Plasmonic nanofibers for the enhance of Brillouin scattering

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Introduction

The rich and complex dynamics of light and sound interactions in tiny optical waveguides such as photonic nanofibers and microstructured optical fibers has recently gained high interest. For instance, photonic nanofibers are hair-like glass wire, manufactured by tapering optical fibers down to submicron diameters [1]. In addition to providing strong light confinement and, hence, enhanced nonlinear optical effects, photonic nanowires also exhibit a large evanescent field. They thus have a number of optical and mechanical properties that make them very attractive for both fundamental physics and technological applications not currently possible with comparatively bulky optical fibers [2]. To date, Brillouin scattering in these tiny waveguides has yet to be explored. Brillouin scattering between sound and light waves has been extensively investigated in optical fibers. It is well-known that tapered optical fiber support many transverse, longitudinal and surface acoustic waves over a broad frequency range from 50 MHz to 11 GHz.
We propose to functionalized surface of nanofiber with a gold or silver coating for infrared applications and enhanced nonlinear phenomena as represented in figure 1. Circulating cylindrical coating with metallic layer is perfectly adapted to generate surface plasmon at telecom wavelengths and is suitable for filters, polarizers, and sensors applications [3-6].

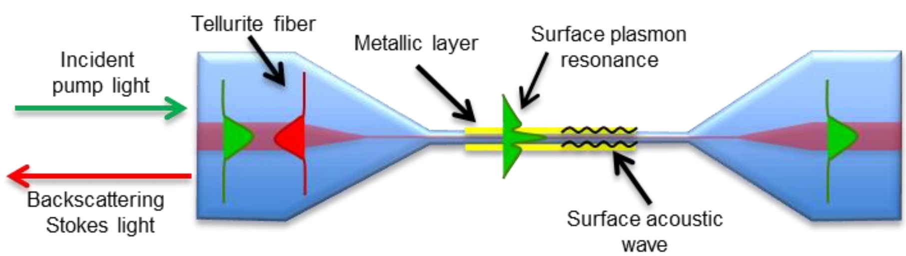

Figure 1: Schematic of the Brillouin backscattering interaction within a tellurite tapered optical fiber coated with gold thin film.

In particular, reference [7] showed that the Brillouin signals could be enhanced by orders of magnitude when surface plasmon fields are involved. The main idea of our paper is to enhance Brillouin light scattering from surface acoustic waves in a subwavelength-diameter optical fibre [8] coated with a thin metal film in order to take advantage of the surface plasmon modes existing in these kind of cylindrical structures [9].
In this context, we design tellurite nanofiber coated with 10 to 40 nm thick gold layers. We numerically demonstrated that the nanofibers with 2.5 µm diameter support two surface modes of azimuthal order 0 and 1 at a wavelength of 1550nm. The optical power distribution of optical mode with an effective index of 2.134+i5.26e-3 is represented in Fig.2 (d). For calculation, the refractive index of tellurite glasses and gold layer are 2.119 and 0.4649+i.10.56, respectively. For comparison, the optical power distribution of optical mode in tellurite fibre (without coating) is represented in Fig 2(a). These surface plasmonic modes in a cylindrical geometry confine the energy at the surface of the nanofiber and the main idea is then to allow Brillouin scattering enhancement from surface acoustic waves. In tiny optical waveguides, several families

of acoustic modes can be exalted by Brillouin scattering. We have experimentally demonstrated the generation of surface acoustic waves propagating at the surface of the nanofibers [8]. We performed numerical calculations of Brillouin interaction by solving the elastodynamic equation subject to an electrostrictive force [8]. As a first approximation, the photoelastic coefficient in gold is neglected [10-11]. As we can see on figure 2(b,e), the amplitude of longitudinal displacement is 5 times larger in plasmonic configuration.

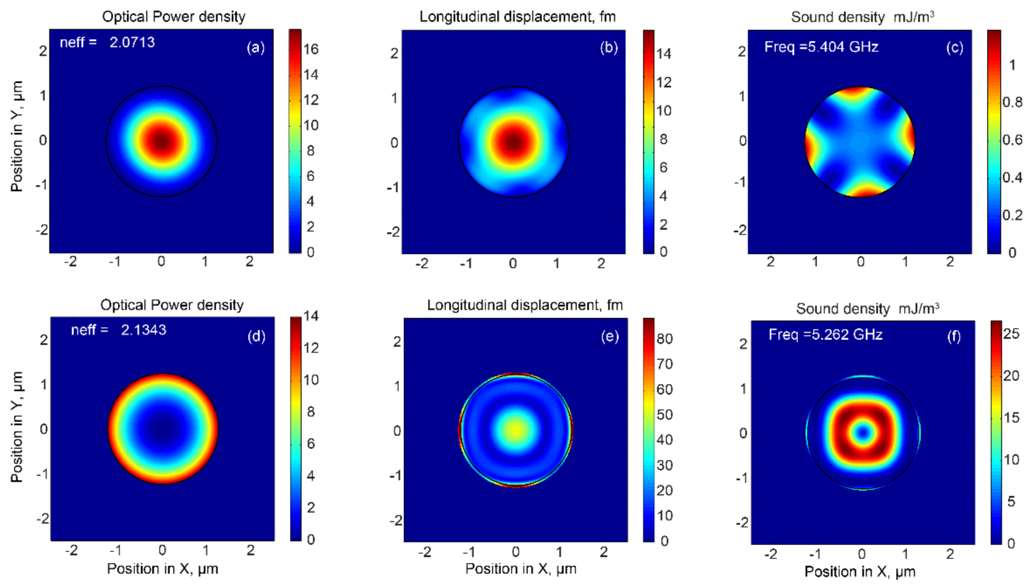

Figure 2: Numerical calculation of Brillouin backscattering interaction in 2.5µm diameter tellurite nanofibers with a gold layer of 40nm (d-f) and without metal coating (a-c). The incident optical wavelength is 1550nm. The deformation and sound density are calculated for an incident optical power of 1 W.

Conclusions

In tellurite rod coating with a gold thin film, surface acoustic wave involved in Brillouin scattering can be enhanced by plasmonic effect at telecommunications wavelength.

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