

beam, and several parameters that characterize the transmitting and receiving optics, the receiving electronic circuitry, and the optical properties of the atmosphere and the terrain. When the input data have been entered, LRSP computes the signal-to-noise ratio as a function of range, signal

and noise currents, and ranging and pointing errors.

This program was written by Sabino Piazzolla of USC and Hamid Hemmati and David Tratt of Caltech for **NASA's Jet Propulsion Laboratory**. For further information, access the Technical Support

Package (TSP) **free on-line at www.nasatech.com**.

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30549.

Micro-Ball-Lens Optical Switch Driven by SMA Actuator

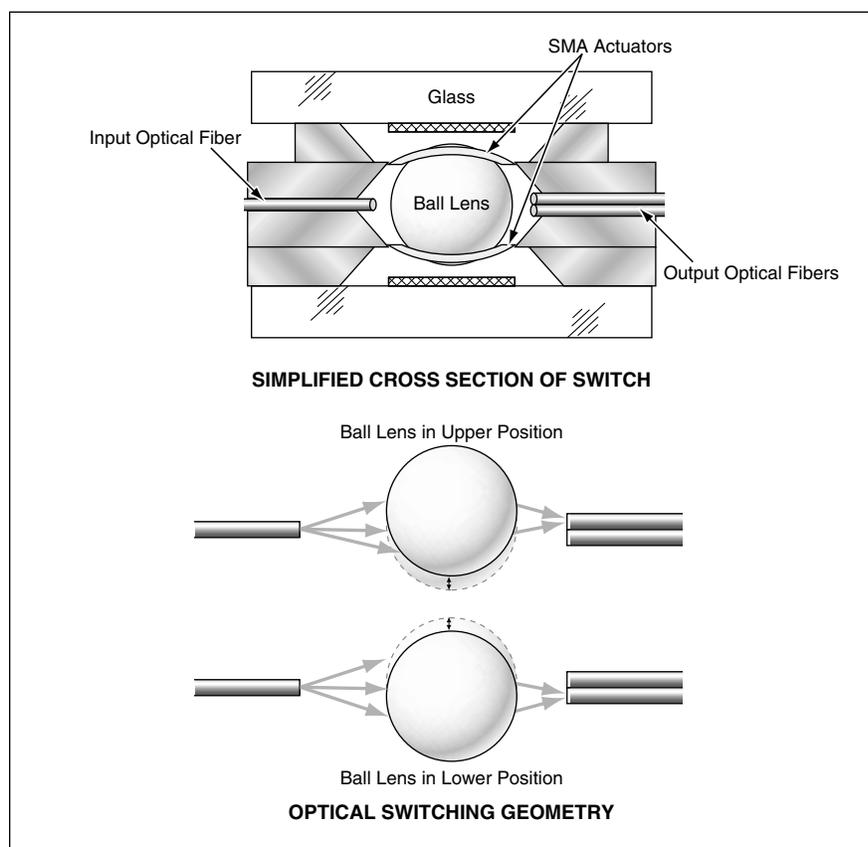
This could be a prototype of low-loss, mass-producible optical switches.

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The figure is a simplified cross section of a microscopic optical switch that was partially developed at the time of reporting the information for this article. In a fully developed version, light would be coupled from an input optical fiber to one of two side-by-side output optical fibers. The optical connection between the input and the selected output fiber would be made via a microscopic ball lens. Switching of the optical connection from one output fiber to another would be effected by using a pair of thin-film shape-memory-alloy (SMA) actuators to toggle the lens between two resting switch positions.

There are many optical switches — some made of macroscopic parts by conventional fabrication techniques and some that are microfabricated and, hence, belong to the class of micro-electromechanical systems (MEMS). Conventionally fabricated optical switches tend to be expensive. MEMS switches can be mass-produced at relatively low cost, but their attractiveness has been diminished by the fact that, heretofore, MEMS switches have usually been found to exhibit high insertion losses. The present switch is intended to serve as a prototype of low-loss MEMS switches. In addition, this is the first reported SMA-based optical switch.

The optical fibers would be held in V grooves in a silicon frame. The lens would have a diameter of $1\ \mu\text{m}$; it would be held by, and positioned between, the SMA actuators, which would be made of thin films of TiNi alloy. Although the SMA actuators are depicted here as having simple shapes for the sake of clarity of illustration, the real actuators would have complex, partly netlike shapes. With the exception of the lens and the optical fibers, the SMA actuators and other components of the switch would be made by microfabrication techniques. The components would be



The **SMA Actuators** would move the ball lens between its two resting positions. Light would be coupled to one or the other output optical fiber, depending on which position was selected.

assembled into a sandwich structure to complete the fabrication of the switch.

To effect switching, an electric current would be passed through one of the SMA actuators to heat it above its transition temperature, thereby causing it to deform to a different "remembered" shape. The two SMA actuators would be stiff enough that once switching had taken place and the electrical current was turned off, the lens would remain latched in the most recently selected position.

In a test, the partially developed switch exhibited an insertion loss of only $-1.9\ \text{dB}$

and a switching contrast of $70\ \text{dB}$. One the basis of prior research on SMA actuators and assuming a lens displacement of $125\ \mu\text{m}$ between extreme positions, it has been estimated that the fully developed switch would be capable of operating at a frequency as high as $10\ \text{Hz}$.

This work was done by Eui-Hyeok Yang of Caltech for **NASA's Jet Propulsion Laboratory**. For further information, access the Technical Support Package (TSP) **free on-line at www.nasatech.com**.

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