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Researchers have achieved much progress in fabricating complex photonic circuits, laying the groundwork for revolutionary applications in optical computing, communications and fundamental science. Yet attenuation of light primarily caused by surface roughness and insufficient fabrication precision remains a major bottleneck.

Recently, we demonstrated a new photonic fabrication platform called the SNAP: surface nanoscale axial photonics. It enables fabrication of ultra-low-loss miniature photonic circuits with angstrom precision. This is at least an order-of-magnitude better than the precision achieved in other photonic fabrication technologies.

The SNAP devices are fabricated on the smooth outer surface of an optical fiber. Their extraordinary low-loss performance is similar to that of the whispering gallery mode (WGM) microresonators fabricated from silica by melting, exhibiting the Q-factor as large as a billion. However, in contrast to SNAP devices, WGM microresonators cannot be integrated into robust photonic circuits and their fabrication precision is unacceptably low.

We have shown that a nanoscale effective radius variation (ERV) of the fiber (a combination of the fiber average physical radius and refractive index variations) is sufficient to completely localize WGMs.\(^1,2\)

Crucially, we have demonstrated the introduction of such nanoscale variations by focused CO\(_2\) laser heating with unprecedented angstrom accuracy.\(^3\) We achieved similar accuracy with UV exposure of Ge-doped photosensitive fibers,\(^3,4\) which may also be feasible for chalcogenide fibers.\(^5\)

For example, the SNAP device shown in the figure consists of ten coupled microresonators introduced by a focused CO\(_2\) laser beam along a 500 μm section of a 19 μm radius fiber. In this section, the fiber radius was increased by 7 nm and modulated with a period of 50 μm and amplitude of 1.1 nm. The performance and the ERV were characterized by measuring the transmission spectra of the microfiber, which was coupled to the SNAP fiber and scanned along its axis with 2-μm steps.

The measurements are in excellent agreement with calculations, which allowed us to extract the introduced ERV. This figure clearly demonstrates a transmission band formed by periodic modulation of ERV followed by a bandgap. The ERV reproducibility of microresonators is better than an angstrom.

SNAP circuits may have intriguing potential applications in filtering, switching, slowing light and sensing. They can potentially be incorporated into silicon photonics integrated circuits.

(a) A SNAP fiber with nanoscale variation of the effective radius and coupled to a microfiber. (b) Experimental characterization of the transmission amplitude of a SNAP device consisting of 10 coupled microresonators. The spectral measurements are performed with 2 μm steps along the fiber axis. The black curve is the ERV theoretically calculated from these spectra.

Researchers
Misha Sumetsky
sumetski@ofsoptics.com, David J. DiGiovanni, Yury Dulashko, John M. Fini, Xiaoping Liu, Eric M. Monberg and Thierry F. Taunay
OFS Laboratories, Somerset, N.J., U.S.A.

References