Optical Switching in Nanomechanical Optical Fibers

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Optical fibers are ubiquitous in optical communication networks as low-loss point-to-point communication channels. On the other hand, signal processing, buffering, and routing are almost exclusively performed in the electronic domain, thus requiring frequent optical-electronic-optical (O-E-O) signal conversion. Finding all-optical and, ideally, all-fiber alternatives to signal processing could remove the O-E-O bottleneck and significantly increase networking speed while reducing power consumption. Here we review our recent progress on developing an all-fiber optical switch based on novel nanomechanically reconfigurable optical fibers.

Our fibers comprise two optically guiding cores suspended individually by thin glass membranes inside a central air hole in the fiber. The separation between the two cores is chosen small enough to ensure overlapping evanescent mode fields and the two cores thus form a directional coupler. Only minute forces are required to mechanically actuate the suspending membranes, modifying the core-to-core separation and therefore the optical coupling strength, which allows for tunable in-fiber switching. We have developed corresponding fiber fabrication techniques and are investigating various different actuation mechanisms theoretically as well as experimentally.

In the first instance, we used pressurization of one of the internal air holes to move one suspended fiber core [1]. This proof of principle experiment demonstrated optical switching between the two fiber cores by applying about 100 mbar of pressure. For practical applications, faster and more robust actuation mechanisms are desirable and we are thus focusing now on electrical actuation. We have developed a multi-material draw technique that allows us to incorporate metal electrodes into the cladding of our dual-core fiber [2]. By running electric currents through the electrodes we can locally heat the fiber structure. Watt-level powers and corresponding temperature changes of order 10 ^{o}C were found to modify the optical coupling between cores sufficiently for optical switching by thermal expansion of the fiber structure and the temperature dependence of the refractive index. Another faster and low-power consumption actuation mechanism could be provided by electrostatically induced dipole forces in the fiber cores [3]. We analyzed theoretically various geometries of arranging metal electrodes in the fiber cladding and found that, in an optimized quadrupole configuration, voltages as low as 35 V will lead to optical switching in a 10 cm fiber device.

The fibers used in these experiments [1,2] were made of lead-silicate glass using an extrusion technique. We are also experimenting with a sheet-stacking technique [4] that allows us to fabricate similar dual- and multi-core fibers with a much larger flexibility of geometries and materials, paving the way to additional functionalities and applications beyond optical switching.

References

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