10-W-level CW waveguiding in an optical micro/nanofiber

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***Abstract*—Optical micro/nanofibers (MNFs) with a diameter below or close to the wavelength of the light, have attracted significant interest for applications ranging from optical sensing, nonlinear optics, to optomechanics and atom optics. While continuous-wave (CW) optical waveguiding is frequently adopted, so far most of the MNFs are operated in a low-power region (e.g., < 0.1 W). Here we demonstrate high-power CW optical waveguiding around 1550-nm wavelength in a silica MNF with power up to 13 W, which is more than 30 times higher than demonstrated previously. Our results may pave a way towards high-power MNF optics, for both scientific research and technological applications.**

Keywords—high power, optical waveguiding, micro/nanofiber

I. Introduction

Since its first experimental demonstration in 2003 [1], low-loss silica micro/nanofiber (MNF) has been emerging as a versatile fiber-optic platform in the field of optical sensing, nonlinear optics, optomechanics and atom optics [2]. Generally, increasing the power of the waveguiding mode is the most effective approach to enhance light-matter interaction, and explore new opportunities for both scientific research and technological applications. However, the highest continuous-wave (CW) power waveguided in a silica MNF reported so far is ~0.4 W [3], with typical waveguiding power below 0.1 W (in CW or averaged power). Also, the optical damage threshold of a silica MNF remains unknown.

II. High-power CW optical waveguiding characteristics

Experimentally, we fabricated high-quality MNFs by taper drawing standard single-mode silica fibers (Corning, SMF-28e) via a traveling-stage taper-drawing scheme [4,5], with excellent diameter uniformity and surface smoothness. To investigate the high-power optical waveguiding properties, an as-fabricated MNF (0.9 μm in diameter, 8 cm in waist length) was sealed inside an airtight box to keep its pristine surface isolated from possible contamination, as shown in Fig. 1a. A 1552-nm-wavelength CW fiber laser was amplified by a low-noise erbium-doped fiber amplifier (EDFA), which can offer a CW output up to 13 W around 1550-nm wavelength. The input end of the MNF (i.e., the standard single-mode fiber) was fusion spliced to the output fiber of the EDFA with a splicing loss lower than 0.05 dB, and the output of the MNF was measured by a thermopile power meter. As shown in Fig. 1b, the measured output power (P_{out}) changes quite linearly with the input power (P_{in}) and the MNF maintains a high optical transmittance of 90% with waveguided power up to 13 W, which is more than 30 times higher than the highest power reported before [3]. The possibility of waveguiding such a high optical power in the MNF can be attributed to the ultralow absorption of silica fiber (used as the preform), high precision in the fiber-pulling process and high cleanliness of both fiber-pulling and testing environment. Based on the absorption-induced thermal effect, we predict an optical damage threshold of 70 W in CW power [6]. In high-power CW waveguiding MNFs, we demonstrate high-speed optomechanical driving of microparticles, and nonlinear frequency conversion with second harmonic generation efficiency higher than those pumped by short pulses.

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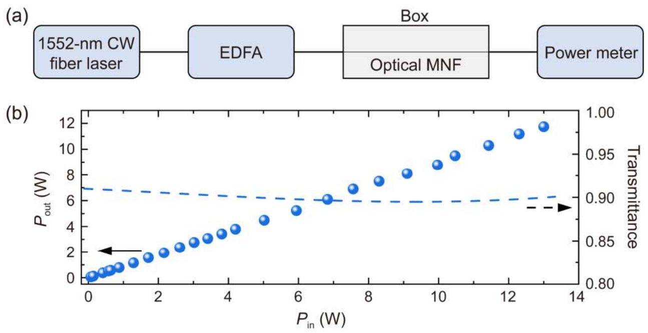

Fig. 1. (a) Schematic diagram of the experimental setup. SMF, single-mode fiber. EDFA, erbium-doped fiber amplifier. (b) Measured optical transmittance of a 0.9-μm-diameter MNF with a CW waveguided power from 0 to 13 W.

III. Conclusion

We have demonstrated high-power CW optical waveguiding in a silica MNF around 1550-nm wavelength. With optical power up to 13 W, a 0.9-μm-diameter MNF maintains a high optical transmittance of 90%. As CW waveguiding is desired in a variety of MNF-based applications noted above, we foresee that our results on high-power waveguiding MNFs may extend MNF optics into the high-power region, and open an avenue for MNF-based technology ranging from fiber laser, nonlinear frequency conversion, optomechanics to biophotonics and atom optics.

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