Photonics On a Fiber For Wavefront Manipulation

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Integration of complex three-dimensional (3D) photonic structures onto optical fiber facets enables powerful platforms with unique optical functionalities. The 3D optical structures can manipulate the light's properties, i.e. phase and wavefront, which enables a variety of integrated optics applications including laser machining, lab-on-a-fiber, and sensors. Conventional nanofabrication technologies, however, prohibits viable integration of small and complex 3D structures onto optical fibers due to their low throughput and high cost. In this work, we report the fabrication of three-dimensional photonic structures directly onto an optical fiber using nanoimprint lithography, which offers many advantages in terms of reproducibility, flexibility in the design of optical structures, as well as cost.

The team between aBeam Technologies. Inc. and Lawrence Berkeley National Laboratory have developed novel fiber nanoimprint tool and processes to directly imprint free-form optical elements onto a facet of fiber. The process is achieved with high lithographic accuracy and precise coaxial alignment (relative to the fiber core) to ensure high optical performance. To demonstrate, we have fabricated a 3D diffractive beam splitter that splits light into four beams of equal intensities upon exiting the fiber (Figure 1). Scanning electron microscopy and optical measurements confirmed the good lithographic capabilities and the optical performance that is consistent with the intended design.[1]

One of the key advantages of our fiber imprint approach is in the unique capacity to imprint optical elements comprised of materials with functional properties, for example, high-refractive index. In this regard, we present direct imprinting of high refractive index Fresnel lens, where the lens itself is made out of aBeam's proprietary high refractive index imprint polymer (n = 1.68). (Figure 2) The imprinted lens is immersion compatible which enables efficient light focusing even inside other media, such as water or an optical adhesive where other types of fiber lenses do not work. Measurement of the lens performance in an immersion liquid (n = 1.51) shows a near diffraction-limited focal spot of 810 nm in diameter at the $1/e^2$ intensity level for a wavelength of 660 nm.[2]

Fiber imprint technology can be applied to imprint many other types of 3D components that manipulate light in various ways; including diffractive lenses, beam shapers, vortex beam generators, and can be done at a high throughput and low cost. The novel technology should enable advancements in areas such as integrated optics, display, and sensing, achieving enhanced portability and versatility of fiber optic components.

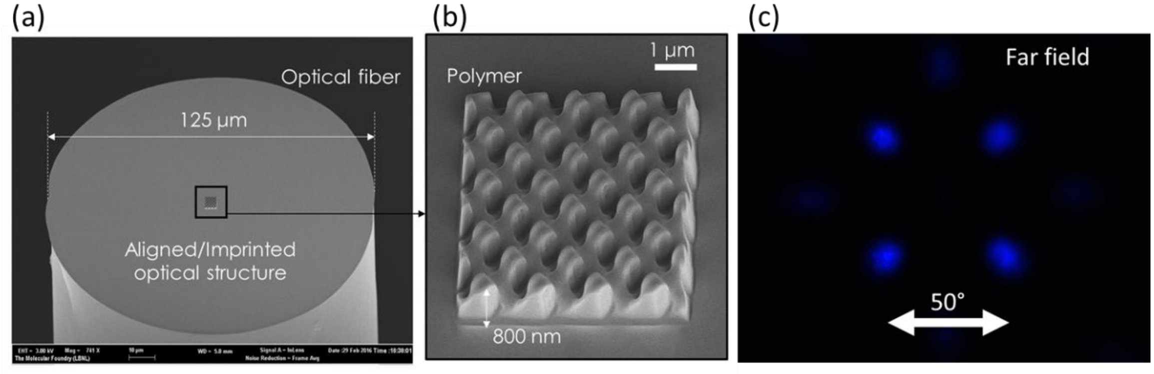

Figure 1: (a) SEM tilted-view of an imprinted fiber. The 3D structure is aligned to the fiber core to a very good accuracy. (b) Close-up SEM image of the imprinted 3D structure (tilt angle 4°). c) Photograph of the far-field light distribution produced by the 3D splitter imprinted onto a fiber.

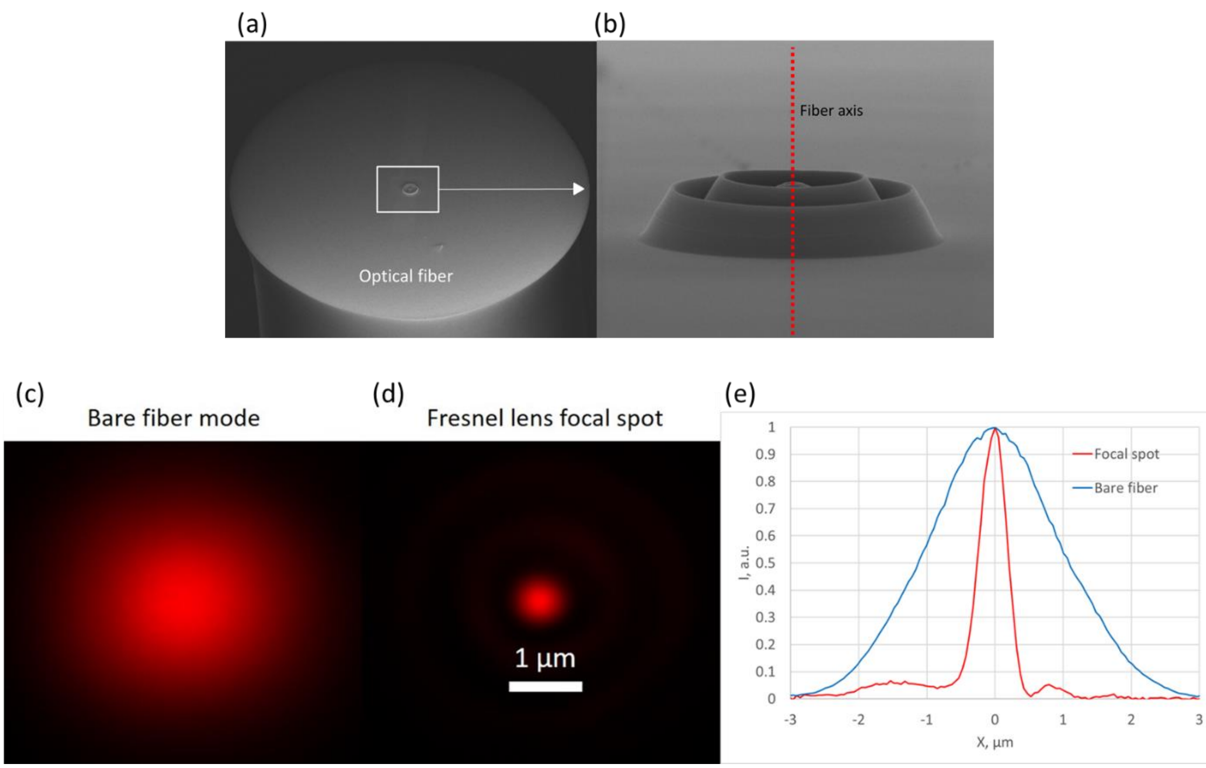

Figure 2: (a) SEM tilted-view of a high-refractive index Fresnel lens on top of the fiber.) (b) Close-up SEM image of the lens. Light intensity distributions measured using an oil immersion microscope for (c) a bare single-mode fiber, and (d) the focal spot of the imprinted Fresnel lens on the fiber. (e) Corresponding intensity profiles. All intensities are normalized.

References:

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2. Koshelev, A.; Calafiore, G.; Piña-Hernandez, C.; Allen, F. I.; Dhuey, S.; Sassolini, S.; Wong, E.; Lum, P.; Munechika, K.; Cabrini, S. *Optics Letters* **2016,** 41, (15), 3423-3426.