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Suspended core high numerical aperture multimode polymer fiber

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Abstract: The transmission performances of a novel high numerical aperture polymer made multimode fiber are presented. The suspended core structure offers a low propagation loss in the visible and enables microfluidic capabilities.

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1 Introduction

Polymer-based optical devices offer a low-cost and easy to process alternative to more expensive components made of silica. Among others, polymer fibers solutions find applications in short range communications, lighting devices and sensors. When it comes to high numerical aperture waveguides, one usually faces the problem of a lack of materials with a high enough refractive index contrast. The use of a partially air-filled porous cladding is one way of achieving such a high index step, but it comes with the cost of inefficient guiding due to power leakage through the structure. We now report a novel concept of polymer-based multimode fiber that consists of a large core suspended in a hollow tube by three thin-wall structures. Due to the important index step between the fiber core and its merely air cladding, our fiber offers a very high numerical aperture (NA) and low propagation loss due to efficient light confinement within the core. Moreover, the presence of a broad channel in direct contact with the fiber core enables sensing applications with microfluidic capabilities. The fiber fabrication process and optical performances are presented.

2 Concept and fabrication

Our fiber design involves a large core embedded in a hollow tube using three sets of supporting capillaries. The thin-wall pillars are positioned to reduce power leakage through the cladding by evanescent coupling. It has been found that our design of suspension pillars offer the advantages of a good core isolation and easy to process mechanical structure. For transparency and processing considerations, the whole fiber is made of commercially available polymethyl-methacrylate (PMMA) tubes and rods. They are preliminarily degassed and annealed in a vacuum oven at $90°C$ for $48h$ and then assembled in a $30cm$ long preform. Prior to drawing, the preform is consolidated in a oven at $180°C$ for $8h$. The drawing process is set at $175°C$ with a speed of $1m/min$ in order to obtain a millimeter scale fiber. The fiber dimensions are $900\mu m$, $520\mu m$ and $45\mu m$ for the cladding, core and pillar diameters, respectively. Figure 1 shows a schematic view of our fiber design as well as an SEM picture of its cross-section. It demonstrates that the fiber geometry was properly maintained during the drawing process, even though the supporting capillaries integrity suffered from the hot blade cutting.

3 Transmission performances

The transmission characteristics of our fiber have been measured by means of a well established cut-back technique. As an optical probe source, the broadband spectrum of a collimated supercontinuum source was injected in the fiber core using a proper NA microscope objective. In order to minimize the effect of fluctuating input coupling conditions that are critical for multimode fibers, the image of the fiber input face was projected using a beamsplitter cube. Thus, when the fiber was removed for cutting and put back in place, the input coupling conditions were properly reproduced. A quick repeatability test proved the technique efficient.

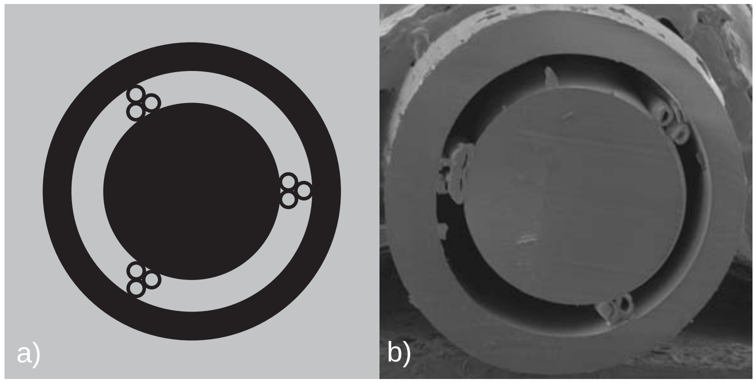

Fig. 1. a) Schematic view of our fiber design. b) SEM picture of the prototype cross-section.

The fiber output was then coupled to a monochromator using beam shaping lenses and a spectral trace was acquired for different fiber lengths, revealing the fiber longitudinal propagation loss over wavelength. In order to evaluate the power leakage to the cladding, the fiber transmission spectrum was compared to that of a PMMA rod drawn down to an equal diameter of $520\mu m$. To make sure that no light from the cladding was coupled to the monochromator, a diaphragm was used in the beam shaping assembly. Figure 2 shows a comparison between the loss of the suspended core fiber and the reference rod.

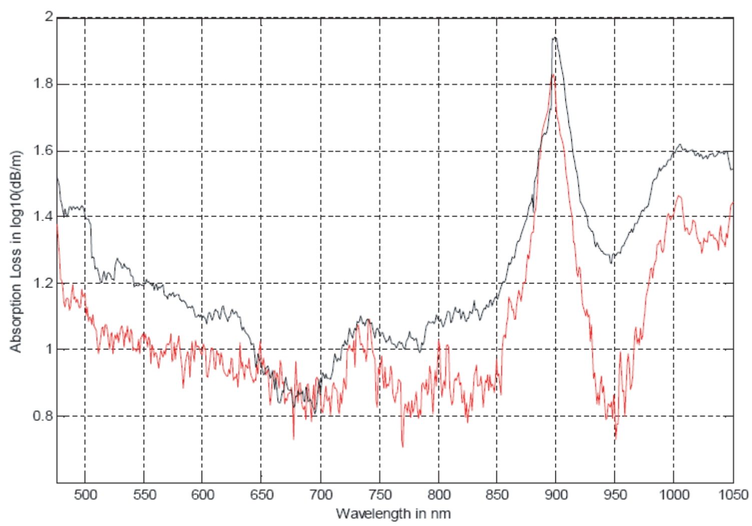

Fig. 2. Measured transmission performances of our proposed fiber (black curve) in comparison with a PMMA rod of same diameter (red curve).

There is a good agreement between the transmission response of a single rod and that of our suspended core fiber. Thus, we can conclude that power leakage through the core suspension is low when compared to other loss causes such as scattering and material absorption. Our polymer made high-NA suspended core fiber design is proven efficient for light transmission in the visible and chances are good that its performances could be improved by means of material and processing optimization.

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