OPTICAL FIBRE SCANNER

FIELD OF INVENTION

The present invention relates broadly to an optical fibre scanner, a method of operating the optical fibre scanner, and a method of fabricating an optical fibre scanner.

BACKGROUND

Any mention and/or discussion of prior art throughout the specification should not be considered, in any way, as an admission that this prior art is well known or forms part of common general knowledge in the field.

Laser scanning is a common technique for image formation in microscopes, and is also used in advanced endoscopes. When used in endoscopy, laser scanning enables advantages such as (1) powerful optical techniques, e.g. confocal imaging, fluorescence, or nonlinear optical methods, and (2) much smaller dimensions than traditional endoscopes that use camera sensors for imaging. Scanning for 2-D image formation typically requires actuators capable of 2-D actuation or motion, such as piezoelectric tubular actuators or 2-D microelectromechanical systems (MEMS)-based scanning mirrors.

However, with reference to Fig. 1A, piezoelectric tubes are (1) only capable of very small actuation ranges, which limit the imaging field of view, (2) require very high driving voltages to achieve useful actuation, which limit their utility as medical devices, and (3) expensive to manufacture and procure, which limit their commercial potential. On the other hand, with reference to Fig. 1B, MEMS-based actuators are (1) bulky when packaged, and (2) suffer from optical aberrations and scanner stability, which limit the image quality and their utility as medical devices.

Other 2-D image formation methods include stacking two 1-D actuators, such as piezoelectric benders, in orthogonal bending axes. However, with reference to Fig. 1C, the stacked benders require (1) each bender to be driven separately and (2) additional assembly and design, which adds to the complexity of the system.

Embodiments of the present invention seek to address at least one of the above problems.

SUMMARY

In accordance with a first aspect of the present invention, there is provided an optical fibre scanner comprising:

a one dimensional, 1-D, actuator;

a clamping structure for mounting the 1-D actuator such that a free end of the 1-D actuator can be actuated to vibrate in a major axis; and

at least one optical fiber attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator;

wherein the clamping structure is configured for adjusting the force applied on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

In accordance with a second aspect of the present invention, there is provided a method of operating the optical fibre scanner of the first aspect, comprising the steps of:

applying a driving signal to the 1-D actuator for vibrating a free end of the 1-D actuator in the major axis; and

adjusting the force applied on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, for tuning coupling of vibration of the free end of the optical fiber in the major axis to vibration in the minor axis for 2-D optical fibre scanning.

In accordance with a third aspect of the present invention, there is provided a method of fabricating an optical fibre scanner, comprising the steps of:

providing a one dimensional, 1-D, actuator;

mounting the 1-D actuator in a clamping structure such that a free end of the 1-D actuator can be actuated to vibrate in a major axis;

attaching at least one optical fiber to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the at least one optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator; and

wherein the clamping structure is configured for adjusting the force applied on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

In accordance with a fourth aspect of the present invention, there is provided an assembly for fabricating an optical fibre scanner, comprising:

a one dimensional, 1-D, actuator;

a glue guide for aligning and positioning multiple optical fibres on the actuator;

a two-part manufacturing fixture for the precise measurement of protruded optical fibre(s) length(s), whereby the 1-D actuator is aligned to optical fibre(s) mounted on a micrometer screw translation stage.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Fig. 1A shows a schematic drawing illustrating existing laser scanning using piezoelectric tubes.

Fig. 1B shows a schematic drawing illustrating existing laser scanning using MEMS 2-D scanning mirrors,.

Fig. 1C shows a schematic drawing illustrating existing laser scanning using two piezoelectric benders stacked in orthogonal bending axes.

Fig. 2A shows a schematic perspective view drawing illustrating a scanner attached with one fibre, according to an example embodiment.

Fig. 2B shows an annotated photograph of a close up cross sectional view of the clamping mechanism in the scanner of Fig. 2A. The clamping force on the actuator along the major axis and minor axis is controlled by a top and side screw respectively, where the coupling along the minor axis occurs when sufficient amount of physical space is present.

Fig. 2C shows a close up schematic perspective view drawing illustrating the single fibre tip with a custom glue guide for one fibre in the scanner of Fig. 3A.

Fig. 2D shows a close up photograph of the three fibres with a custom glue guide for three fibres in the scanner of Fig. 2D.

Fig. 2E shows a photograph of a manufacturing fixture for repeatable and strong bonding between the actuator and the fibre(s), according to an example embodiment.

Fig. 3A scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically tunable 2-D scan trajectories in a line scan (no orthogonal coupling), according to an example embodiment.

Fig. 3B shows scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically tunable 2-D scan trajectories in an elliptical scan (small orthogonal coupling), according to an example embodiment.

Fig. 3C shows scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically tunable 2-D scan trajectories in a circular scan (large orthogonal coupling nearly equal to that in the major axis), according to an example embodiment.

Fig. 3D shows scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically multiplexed simultaneous 2-D scans in two modes: One maximally large scan with accompanying smaller-sized scans, when the actuator drive frequency matches one of the fibre resonant frequencies, according to an example embodiment.

Fig. 3E shows scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically multiplexed simultaneous 2-D scans in two modes: Similar sized scans, when the actuator drive frequency matches none (or all) of the fibre resonant frequencies, according to an example embodiment.

Fig. 3F shows scan trajectories captured by a camera placed in front of the scanning fibre(s), specifically multiplexed simultaneous 2-D scans in two modes: Overlapping 2-D scans, according to an example embodiment.

Fig. 4 shows a flow chart illustrating a method of operating the optical fibre scanner, according to an example embodiment.

Fig. 5 shows a flow chart illustrating a method of fabricating an optical fibre scanner, according to an example embodiment.

DETAILED DESCRIPTION

Embodiments of the present invention can provide a low cost compact scanner that is capable of generating 2-D scans with a large field-of-view at a low voltage, for optical imaging, sensing, projection or other purpose of light delivery or collection. Embodiments of the present invention can be used with any optical scanning technique/modality including but not limited to confocal microscopy, optical coherence tomography, two-photon microscopy, etc. In example embodiment, a method of 2-D image formation by generating a 2-D scan with an actuator capable of only 1-D motion is provided. The features of an example embodiment of the present invention include: (1) generating and tuning a 2-D scan with precisely controlled clamping of a 1-D actuator, (2) aligning and attaching the fibre(s) to the actuator via a repeatable and precise manufacturing process, and (3) multiplexing simultaneous 2-D scans with multiple scanning fibres and/or multiple actuators.

In an example embodiment, the laser beam is carried in one or more optical fibre(s), which is/are attached to an actuator that need only be capable of 1-D electromechanical motion, such as a piezoelectric bender. When the 1-D actuator is driven at or near the fibre's resonant frequency, mechanical vibratory motion of the 1-D actuator is translated into a 2-D path at the fibre tip. This is achieved in an example embodiment by (1) tuning the scan shape (or path) with precisely controlled clamping of the actuator and (2) aligning and attaching the fibre(s) to

the actuator via a repeatable and precise manufacturing process. In addition, an example embodiment of the present invention can enable (3) scalable multiplexing of multiple simultaneous 2-D scans on a single actuator, as well as multiple actuators. The 2-D scan(s) can then be driven to cover e.g. a 2-D circular or elliptical imaging area by modulating the amplitude of the driving voltage signal to the actuator. Embodiments of the present invention can be used with any optical scanning technique/modality including but not limited to confocal microscopy, optical coherence tomography, two-photon microscopy etc.

Tuning scan shape from 1-D to 2-D according to an example embodiment

As shown in Figs. 2A-C, in a scanner 200 according to an example embodiment, the actuator 202 is sufficiently secured in a clamp 204 such that large motion or displacement is generated without the damping of mechanical vibrations in both axes. At or near the fibre's 206 resonant frequencies, some vibratory motion is naturally coupled into the minor axis (or orthogonal axis) That is, the displacements from the actuated major axis, indicated at numeral 207, are coupled to displacements in the minor axis, indicated at numeral 209, and form the 2-D scan shape 208 of the tip of the fibre 206. The clamping force on the actuator 202 along the major axis is precisely controlled by, in this example embodiment, the use of a top screw 211; and the clamping force and the physical space around the actuator along the minor axis is tunable by, in the example embodiment, two screws 213a, b . The magnitude of coupling is optimised with both the top and the side screws.

The scan shape can be tuned from a 1-D line scan (no orthogonal coupling, see Fig. 3A) to a 2-D elliptical scan (small orthogonal coupling, see Fig. 3B), up to a 2-D substantially circular scan (large orthogonal coupling nearly equal to that in the major axis, see Fig. 3C).

Non-limiting examples for the actuator 202 material include lead zirconate titanate (PZT), potassium niobate or sodium potassium niobate. Non-limiting examples for the optical fibre(s) material include borosilicate glass or fluoride glass.

Aligning and attaching fibre(s) to an actuator via a repeatable and precise manufacturing process according to an example embodiment

With reference to Figs. 2D, the fibre(s) 206 are attached to the actuator 202 such that the mechanical motion or force is maximally transferred to the fibre(s) 206. In an example embodiment, this involves the use of a hardened glue or adhesive such as a two-part epoxy, a customised glue guide 212 and a manufacturing fixture 214 (see Fig. 2E) that ensures repeatable and strong bonding between the actuator 202 in the actuator holder 215 and the fibre(s) 206. The glue guide 212 directs the flow of the glue such that it engulfs the fibre(s) 206 at its fixed end, and such that it is in full contact with the actuator 202. With reference to Fig. 2E, the manufacturing fixture 214 aligns one or more fibre(s) 206 to the actuator 202, and maintains their relative position to each other while glue is applied. The manufacturing fixture 214 precisely controls and enables fine adjustment of the fiber length (and hence its resonant frequency), up to a tolerance of a tenth of a millimetre, by the use of a micrometer screw

translation stage 216 and fiber holder 218. The manufacturing fixture 214 is not part of the assembled product, and can be reused.

Scalable multiplexing of simultaneous 2-D scans according to an example embodiment

With the same manufacturing and actuator clamping process, multiplexed 2-D scans can be achieved by attaching multiple fibres to the actuator and actuating them in parallel. However, given the manufacturing tolerance, the actual frequency response of each fibre may differ, which results in a different scan shape and size at a given drive frequency. Hence, within their resonant response range, multiple fibre scans can be operated in two modes according to an example embodiment:

1. one maximally large 2-D scan with accompanying smaller-sized scans, produced by the actuator driven at frequency matching to one of the fibre resonant frequencies, or

2. multiple 2-D scans of similar sizes, produced by the actuator driven at frequency matching none (or more rarely, all) of the fibre resonant frequencies.

In mode 1, when the actuator drive frequency matches one of the fibre resonant frequencies, a single large scan with accompanying smaller-sized scans can be achieved at a low drive voltage, see Fig. 3D. In mode 2, when the actuator drive frequency matches none of the fibre resonant frequencies, all scans decrease to a similar size, see Fig. 3E, which allows a greater ease of control of the simultaneous scans. The decreased scan size driven off-resonance can be compensated/adjusted e.g. by increasing the drive voltage along with adjustments of the clamping screws, given that large motion/displacements can be achieved at low voltages when using an actuator such as a piezoelectric bender. Accordingly, for example overlapping (larger) scans of similar size can be achieved, see Fig. 3F. It is noted that similarly, in mode 1 the adjacent scans can also be made to overlap with each other. Overlapping 2-D scans in either mode can be advantageous for image mosaicking, combining multiple imaging modalities or high speed image acquisition.

The field of view of the optical fibre scanner can be extended by attaching more fibers on the top and bottom of the actuator or increasing the number of actuators (with attached fibers) used in an imaging system. enabling even larger scalability.

As described above, in an example embodiment a device capable of 2-D image formation by generating a 2-D scan with an actuator of only 1-D electromechanical or other motion can be provided. The features of an example embodiment can include:

(1) a tunable scan from 1-D to 2-D with only 1-D actuation,

(2) a manufacturing process with precise control of aligning and attaching fibre(s) to an actuator, and

(3) scalable multiplexing of multiple simultaneous 2-D scans with multiple fibres on a single actuator, and/or with multiple actuators.

In contrast to the limitation that 2-D scans conventionally require 2-D actuators (actuators with two driving signals to control motion in two directions), embodiments of the invention enable 2-D scans using a 1-D actuator, by precisely controlling the vibration of the actuator and attached fibre(s), such that coupled motion from the actuated major axis is optimised in the minor axis (or orthogonal axis). With a single driving signal, the orthogonal resonant frequency of the fibre(s) is exploited to generate motion or displacement in the minor axis. This coupled minor axis displacement, on top of the actuated major axis displacement, forms a 2-D scan. When the coupling is optimised, the minor axis displacement could be comparable to that of the expected major axis displacement.

Also, resonant scanners are typically operated at its resonant frequency to obtain the maximum scan range or displacement. Embodiments of the present invention can be operated off-resonance without compromising the scan range and exceeding the voltage safety limit, by the use of a low voltage requirement actuator (such as a piezoelectric bender) and a repeatable manufacturing process, such that mechanical motion transfer from the actuator to the fibre is optimised. This can achieve multiple simultaneous 2-D scans, especially when scans of similar size are desired.

An example embodiment provides an optical fibre scanner comprising a one dimensional, 1-D, actuator; a clamping structure for mounting the 1-D actuator such that a free end of the 1-D actuator can be actuated to vibrate in a major axis; and at least one optical fiber attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator; wherein the clamping structure is configured for adjusting the force on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

The clamping structure may comprise a first clamping member for controlling a clamping force on the 1-D actuator along the major axis.

The clamping structure may comprise a pair of second clamping members for adjusting the clamping force and physical space around the 1-D actuator in the direction along the minor axis.

The optical fibre scanner may comprise a glue guide on the 1-D actuator, wherein the at least one optical fiber passes though the glue guide and is attached to the 1-D actuator by a cured glue disposed in the glue guide.

The optical fibre scanner may comprise two or more optical fibres attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to each optical fibre, wherein each optical fibre protrudes the 1-D actuator with a free end of each optical fibre disposed at a distance from the actuator, wherein coupling of vibration of the free end of each optical fiber in the major axis to vibration in the minor axis is tunable.

Fig. 4 shows a flow chart 400 illustrating a method of operating the optical fibre scanner, according to an example embodiment. At step 402, a driving signal is applied to the 1-D actuator for vibrating a free end of the 1-D actuator in the major axis. At step 404, the clamping force on the 1-D actuator in the direction along the major axis and the minor axis perpendicular to the major axis is adjusted for tuning coupling of vibration of the free end of the optical fiber in the major axis to vibration in the minor axis for 2-D optical fibre scanning.

The method may comprise adjusting a frequency the driving signal for operation on- or off-resonance with regard to a resonance frequency of the at least one optical fibre determined by a distance of the free end of the optical fibre from the 1-D actuator.

The method may comprise adjusting an amplitude of the driving signal to tune an amplitude of vibration of the free end of the at least one optical fibre.

The optical scanner may comprise two or more optical fibres, the method comprising multiplexing 2-D scans from each optical fibre. The method may comprise adjusting one or more of a group consisting of the frequency of the driving signal, the amplitude of the driving signal, the clamping force in both axes and the physical space around the 1-D actuator in the direction along the minor axis. The method may comprise adjusting the one or more of the group consisting of the frequency of the driving signal, the amplitude of the driving signal, the clamping force in both axes and the physical space around the 1-D actuator in the direction along the minor axis such that 2-D scans of adjacent optical fibres overlap.

Fig. 5 shows a flow chart 500 illustrating a method of fabricating an optical fibre scanner, according to an example embodiment. At step 502, a one dimensional, 1-D, actuator is provided. At step 504, the 1-D actuator is mounted in a clamping structure such that a free end of the 1-D actuator can be actuated to vibrate in a major axis. At step 506, at least one optical fiber is attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the at least one optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator and wherein the clamping structure is configured for adjusting the force applied on the 1-D actuatorin a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

The clamping structure may be provided with a first clamping member for controlling a clamping force on the 1-D actuator along the major axis.

The clamping structure may be provided with a pair of second clamping members for adjusting the clamping force and physical space around the 1-D actuator in the direction along the minor axis.

The method may comprise providing a glue guide on the 1-D actuator, wherein the at least one optical fiber passes though the glue guide and attaching of the at least one optical fibre to the 1-D actuator by a cured glue disposed in the glue guide.

The method may comprise providing two or more optical fibres attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to each optical fibre, wherein each optical fibre protrudes the 1-D actuator with a free end of each optical fibre disposed at a distance from the actuator, wherein coupling of vibration of the free end of each optical fiber in the major axis to vibration in the minor axis is tunable.

An example embodiment provides an assembly for fabricating an optical fibre scanner, comprising a one dimensional, 1-D, actuator; a glue guide for aligning and positioning multiple optical fibres on the actuator; a two-part manufacturing fixture for the precise measurement of protruded optical fibre(s) length(s), whereby the 1-D actuator is aligned to optical fibre(s) mounted on a micrometer screw translation stage.

Embodiments of the present invention can have one or more of the following advantages:

• Overcomes manufacturing inconsistencies/fibres of different resonant frequencies (within tolerance of 0.1mm)

• Ability to control multiple scans: e.g. equal size scans, i.e. multiplexing simultaneous scans on a single actuator, which overcomes limitations of only 1 scan per actuator

• Enable large field of view, and/or multiplexing different imaging modalities

• Enables exceptionally low cost scanning

• Requires low driving voltage, i.e. driving voltage well under the safety limit for medical device regulations

• Scalable, in terms of cost, manufacturing and assembly

Embodiments of the present can have one or more of the following industrial applications:

• Optical imaging

• Sensing

• Projection

• Other purpose of light delivery and/or collection, e.g. endoscopy, microscopy, compact projectors, optical headsets

The various functions or processes disclosed herein, such as the control signal generation for the 1-D actuator and the image capture/processing via the optical fibre(s), may be described as data and/or instructions embodied in various computer-readable media, in terms of their behavioral, register transfer, logic component, transistor, layout geometries, and/or other characteristics. Computer-readable media in which such formatted data and/or instructions may be embodied include, but are not limited to, non-volatile storage media in various forms (e.g., optical, magnetic or semiconductor storage media) and carrier waves that may be used to transfer such formatted data and/or instructions through wireless, optical, or wired signaling media or any combination thereof. When received into any of a variety of circuitry (e.g. a computer), such data and/or instruction may be processed by a processing entity (e.g., one or more processors).

The above description of illustrated embodiments of the systems and methods is not intended to be exhaustive or to limit the systems and methods to the precise forms disclosed. While specific embodiments of, and examples for, the systems components and methods are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the systems, components and methods, as those skilled in the relevant art will recognize. The teachings of the systems and methods provided herein can be applied to other processing systems and methods, not only for the systems and methods described above.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive. Also, the invention includes any combination of features described for different embodiments, including in the summary section, even if the feature or combination of features is not explicitly specified in the claims or the detailed description of the present embodiments.

In general, in the following claims, the terms used should not be construed to limit the systems and methods to the specific embodiments disclosed in the specification and the claims, but should be construed to include all processing systems that operate under the claims. Accordingly, the systems and methods are not limited by the disclosure, but instead the scope of the systems and methods is to be determined entirely by the claims.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in a sense of "including, but not limited to." Words using the singular or plural number also include the plural or singular number respectively. Additionally, the words "herein," "hereunder," "above," "below," and words of similar import refer to this application as a whole and not to any particular portions

of this application. When the word "or" is used in reference to a list of two or more items, that word covers all of the following interpretations of the word: any of the items in the list, all of the items in the list and any combination of the items in the list.

CLAIMS

1. An optical fibre scanner comprising:

a one dimensional, 1-D, actuator;

a clamping structure for mounting the 1-D actuator such that a free end of the 1-D actuator can be actuated to vibrate in a major axis; and

at least one optical fiber attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator;

wherein the clamping structure is configured for adjusting the force applied on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

2. The optical fibre scanner of claim 1, wherein the clamping structure comprises a first clamping member for controlling a clamping force on the 1-D actuator along the major axis.

3. The optical fibre scanner of claims 1 or 2, wherein the clamping structure comprises a pair of second clamping members for adjusting the clamping force and physical space around the 1-D actuator in the direction along the minor axis.

4. The optical fibre scanner of any one of claim 1 to 3, comprising a glue guide on the 1-D actuator, wherein the at least one optical fiber passes though the glue guide and is coupled to the 1-D actuator by a cured glue disposed in the glue guide.

5. The optical fibre scanner of any one of claims 1 to 4, comprising two or more optical fibres attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to each optical fibre, wherein each optical fibre protrudes the 1-D actuator with a free end of each optical fibre disposed at a distance from the actuator, wherein coupling of vibration of the free end of each optical fiber in the major axis to vibration in the minor axis is tunable.

6. A method of operating the optical fibre scanner of any one of claims 1 to 5, comprising the steps of:

applying a driving signal to the 1-D actuator for vibrating a free end of the 1-D actuator in the major axis; and

adjusting the clamping force applied on the 1-D actuator in the direction along the major axis and the minor axis perpendicular to the major axis for tuning coupling of vibration of the free end of the optical fiber in the major axis to vibration in the minor axis for 2-D optical fibre scanning.

7. The method of claim 6, comprising adjusting a frequency of the driving signal for operation on- or off-resonance with regard to a resonance frequency of the at least one optical fibre determined by a distance of the free end of the optical fibre from the 1-D actuator.

8. The method of claims 6 or 7, comprising adjusting an amplitude of the driving signal to tune an amplitude of vibration of the free end of the at least one optical fibre.

9. The method of any one of claims 6 to 8, wherein the optical scanner comprises two or more optical fibres, the method comprising multiplexing 2-D scans from each optical fibre.

10. The method of claim 9, comprising adjusting one or more of a group consisting of the frequency of the driving signal, the amplitude of the driving signal, the clamping force in both axes and the physical space around the 1-D actuator in the direction along the minor axis.

11. The method of claim 10, comprising adjusting the one or more of the group consisting of the frequency of the driving signal, the amplitude of the driving signal, the clamping force in both axes and the physical space around the 1-D actuator in the direction along the minor axis such that 2-D scans of adjacent optical fibres overlap.

12. A method of fabricating an optical fibre scanner, comprising the steps of:

providing a one dimensional, 1-D, actuator;

mounting the 1-D actuator in a clamping structure such that a free end of the 1-D actuator can be actuated to vibrate in a major axis;

attaching at least one optical fiber to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to the at least one optical fibre, wherein the at least one optical fibre protrudes the 1-D actuator with a free end of the at least one optical fibre disposed at a distance from the actuator; and

wherein the clamping structure is configured for adjusting the force applied on the 1-D actuator in a direction along the major axis and a minor axis perpendicular to the major axis, whereby coupling of vibration of the free end of the at least one optical fiber in the major axis to vibration in the minor axis is tunable for two dimensional, 2-D, optical fibre scanning.

13. The method of claim 12, wherein the clamping structure is provided with a first clamping member for controlling a clamping force on the 1-D actuator along the major axis.

14. The method of claims 12 or 13, wherein the clamping structure is provided with a pair of second clamping members for adjusting the clamping force and physical space around the 1-D actuator in the direction along the minor axis.

15. The method of any one of claim 12 to 14, comprising providing a glue guide on the 1-D actuator, wherein the at least one optical fiber passes though the glue guide and attaching of the at least one optical fibre to the 1-D actuator by a cured glue disposed in the glue guide.

16. The method of any one of claims 12 to 15, comprising providing two or more optical fibres attached to the 1-D actuator such that vibration of the free end of the 1-D actuator in the major axis is transferrable to each optical fibre, wherein each optical fibre protrudes the 1-D actuator with a free end of each optical fibre disposed at a distance from the actuator, wherein coupling of vibration of the free end of each optical fiber in the major axis to vibration in the minor axis is tunable.

17. An assembly for fabricating an optical fibre scanner, comprising:

a one dimensional, 1-D, actuator;

a glue guide for aligning and positioning multiple optical fibres on the actuator;

a two-part manufacturing fixture for the precise measurement of protruded optical fibre(s) length(s), whereby the 1-D actuator is aligned to optical fibre(s) mounted on a micrometer screw translation stage.