Glass nanowires for nonlinear optics and sensing: a top-down approach

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Optical microfibers (OMs) are waveguides of diameters comparable to the wavelength of the light propagating in them. Fig.1 (a) shows a schematic of a typical microfiber: it consists of a region with thin waist connected to two conventional optical fibres by transition regions. Their sub-micron size, easy connectivity to conventional optical fibres and relatively high mechanical strength have made them ideal for a variety of applications including sensors, lasers and light sources(1). Moreover, their strong evanescent field, good light confinement and high nonlinearity have raised the interest in exploring the possibility to use these microfibers for cheap, compact optical devices.

The large majority of OM applications can be categorized in two groups according to the feature they exploit, namely strong light confinement and large evanescent field.

The first group of applications exploits the strong confinement to provide large optical nonlinearities. OMs have gained an increasing interest because, in addition to the high modal confinement and high nonlinearity, they also display a tailorable dispersion profile. When compared to microstructured fibers (which also hold similar nonlinearities), OMs benefit from lower fabrication cost, easier manufacturing and negligible input/output coupling losses. Our recent work focused on OM nonlinearities in relation to supercontinuum (SC), third harmonic (THG) and second harmonic generation (SHG). Novel methods to increase the effective OM nonlinearities were proposed using resonators, in which the enhancement is raised by the circulation of the pump power at the resonant wavelength(2).

The second group of applications relies on the large evanescent field. As shown in fig. 1(a), in the minimum waist region light is not confined in the silica only, but it has a significant fraction of power propagating outside the fibre physical boundary. This has been exploited for sensors, plasmonic and optical components. Two examples of devices are shown in fig. 1 (b) and 1 (c), where a coupler and a plasmonic resonator are presented.

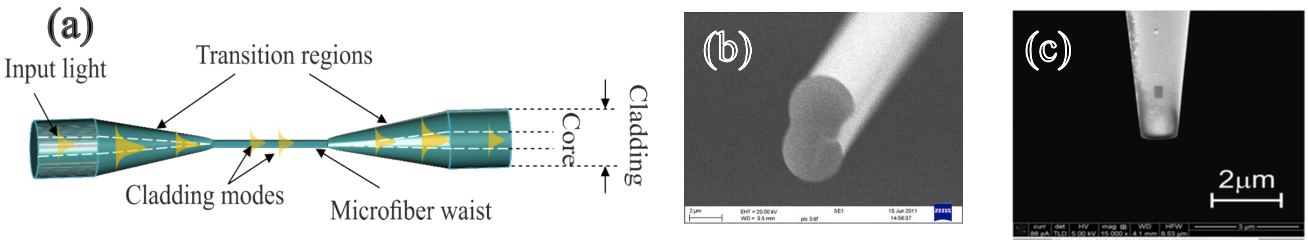

Fig1. (a) schematic of an optical microfiber. (b) SEM image of the coupler cross-section used for Bio-sensing applications. (c) Plasmonic slot nanoresonators embedded in a gold-coated microfiber tip.

OMs have found numerous applications in sensing because the large evanescent field surrounding the waist allows the propagating light to interact with the surrounding medium. The change in the surroundings is monitored by the change in the transmission of the device and sensitivities in excess of ~1000nm/RIU and detection limits smaller than 10^{-6} RIU were recorded. Sensors for temperature, current and biological molecules have also been demonstrated.

Plasmonics in OMs were investigated by coating them with a metal and exploiting the overlap of the evanescent field with the metal. Plasmonic slot nanoresonators embedded in a gold-coated microfiber tips (Fig. 1(c)) were demonstrated and showed strong localization in three dimensions and strong enhancement factor (7.24×10^3). The proposed geometry is suitable for wide range of applications, such as surface enhanced Raman scattering, optical filtering, bio sensing and spectroscopy (3).

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