Image Transport Through Silica-Air Random Core Optical Fiber

Jian Zhao,[1,*] Jose Enrique Antonio-Lopez,[1] Rodrigo Amezcua Correa,[1] Arash Mafi,[2] Marie Windeck,[1] and Axel Schülzgen[1]
[1]CREOL, College of Optics and Photonics, University of Central Florida, Orlando, FL 32816, USA
[2]Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM 87131, USA
[*]Corresponding author: JianZHAO@knights.ucf.edu

Abstract: Optical image transport through low-loss silica-air based disordered fiber is reported for the first time. Transverse Anderson localization is confirmed by propagating a 976nm laser beam through a 4.6-cm-long segment of random fiber.

OCIS codes: (060.2280) Fiber design and fabrication; (060.2310) Fiber Optics; (060.4005) Microstructured fibers

1. Introduction

Transverse Anderson localization of light was first proposed by De Raedt *et al*. [1], and was observed experimentally by Schwartz *et al*. in 2007 [2]. Since then considerable attention has been paid to develop device applications that benefit from transverse Anderson localization in waveguide structures. In 2012, transverse Anderson localization was first observed in polymer random fiber [3], and this type of polymer random fiber was reported to transport image successfully in 2014 [4]. The quality of the transported images was found to be comparable to or even better than that of images send through some of the best commercial multicore imaging fibers [4] indicating great potential for applications such as endoscopy. However, several challenges remain to further improve the image transport quality. For instance, the beam localization radius, which limits the image resolution, can be decreased by increasing the refractive index difference between random sites in the fiber. In the previously applied random polymer fibers, the refractive index contrast between the two materials is only on the order of 0.1 [4]. There was also a rather large signal attenuation in the polymer fiber limiting the image transmission to a few centimeters. This is another important application aspect, where typically longer image transmission distances are desired and, therefore, fiber materials and structures with low signal attenuation are required. Due to high refractive index contrast and low loss, glass-air random fibers with about 50% air-hole-fill-fraction were proposed as potential improvements [4]. Although previous attempts in glass random fibers were reported [5,6], it still remains a challenge to demonstrate small beam localization radii or any image transport in these fibers due to low air-hole-fill-fraction (<8%) in these glass fibers.

In this work, we fabricated a glass-air random fiber (GARF) with high air-hole-fill-fraction (~26%) in the 270μm diameter core and low attenuation on the order of 1 dB per meter. Transverse Anderson localization is observed by sending a Gaussian probe beam into a 4.6-cm-long GARF and image transport through the same GARF is demonstrated for the first time.

2. Random fiber characterization and observation of transverse Anderson localization

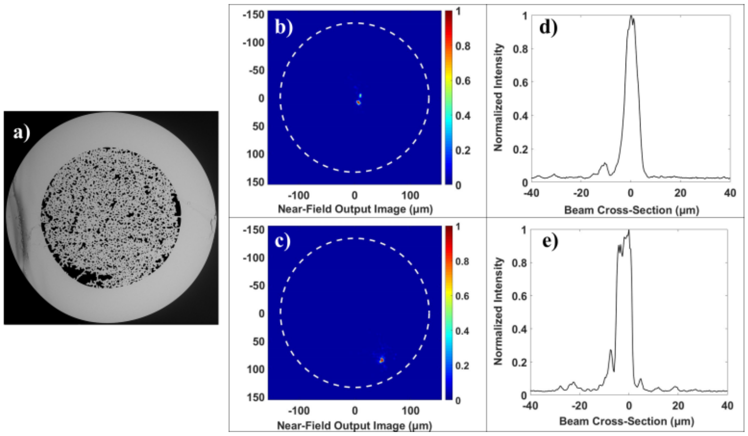

Fig. 1. a) SEM cross-section image of CREOL's GARF with a random core diameter of 270μm and 405μm outer diameter. b) and c) Near-field intensity measurement at the output facet of the GARF for two different launch positions. d) and e) The corresponding intensity profile cross sections of the respective localized beam.

The GARF was fabricated at CREOL using fused-silica rods and tubes and the well-known stack-and-draw. A SEM image of GARF is shown in Fig. 1(a). The outer diameter of fused silica fiber cladding is 405μm and the diameter of the random core is 270μm. The air-hole-fill-fraction in the whole random core is 26%. Excluding boundary areas containing the largest air holes, the air-hole-fill-fraction is 22.4%. The air hole feature sizes range from 0.2μm to 26μm with a maximum in the air hole size distribution around 1.8μm. The GARF attenuation was measured to be 0.9 dB/m at 635nm and 1.4 dB/m at 976nm.

To observe transverse Anderson localization, a laser beam from a 976nm laser diode delivered by single mode fiber SM980 (Thorlabs) is butt-coupled to the GARF. The output beam profile is projected on a CCD camera using a 4f imaging system formed by a 20x microscope objective and a lens with 200 mm focal length. By launching beams into different positions of the GARF core, strong transverse Anderson localization is observed both in the center and at off-center positions of the random core. Near-field intensity distributions and the corresponding intensity profiles are shown in Fig. 1 (b) to (e).

3. Image transport through GARF

Numbers from group 3 on the 1951 U.S. Air Force resolution test target (see Fig. 3a)) are imaged directly to the cleaved input end of a 4.6 cm-long GARF segment. A Beam from a 976nm laser diode serves as the light source. The output facet of the GARF is imaged onto a CCD camera by the 4f imaging system described above. Transported image intensity profiles are shown in Fig. 2. The transmitted numbers can be clearly identified. In future experiments, the image resolution might be further improved by decreasing the beam localization radius. We will attempt this by targeting air-hole fractions closer to 50% as recommended in [4]. Narrower air-hole size distributions and different light sources might also reduce the beam localization radius. Another potential factor related to the image quality is the degree of spatial coherence and spectral bandwidth of the laser source which will also be investigated.

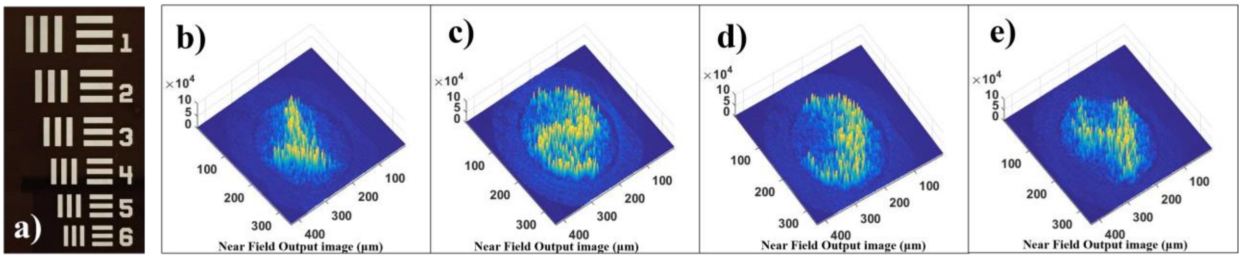

Fig. 2. a) Elements of group 3 on the 1951 USAF resolution test target. b)-e) Near field intensity profiles at the GARF output facet. Images of four different test target numbers (1,2,3,4 all from group 3) are transmitted through a 4.6 cm GARF segment.

4. Conclusion

In conclusion, we have fabricated glass-air based disordered optical fiber with high air-hole-fill-fractions and demonstrated strong transverse Anderson localization of near-IR light. Optical images have been transmitted successfully for the first time through a random glass-air fiber structure. Light attenuation of the order of 1 dB/m shows potential for the transmission of images through meters of random fiber.

5. References

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