Optical fuse generated Chalcogenide microspheres: Evanescent probing and prospects

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Abstract

We report the manufacturing and optical characterization of chalcogenide microsphere. We show that high-Q modes of chalcogenide glass microspheres can be efficiently excited using a tapered fiber.

Introduction

Solid state microsphere resonators have been a subject of enormous interest in areas as diverse as sensing, cavity quantum electro-dynamics experiments, low-threshold lasers, spectroscopy and all optical switching [1]. Numerous applications have been achieved using amorphous glasses, like fused silica [2] or Er:Yb-doped phosphate glass [3], first because they are easy to manufacture and also because they can sustain morphology-dependant resonances (MDR) displaying high Q factors [4]. One of the disadvantage of these silica microspheres is that, compared to characteristic modal volume achievable in high index material shaped in a ring, disk or planar photonic crystal platform, the modal volumes in these microspheres are still several orders of magnitude higher.

In this respect, Chalcogenide glasses are an attractive alternative to silica based material for these applications. They possess a relatively high refractive linear index (typically between 2.6 and 3) leading to a higher natural confinement, thus possibly lower modal volume. Depending on the composition, these glasses can also offer excellent transparency from 1.5 µm to 20 µm opening the prospect of high sensitivity chemical sensing operation in the mid-infrared (MIR). In addition to its linear properties, these glasses are known to exhibit several substantial advantageous non linear properties including high pure kerr-nonlinearity, and low two photon absorption (TPA) [5].

we report a simple fabrication technique of chalcogenide microspheres and the characterization of these chalcogenide microspheres. Strong polarization dependant resonances are observed corresponding to coupling to MDR. We show that we can produce high quality chalcogenide microspheres and that we can exploit these microspheres as a possible platform for controlling and manipulating light at telecom wavelength.

Fabrication

Figure 1 summarizes the procedure we developed to obtain our microspheres. The technique is based on creating an optical fuse. It relies on our capability of tapering chalcogenide fibers [6] and does not require a dedicated infrastructure to process bulk glasses [7].

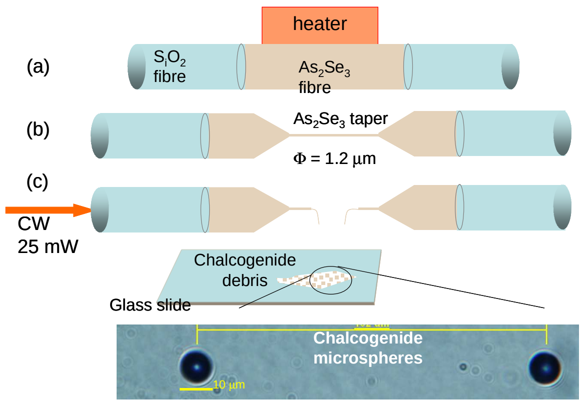

Figure 1: Fabrication process for obtaining chalcogenide microspheres. In inset: Optical microscope image of two chalcogenide microspheres.

We first couple a section of chalcogenide (As2Se3, refractive index n~2.83) fibre having initial diameter of 75 µm to single mode silica fibre pigtails (Figure 1. a). We then taper the chalcogenide section down to have a waist diameter between 1 µm and 2 µm (Figure 1. b). For the results shown in this paper, the chalcogenide fibre taper had a waist length and diameter of 20 mm and 1.2 µm respectively. The fibre taper was suspended above a glass microscope slide by a few millimeters and subjected to a ~ 25 mW CW light with wavelength of 1550 nm (Figure 1. c). The taper rapidly heated and fused creating a field of chalcogenide debris on the glass slide which included hundreds of spheres with the diameters ranging from <3 µm to 25 µm

Characterisation- Results

Figure 2 is a schematic of our characterisation setup. Once the microspheres obtained, an evanescent coupling technique relying on silica tapered fiber [8-10] is used to couple light into these microspheres. A chalcogenide microsphere with Diameter D~ 9.2 µm, standing on a glass slide, is probed using a silica taper (waist diameter 800 nm) placed in direct contact with the equator of the microsphere. Light is launched into the single mode fiber using an ASE source. An

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adjustable polariser was put in place to select the polarisation. In the taper region, light is adiabatically converted into the fundamental air-guided mode, allowing its evanescent tail to interact with the microsphere modes. The output end of the fiber is connected to an optical spectrum analyser (Agilent 86140B) where the transmission spectrum through the nanotaper is measured.

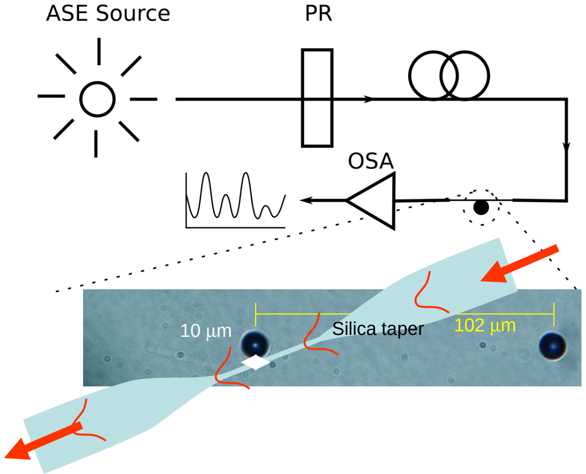

Figure 2: Experimental setup schematic. Inset: image of the chalcogenide MS/taper coupled system. PR is a polarization rotator.

Figure3 is the measured TM transmission spectrum of the taper coupled to the MS around 1615nm. Fig 3b is a close up around 1619nm. We observe a series of resonances corresponding to excitation of microsphere modes with transmission suppressed by as much as 8dB.

A linewidth of approximately 80 pm is measured for the resonance at 1619.9 nm leading to a loaded Qfactor of 20000 associated to a 3 dB transmission depth. The observed fine structure with regularly spaced dips with spacing between successive modes of approximately 0.35 nm is associated to the deviation from a perfect spheroid shape resulting in the lifting of the degeneracy of the azimuthal modes [11]. This splitting corresponds to a spheroidal eccentricity of less than a percent (roughly ΔR~70 nm), proving our ability to generate near perfect spherical shape, as observed using specular reflection.

Conclusion

In conclusion, we have developed a simple method to produce chalcogenide microspheres. We have shown that we can excite modes of a 9.2 µm diameter chalcogenide microsphere using a tapered silica fiber. The fine analysis of the transmission spectrum around 1619 nm led to an estimation of the microsphere eccentricity of less than one %. Loaded Q factors of more than 20000 with a 3 dB transmission depth have been measured.

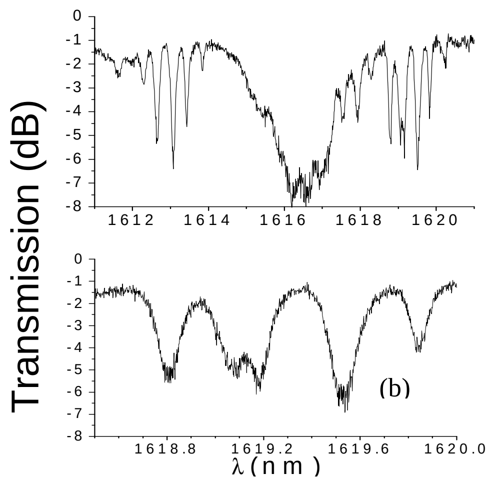

Figure 3 Experimental TM transmission spectra b) Close-up experimental spectrum around 1619nm.

The ability to couple to high Q chalcogenide microsphere modes opens up the prospect of a wealth of new science in both telecom and mid-infrared windows. It is expected that applications of chalcogenide microspheres can be as versatile as silica microspheres with the added advantage of the higher nonlinearity and low TPA provided by the chalcogenide.

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