationship between the beam splitter **4** and the mirror **8** of the movable assembly **22** is satisfied when an angle of a surface of the beam splitter **4** is maintained relative to an angle of a surface of the mirror **8** of the movable assembly **22**. Similarly, the optical relationship between the beam splitter **4** and the mirror **8** of the movable assembly **22** is satisfied when an angle of an axis of a beam, from the beam splitter **4** toward the mirror **8** of the movable assembly **22**, is maintained at a predetermined angle relative to the surface of the mirror **8** of the movable assembly **22**.

[0024] As discussed above, the beam splitter **4**, the mirror **9** of the fixed assembly **40**, and the mirror **8** of the movable assembly **22** are positioned in the space between planes **70**, **72** containing the first and second flat springs **27a**, **27b** in their flat condition. However, other embodiments in which one or more of the beam splitter **4**, the mirror **9** of the fixed assembly **40**, and the mirror **8** of the movable assembly **22** are not positioned in the space between planes **70**, **72** are also contemplated.

[0025] **FIGURE 3** illustrates the spring/bearing **27a**. It is to be understood that the spring/bearing **27a** is representative of the spring/bearing **27b**. With reference to **FIGURES 1–3**, the spring/bearing **27a** includes a substantially rectangular opening **31** for providing unrestricted transmission of the recombined radiation **10**. The rectangular opening **31** also provides appropriate modulus characteristics for both bearing the weight of the movable assembly and providing resistance to undesirable shocks, torques, and shears imposed by environmental forces. It is to be understood that changing the location of the source **2** with the sampling apparatus **11** and the detection system **13** is known to those in the art. Although the opening **31** is rectangular in the illustrated embodiment, it is to be understood that other embodiments including other shapes for the opening of the spring/bearing are also contemplated.

[0026] In the illustrated embodiment, the clamped areas **32** of the spring/bearing **27a** further align with the edges of the clamp members **23a**, **42a** (**23b**, **42b** for the spring/bearing **27b**) to define the unrestricted clamping length **30**. Clearance holes **33** are

provided for the fasteners **24a**, **43a** (**24b**, **43b** for the spring/bearing **27b**), and alignment holes **34** are provided to accommodate high tolerance pins (not shown) for precise positioning. Although the opening **31** is rectangular in the illustrated embodiment, it is to be understood that other embodiments are also contemplated in which the opening **31** is oblong, elliptical, circular, or any other shape that might improve robustness and/or stability.

[0027] With reference to **FIGURES 2 and 4**, the fixed mirror **9** is positioned in a fixed mirror cavity **50**. More specifically, a spherical surface portion **51** of the fixed housing **41** contacts a spherical surface portion **52** of the fixed mirror **9**. Six (6) adjustment screws, one of which is illustrated as **54**, contact a conical section **53** of the fixed mirror **9**. In one embodiment, the screws **54** are placed approximately symmetrically around a circumference of the conical surface **53**. In this manner, the screws **54** are used both to adjust the orientation of the fixed mirror **9** and, once the adjustment is complete, to rigidly affix the mirror **9** to the fixed housing **41**.

[0028] During use, the two primary sources of optical misalignment and instability are strains from mechanical and thermal stresses on the interferometer **1**. In one embodiment, the flat spring/bearings **27a**, **27b** are manufactured in matched sets and assembled to the movable and fixed assemblies **22**, **40**, respectively, to assure substantially precisely repeatable trajectories and relationships between the mirror **8** on the movable assembly **22** and the beam splitter/fixed mirror **4**, **9**, which remain precisely fixed relative to each other.

[0029] Using at least one pair of the flat springs **27a**, **27b** whose respective planes bound a space **62** that contains the interferometer optical elements (e.g., the beam splitter **4**, the movable mirror **8**, and the fixed mirror **9**) provides significant symmetry, minimum optical path lengths for the radiation, and minimum structural lengths. These features, along with the proper selection of materials, minimizes the effects of thermal changes in the surrounding spaces. The illustrated design further provides a clear optical path for input or output radiation and a mechanical means for conveniently driving the movable assembly **22** including the mirror **8** included therein. Simultaneously, the symmetry and

compactness of the flat springs **27a**, **27b** minimize strains from thermal and mechanical stresses. Significantly reduced strains results in significantly improved optical stability.

[0030] Temperatures change constantly and are typically unpredictable in many instrument operating environments. Interferometers that need to function in such environments typically need to (1) be isolated from the changes, (2) have compensation means to counteract the effects of the changes, and/or (3) be designed in such a way that the effects of such changes are minimized. Historically, interferometers have been designed to be isolated from environmental changes and to counteract the effects of environmental changes. The illustrated embodiment of the present invention helps reduce and/or minimize the effects of environmental changes.

[0031] In general, the dimensions of a substance increases as the temperature of the substance itself increases. This relationship is typically stated according to the following formula:

[0032]
$$L = L_o (1 + A (t - t_o))$$

where: L_o is the length of an object at temperature, t_o

A is the coefficient of linear expansion, and

L is the length of the object at temperature, t

[0033] The coefficient of linear expansion, A , is known and documented for most commonly known materials. In an infrared interferometer, the selection of the beam splitter material determines the useful frequency range of the instrument. One commonly used material, Zinc Selenide (ZnSe) has $A = 7.2 \times 10^{-6}/C$. When using a typical one inch diameter (25.4 millimeters) beam splitter, there is approximately 1.5 microns of diameter change for each ten degree change on the centigrade scale if the diameter is unrestricted. While this change appears relatively small, it is capable of creating enormous stresses if the beam splitter were constrained. For example, for a ZnSe beam splitter that is securely affixed to an aluminum housing (a very common practice in commercial FTIR's) the aluminum would attempt to change at approximately three times the rate of the ZnSe. The resulting stress, if not properly dissipated, could result in surface distortion and/or angular (e.g., tilt) change that could result in modulation change and instability.

[0034] In one embodiment, the fixed housing **41**, the movable housing **21**, the first and second flat springs **27a**, **27b**, the clamp members **23a**, **23b**, **42a**, **42b**, the fasteners **24a**, **24b**, **43a**, **43b**, and the mirrors **8**, **9** are steel. In addition, it is contemplated that the mirrors **8**, **9** include a metalized film for improved reflectivity in the infrared range.

[0035] Steel and titanium have coefficients of thermal expansion much closer to that of ZnSe. Therefore, using steel or titanium in place of aluminum for the housing would reduce the strain differential between the ZnSe and the housing. However, the benefit of improving strain differential by changing from aluminum to steel or titanium to overcome other factors such as shape, thermal conductivity, thermal absorption, and thermal emissivity, among others, has not been previously demonstrated. Presumably, the improved strain differential has alone not achieved improved results because other factors have been a major source of optical instability. In that regard, our invention strongly suggests that the roles of shape and symmetry are of equal, if not greater, importance than the role of differential coefficients of thermal expansion.

[0036] The illustrated embodiment of the present invention has established that combining highly symmetrical, minimum volume shapes and corresponding minimum path lengths for the interferometer reflected and transmitted portions **6a**, **7a**, respectively, and the reflected beams **6b**, **7b** has resulted in highly stable modulation over a wide temperature range. Minimizing differences between the coefficients of thermal expansion further improves optical stability.

[0037] With reference again to **FIGURE 2**, the illustrated embodiment shows the interferometer **1** is symmetrical about a plane **64**, which is located midway between the sides of the interferometer **1** and the plane of the sheet of paper on which the section shown in **FIGURE 2** is illustrated. Thermal changes to the flat spring/bearings **27a**, **27b** are substantially identical since the surface areas of the springs are substantially identical and are exposed to convection in much the same manner. The structural differences between optical components are held to a minimum, determined by the highest resolution possible for the interferometer, and for the beam splitter size being used.

[0038] While the present invention has been illustrated by the description of embodiments thereof, and while the embodiments have been described in considerable detail, it is not the intention of the applicants to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention, in its broader aspects, is not limited to the specific details, the representative apparatus, and illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of the applicant's general inventive concept.

I/We claim:

1. An interferometer for Fourier transform infrared spectroscopy, comprising:
 - a fixed assembly including a housing, a beam splitter, and a mirror fixedly positioned relative to each other;
 - 5 a movable assembly including a housing, a mirror, and a motor coil, fixedly positioned relative to each other; and
 - a first flat spring, having an opening for providing an unobstructed optical path of radiation therethrough, a first end of the first flat spring being secured to the fixed assembly and a second end of the first flat spring being secured to the movable assembly
 - 10 for providing movement of the movable assembly relative to the fixed assembly via the first flat spring, an optical relationship between the beam splitter and the mirror of the movable assembly being maintained independent of a distance between the movable assembly and the fixed assembly.
2. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 1, wherein, to maintain the optical relationship, a plane containing the mirror of the movable assembly is parallel to all planes containing the mirror of the movable assembly at respective distances between the movable assembly and the fixed assembly.
3. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 1, wherein the optical relationship between the beam splitter and the mirror of the movable assembly is satisfied when an angle of a surface of the beam splitter is maintained relative to an angle of a surface of the mirror of the movable assembly.
4. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 1, wherein the optical relationship between the beam splitter and the mirror of the movable assembly is satisfied when an angle of a beam, from the beam splitter toward the mirror of the movable assembly, is maintained at a predetermined angle relative to a
- 5 surface of the mirror of the movable assembly.

5. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 1, further comprising:

a second flat spring for providing at least one of i) an unobstructed optical path of radiation therethrough and ii) a clearance for at least one of the mirror of the movable assembly and the motor coil, a first end of the second flat spring being secured to the fixed assembly and a second end of the second flat spring being secured to the movable assembly.

6. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 5, wherein the second flat spring has an opening of substantially equal size, shape, and thickness as the opening of the first flat spring.

7. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 5, wherein the beam splitter, mirror of the fixed assembly, and the mirror of the movable assembly are positioned in a space between the planes containing the first and second flat springs while in respective flat conditions.

8. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 5, wherein:

the first and second flat springs restrict movement of the movable assembly relative to the fixed assembly; and

5 the restricted movement of the movable assembly maintains a plane containing the mirror of the movable assembly parallel to all of planes containing the mirror of the movable assembly at respective distances between the movable and fixed assemblies.

9. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 5, further comprising:

means to affix the first flat spring to the fixed housing and to the movable housing.

10. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 9, further comprising:

means to affix the second flat spring to the fixed housing and to the movable housing.

11. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 10, wherein the housing of the fixed assembly, the housing of the movable assembly, the first and second flat springs, the means to affix the first flat spring, and the means to affix the second flat spring are steel.

12. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 10, wherein the housing of the fixed assembly, the housing of the movable assembly, the first and second flat springs, the means to affix the first flat spring, and the means to affix the second flat spring are titanium.

13. The interferometer for Fourier transform infrared spectroscopy as set forth in claim 1, wherein both of the mirrors include a metalized film for improved reflectivity in the infrared range.

14. A Fourier transform infrared spectroscopy system, the system comprising:
a source producing infrared radiation;
an interferometer for Fourier transform infrared spectroscopy receiving the infrared radiation, the interferometer comprising:

5 a fixed assembly including a housing, a beam splitter, and a mirror
fixedly positioned relative to each other;

a movable assembly including a housing, a hole for receiving the
infrared radiation from the source, a mirror, and a motor coil, fixedly
positioned relative to each other, the infrared radiation passing from the
10 hole to the beam splitter, the beam splitter splitting the radiation into a first
component that is directed to and reflected from the mirror in the fixed
assembly and a second component that is directed to and reflected from
the mirror in the movable assembly, the reflected first and second

15 components of the radiation being combined at the beam splitter into a
recombined radiation; and
a first flat spring, having an opening for providing an unobstructed
optical path of the recombined infrared radiation therethrough, a first end
of the first flat spring being secured to the fixed assembly and a second
end of the first flat spring being secured to the movable assembly, a plane
20 containing the mirror of the movable assembly being parallel to all planes
containing the mirror of the movable assembly at respective retardations
between the movable and fixed assemblies so that an axis of a beam from
the beam splitter toward the mirror of the movable assembly is maintained
at a predetermined angle relative to a surface of the mirror of the movable
25 assembly at any of the retardations; and
a detection system for receiving the recombined radiation.

15. The Fourier transform infrared spectroscopy system as set forth in
claim 14, further comprising:

a second flat spring for providing at least one of i) an unobstructed optical path of
the radiation therethrough and ii) a clearance for moving at least one of the mirror of the
5 movable assembly and the motor coil, a first end of the second flat spring being secured
to the fixed assembly and a second end of the second flat spring being secured to the
movable assembly.

16. The Fourier transform infrared spectroscopy system as set forth in
claim 15, wherein the second flat spring has an opening of substantially equal size, shape,
and thickness as the opening of the first flat spring.

17. The Fourier transform infrared spectroscopy system as set forth in
claim 15, wherein the beam splitter, mirror of the fixed assembly, and the mirror of the
movable assembly are positioned in a space between planes containing the first and
second flat springs.

18. A method for Fourier transform infrared spectroscopy, the method including:

- receiving the infrared radiation into a movable housing of an interferometer;
- maintaining an optical relationship, between a beam splitter of a fixed assembly of
- 5 the interferometer and a mirror of a movable assembly of the interferometer, unchanged at respective distances between the fixed and movable assemblies;
- passing the radiation from the movable housing to and through a sample for producing encoded radiation as a function of the sample; and
- receiving the encoded radiation at a detection system.

19. The method for Fourier transform infrared spectroscopy as set forth in claim 18, wherein the step of maintaining includes:

- maintaining a predetermined angle between a beam from the beam splitter and a surface of the mirror of the movable assembly.

20. The method for Fourier transform infrared spectroscopy as set forth in claim 18, wherein the step of maintaining an optical relationship includes:

- maintaining a plane containing the mirror of a movable assembly parallel to all planes containing the mirror of the movable assembly at the respective distances between
- 5 the fixed and movable assemblies.

21. The method for Fourier transform infrared spectroscopy as set forth in claim 20, wherein the step of maintaining a plane includes:

- flexing a first end of a first flat spring, which is secured to the fixed assembly, relative to a second end of the first flat spring, which is secured to the movable assembly.

22. The method for Fourier transform infrared spectroscopy as set forth in claim 21, wherein the step of maintaining a plane further includes:

- flexing a first end of a second flat spring, which is secured to the fixed assembly, relative to a second end of the second flat spring, which is secured to the movable
- 5 assembly.

23. The method for Fourier transform infrared spectroscopy as set forth in claim 22, wherein receiving the infrared radiation includes:

passing the infrared radiation along an unobstructed optical path through the second flat spring.

24. The method for Fourier transform infrared spectroscopy as set forth in claim 18, further including:

identifying the sample as a function of the encoded radiation.

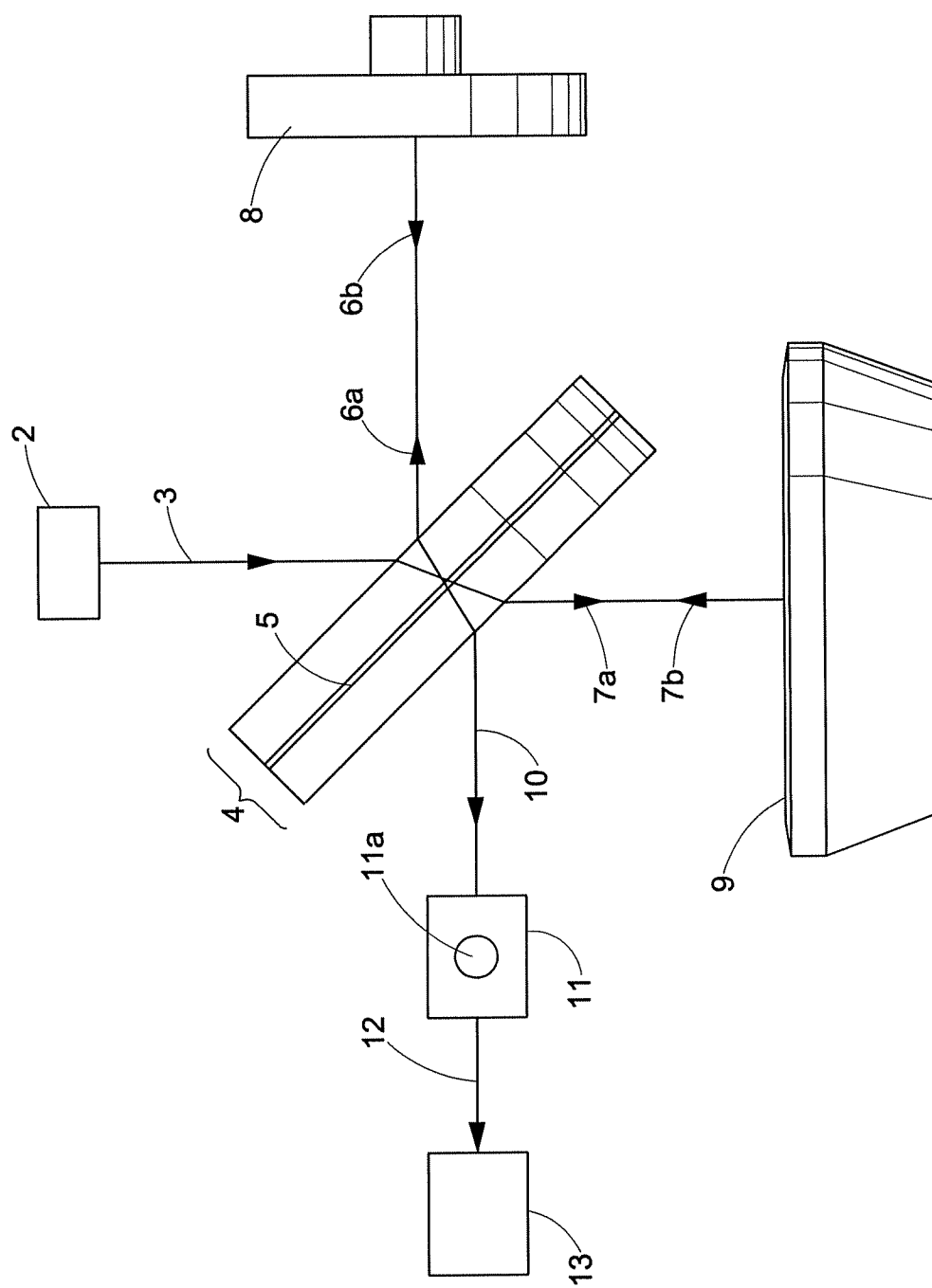
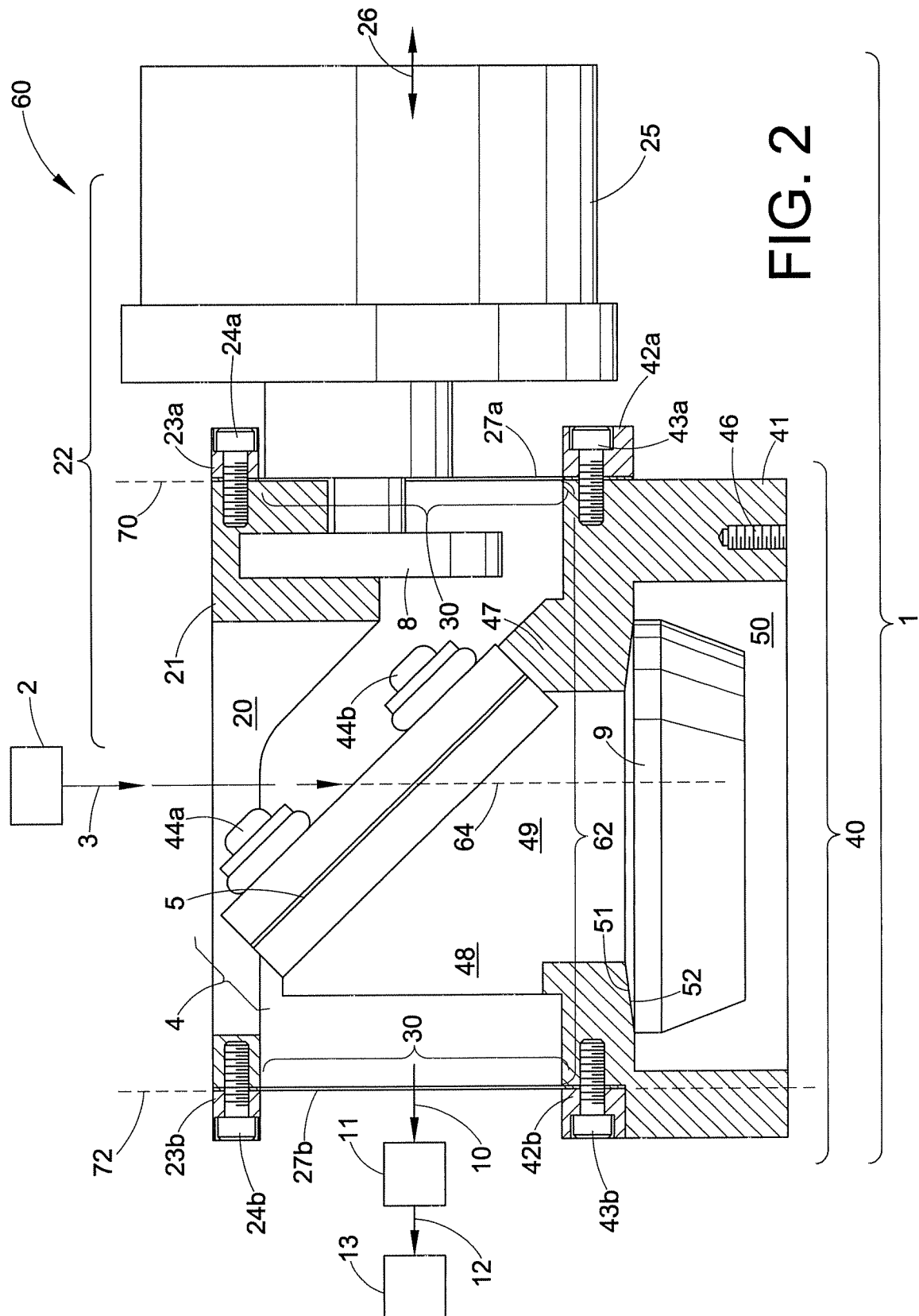


FIG. 1



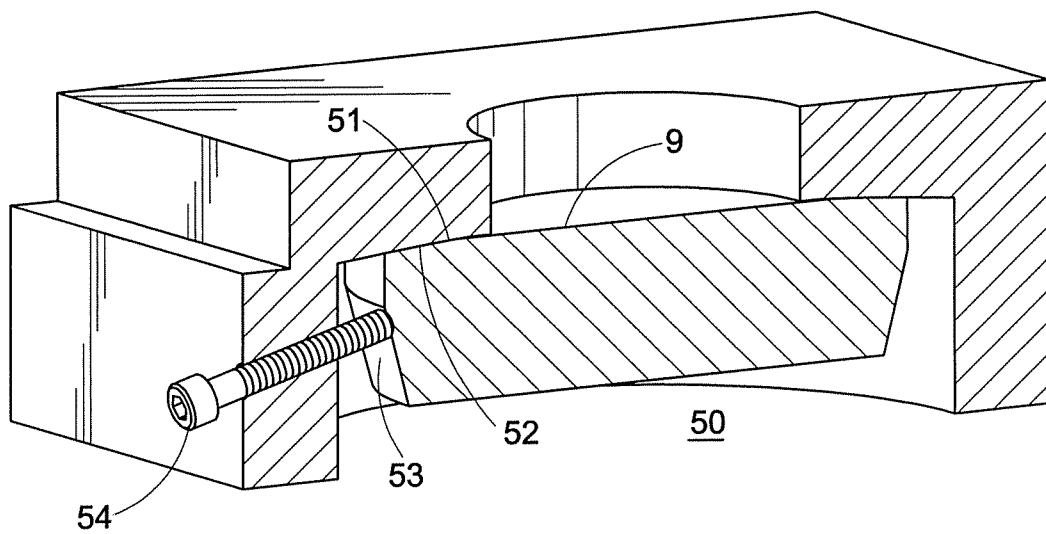
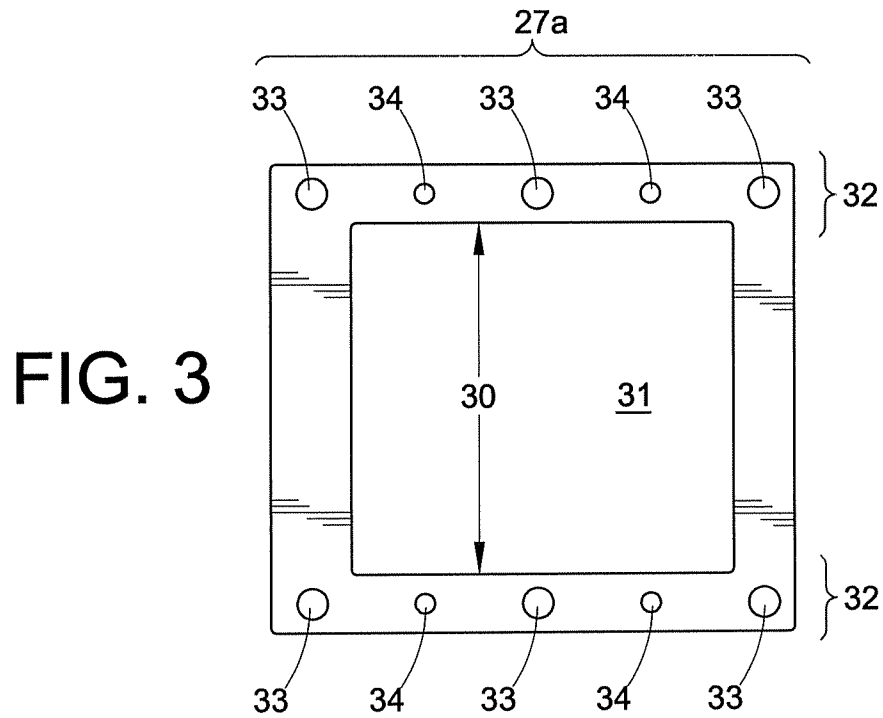


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2007/086713

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01J3/02 G01J3/453 G01B9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01J G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 486 917 A (CARANGELO ROBERT M [US] ET AL) 23 January 1996 (1996-01-23)	1-6, 8-16, 18-24
Y	column 5, line 26 - line 42 column 9, line 35 - column 11, line 54	1,14, 18-22,24
Y	column 12, line 16 - line 38; figures 3,6,10,15	
A	US 4 710 001 A (LACEY RICHARD F [US]) 1 December 1987 (1987-12-01) column 1, line 66 - column 2, line 56; figures 1,2	1,14, 18-22,24 1-17,23
X	US 2002/149777 A1 (SCHREIBER KENNETH C [US]) 17 October 2002 (2002-10-17)	18-22,24
A	paragraph [0023] - paragraph [0034] paragraph [0038]; figures 1,3,6	1-17,23
	-/-	

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

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- *O* document referring to an oral disclosure, use, exhibition or other means
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T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

8 document member of the same patent family

Date of the actual completion of the international search

24 April 2008

Date of mailing of the international search report

07/05/2008

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6 322 037 B1 (NANKO TOMOAKI [JP] ET AL) 27 November 2001 (2001-11-27)	18-22, 24
A	column 2, line 36 - line 59; figures 1, 3	1-17, 23
A	R. V. JONES: "Some uses of elasticity in instrument design" J. SCI. INSTRUM., vol. 39, 1962, pages 193-203, XP007904607 page 195, right-hand column - page 197, left-hand column	1-24

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2007/086713

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			JP	63132122 A	04-06-1988
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