Nanostructures Boost Light Coupling to Optical Fibers

Optical fibers are crucial for many tasks requiring remote sensing and light collection. A key limitation of step-index fibers is their small numerical aperture, which leads to severe shortcomings in the coupling of light into the fiber modes, especially at large incidence angles.

Recently, we suggested a solution to this challenge: placing an all-dielectric nanostructure on a facet of an optical fiber.[1] We found that the addition of the nanostructure allows the boosting of in-coupling efficiency by orders of magnitude. This yields enormous potential for key applications, particularly within the life sciences (for example, *in vivo* scanning imaging) and quantum technology (for example, single-photon collection).

Generally, when the plane end of a single-mode fiber is illuminated at angles of incidence of more than 20 degrees, only a tiny fraction of light is coupled into the fiber mode. In our work,[1] we circumvented this limitation by boosting in-coupling efficiencies at large angles thanks to all-dielectric concentric ring-type nanostructures located in the core region of commercially available step-index fibers. These structures cause additional diffraction channels to emerge, which leads to a vanishing transverse phase distribution of the scattered field across the fiber end face.

We implemented accurate rings by nanostructuring silicon nitride films on the fiber end faces, using a sophisticated combination of sample planarization, wafer-based electron-beam lithography, ion-beam etching and resist removal. We were able to demonstrate record-high efficiencies for coupling of light into the resulting step-index nanostructured fibers at almost a grazing incidence angle. The measured in-coupling efficiencies of the nanostructure-empowered fibers indicated an improvement by several orders of magnitude compared with previously reported results[2] and with fibers with unstructured end faces for large angles of incidence. OPN

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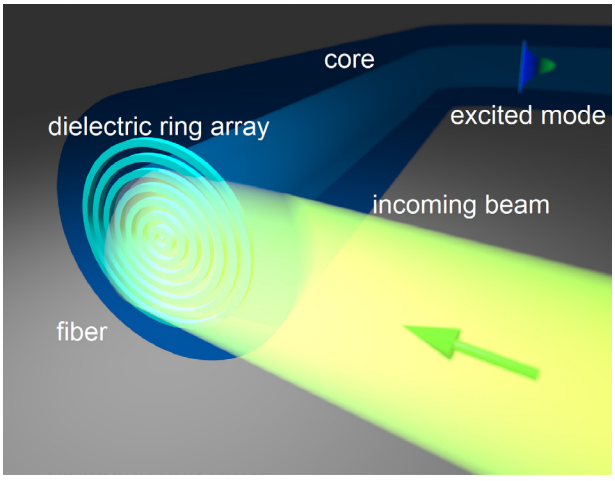

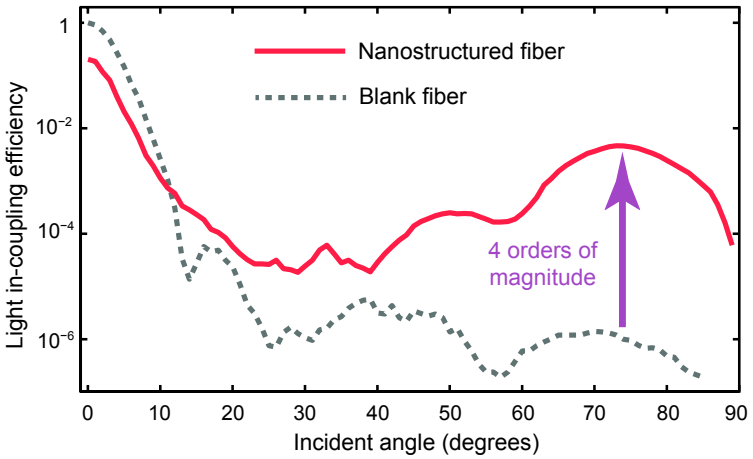

Left: All-dielectric, axially symmetric nanostructures boosted in-coupling efficiencies into optical fibers at almost a grazing incidence angle. Right: Measured in-coupling efficiency into the nanostructure-empowered functionalized fiber (solid red line) as a function of the incidence angle, demonstrating enhancement by several orders of magnitude at large angles. The dashed grey line shows the corresponding curve of a fiber with a blank facet.