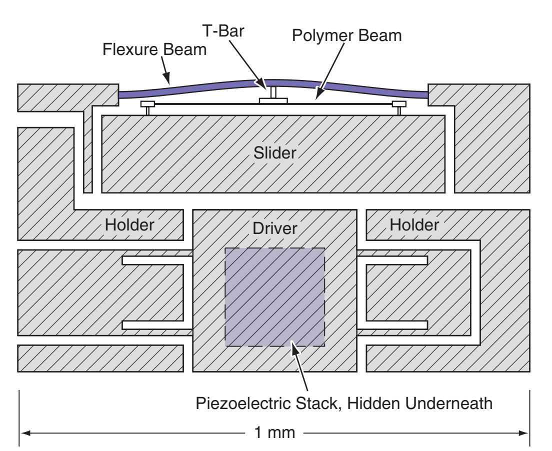
# MEMS-Based Piezoelectric/Electrostatic Inchworm Actuator

**Nanometer steps could be concatenated into overall travel of hundreds of microns.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed inchworm actuator, to be designed and fabricated according to the principles of microelectromechanical systems (MEMS), would effect linear motion characterized by steps as small as nanometers and an overall range of travel of hundreds of microns. Potential applications for actuators like this one include precise positioning of optical components and active suppression of noise and vibration in scientific instruments, conveyance of wafers in the semiconductor industry, precise positioning for machine tools, and positioning and actuation of microsurgical instruments.




This **Piezoelectric/Electrostatic Actuator** would produce motion of the slider into or out of the page in small increments.

The inchworm motion would be generated by a combination of piezoelectric driving and electrostatic clamping. The actuator (see figure), would include a pair of holders (used for electrostatic clamping), a slider (the part that would engage in the desired linear motion), a driver, a piezoelectric stack under the driver, and a pair of polymer beams centrally clamped to the flexure beam via a T bar. The holders would be held stationary. One end of the piezoelectric stack would be held stationary; the other end would be connected to the bottom of the driver, which would be free to move up and down. All of these components except the piezoelectric stack and the polymer beams would be micromachined from a 500-μm-thick silicon wafer by deep reactive-ion etching. The inchworm motion would be perpendicular to the broad faces of the wafer (perpendicular to the plane of the figure).

The combination of the polymer beams and the centrally clamped flexure beam would spring-bias the slider into a position such that, in the absence of electrostatic clamping, the gap between the slider on the one hand and both the driver and the holder on the other hand would be no more than a few microns. This arrangement would make it possible to electrostatically pull the slider into contact with either the holders or the driver at a clamping force of the order of 1 N by applying a reasonably small voltage (of the order of 100 V).

The actuation sequence would be the following:

1. The slider would be electrostatically clamped to the driver.
2. The piezoelectric stack would push the driver upward or downward (out of or into the page, respectively).
3. The slider would be electrostatically clamped to the holders.
4. The slider and the driver would be released from each other.
5. The driver would be moved downward or upward by the piezoelectric actuator while the slider remained clamped to the holders. This would complete the sequence for one increment of motion.
6. The cycle comprising steps 1 through 5 would be repeated as many times as needed to obtain the desired overall upward or downward travel. The repetition rate could be as high as about 1 kHz.

*This work was done by Eui-Hyeok Yang of Caltech for* **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
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# Metallized Capillaries as Probes for Raman Spectroscopy

**These would offer several advantages over fiber-optic probes.**

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A class of miniature probes has been proposed to supplant the fiber-optic probes used heretofore in some Raman and fluorescence spectroscopic systems. A probe according to the proposal would include a capillary tube coated with metal on its inside to make it reflective. A microlens would be hermetically sealed onto one end of the tube. A spectroscopic probe head would contain a single such probe, which would both deliver laser light to a sample and collect Raman or fluorescent light emitted by the sample.

The capabilities of most prior Raman and fluorescence fiber-optic probes are limited because of spurious emission of Raman and fluorescent light by the cores of the optical fibers themselves. To prevent the spurious emissions from overwhelming the desired Raman and/or fluorescence signals, it is necessary to incorporate spectral filters. In a given application, such a filter undesirably limits the probe to a single laser wavelength. Filtration is usually performed by means of free-space optics in the probe head. These optics are vulnerable to misalignment. Alternatively, thin-film filters can be deposited directly on optical fibers or in proximity to the fibers, but the performances of such filters are inferior to those of free-space optical filters.

A typical probe according to the proposal would have an outside diameter of <1 mm. Relative to a typical prior Raman probe, this probe would be much smaller and lighter and could be manufactured at lower cost. The interior of the probe could be evacuated or filled