volume to make these devices more economical and thereby facilitate their widespread use as disposable devices. Microelectromechanical systems (MEMS) technology enables these goals to be achieved using a thin film device with integrated actuators. **FIGS. 4A, 4B**, and 4C illustrate an early prototype of a thin film optical system **140**, in which this approach was shown to be effective. A further alternative **140**' illustrated in **FIG. 4D** includes parallel cantilevered thin film optical waveguides for scanning and detectors. While it is likely that a production version of the thin film imaging system illustrated in these figures will be more compact and more suitable for volume production, the early prototype at least proves that the thin film optical device has an effective scanning capability and is usable in the present invention.

[**0084**] In the thin film optical device, an optical fiber **144** having a cladding **142** is actuated using an electrostatic actuator **156**. However, in this case, instead of causing an optical fiber to scan, electrostatic actuators **156** act on a thin film optical waveguide **150** that is supported on a raised ledge **148**. A distal portion **152** of the thin film optical waveguide is thus caused to scan in the two orthogonal directions indicated by the curved arrows in **FIGS. 4A and 4B**. The thin film optical waveguide is only approximately 0.005 mm in diameter. It should be noted that the scanning motion can be one-dimensional (i.e., along a single axis), or as shown, in two dimensions (along a raster pattern). Optionally, the thin film optical device can be mounted on a rod **143**, which is then manually or mechanically rotated or vibrated to change the orientation or displace the single axis scan. Also provided is a lens **154** that is preferably mounted to a silicon substrate **146** (or other substrate material). As an alternative, external actuators (not shown) can be used instead of the electrostatic actuators, in which case, optical fiber **144** and lens **154** would be supported by silicon substrate **146**, which would be caused to vibrate by the external actuators, causing the cantilevered thin film optical waveguide to resonantly scan. Optical fiber **144** is preferably affixed to silicon substrate **146** within a centering V notch **160** to ensure that it is aligned with thin film optical waveguide **150**. Since the optical fiber is approximately 0.1 mm in diameter, care must be taken to provide accurate alignment between the ends of the optical fiber and the thin film optical waveguide.

[**0085**] **FIGS. 4A and 4B** shows the embodiment using butt-end coupling between optical fiber **144** and a thin film optical waveguide **150**. To ensure appropriate alignment between the optical fiber and the thin film optical waveguide, V notch **160** precisely establishes a disposition of the optical fiber relative to the thin film optical waveguide. In the view of the embodiments shown in **FIGS. 4A, 4B** and 4C, light reflected back from an ROI passes through lens **154** and is received by RGB detectors **162***r*, **162***g*, and **162***b*, respectively. These detectors respond to the light of the corresponding color, producing a signal that is conveyed proximally to the external components, as discussed above. In **FIG. 4D**, separate image and diagnostic/therapeutic thin film optical waveguides are spaced apart and scanned in parallel; this embodiment uses a diagnostic "DIAG" detector **162***d*.

[**0086**] Tapered and Other Scanning Optical Fibers

[**0087**] Other techniques can also be used to produce a relatively small illumination PSF. For example, as shown in **FIGS. 5A and 5B**, a conventional optical fiber **164** includes a micro-fabricated end **168** with a taper **166**. The micro-fabricated end is formed either by etching (most preferable), micro-machining, or by pulling a heated optical fiber and then cutting the pulled fiber at its desired reduced diameter (least preferable). By chemically etching the cladding layer to a minimum thickness at the distal tip, the tapering produces no optical transmission losses. Since there are usually optical transmission losses associated with reducing the optical fiber source size during a pulling process, a reflective coating **167** can optionally be applied to the sides of the tapered waveguide. However, these procedures can be combined to generate a micro-fabricated optical fiber scanner with increased scanning frequency, FOV, and resolution. One advantage of using a scanning optical fiber having micro-fabricated end **168** is that the resonant frequency of the optical fiber shown in **FIG. 5B** is substantially greater than the resonant frequency of a blunt tip optical fiber that has not been micro-fabricated. However, the major advantage is the generation of much greater amplitude of tip deflection at this higher resonant frequency compared to untapered fibers. As mentioned above, the distal motion of micro-fabricated end **168** can produce linear patterns **169***a* and two-dimensional patterns **169***b*. Furthermore, the larger tip deflection has smaller lateral tip displacement, compared to optical fibers that have not been micro-fabricated. The etching process that is preferably used to produce the micro-fabricated tapered end is carried out using techniques well known to those of ordinary skill in the art.

[**0088**] As shown in **FIG. 5**C, the relative PSF and FOV of various forms of optical fibers varies depending upon the nature of the site at the distal end of the optical fiber from which the light travels toward an ROI **170**. Displacements of specific optical fibers in the vibrational first, second, and third modes of resonance are indicated by dash lines in this Figure. An optical fiber **172** having a blunt end is driven to vibrate about in a single axis in a first resonance mode and emits light **174** focused by a lens **184**, producing a PSF **176**, which is the widest due to the larger size of the site at the distal end of the optical fiber. A PSF **182** that is the smallest is produced by light **180** from a tapered optical fiber **178** (either etched, micro-machined, or pulled as discussed above), which is driven in a higher resonance mode along a single axis. It should be noted that the physical scan distance through which this tapered optical fiber vibrates in resonance is relatively small, enabling it to be encased within a small diameter housing. Light **188** from an optical fiber **184** that is coupled to a ball lens **186** at its distal end and driven in the second mode (with a node in the ball lens) provides light that passes through a lens **185**, producing an intermediate size PSF **190** covering the greatest FOV of the three configurations. The second and third mode embodiments exhibited in **FIG. 5C** are generally preferred because they require only a single actuator, they are relatively small in cross-sectional size, and they provide relatively high resolution, while enabling versatile scanning of an ROI.

[**0089**] Other modes of scanning can also be achieved that differ from the linear mode, or the rectilinear or zigzag mode noted above. **FIG. 5D** illustrates a variable radius or spiral scan mode of an optical fiber scanning system **200**, which can be generated by a two axis piezoceramic tube actuator **206**. In this embodiment, a plurality of light detectors **204** are arrayed around single piezoceramic tube actuator **206** in a simple arrangement, to produce signals indicative of the light received from an ROI (not shown in this Figure). Alternatively, a similar array of concentrically arranged and