Raman Scattering Emission in High Q Factor As_2S_3 Microspheres

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Abstract: We present measurements of Raman scattering emission in high Q factor As_2S_3 microspheres. Emission is observed for input powers down to 120 μW and for resonances with Q factor below 10^7.

OCIS codes: (190.5650) Raman effect; (140.3945) Microcavities; (160.4330) Nonlinear optical materials

1. Introduction

Whispering gallery mode (WGM) optical microcavities are excellent candidates for nonlinear processes generation due to their small mode volume and long photon lifetime. Among these processes, stimulated Raman scattering emission was observed in very high Q cavities such as silica spheres, silica toroid and CaF_2 disks [1–3]. In these configurations, due to their $Q > 10^8$, threshold powers as low as 74 μW and 15 μW at operation wavelengths of 1550 nm and 1064 nm were measured, respectively.

Recently, As_2S_3 microspheres with $Q > 10^7$ were reported [4], suggesting that Raman scattering is possible with input power below 100 μW. In this paper, we present what is, to our knowledge, the first demonstration of Raman scattering emission in As_2S_3 optical microcavities.

2. Fabrication and measurement setup

As_2S_3 chalcogenide glass microspheres are made using a CO_2 laser reflow process. A high purity As_2S_3 fiber (CorActive High-Tech) is melted and pulled into a 10-15 μm tip. The microsphere is formed by surface tension of the reflowed glass tip under laser illumination. Fig. 1(a) shows the picture of a microsphere with a radius of 20 μm.

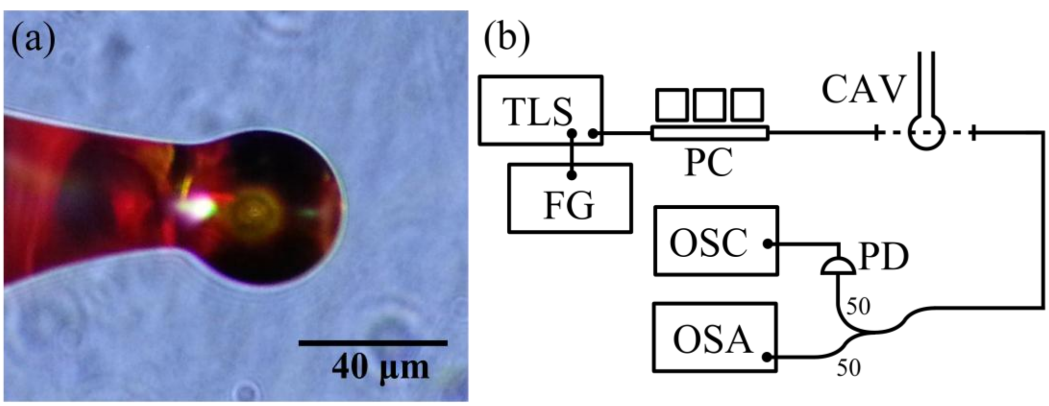

Fig. 1. (a) Micrograph of a high Q factor As_2S_3 microsphere. (b) Schematic of the setup used for Raman scattering measurements.

To measure the Raman scattering emission, we used the setup presented in Fig. 1(b). The emission of an Agilent 81600B tunable laser (TLS) is evanescently coupled to the microsphere with a silica tapered fiber with a diameter of 2 μm. The spectrum around 1550 nm is measured using a Thorlabs DET01CFC photodiode (PD) and an Agilent DSO6032A oscilloscope (OSC). The Raman scattering emission is also collected with the tapered fiber and is analyzed in an Agilent 86146B optical spectrum analyzer (OSA). A polarization controller (PC) is used to optimize the coupling conditions.

Once a spectral region containing a high Q factor resonance is chosen, a function generator (FG) is used to modulate the wavelength of the laser over ±14 pm around the resonance at a repetition rate of 20 Hz. This scanning method minimizes thermal fluctuation for input powers $P_{in} > 100$ μW which prevent a stable Raman scattering emission [5].

3. Raman scattering measurement

The Raman scattering emission spectra at input powers of 136 μW and 204 μW are presented in Fig. 2. The pump is tuned at 1550.4 nm and is scanned across two resonances with loaded Q_L factors of 1.8 x 10^6 and 5.35 x 10^6 respectively. The Raman emission appears around 1633.5 nm, 10.3 THz away from the pump. This corresponds to the Raman shift peak around 345 cm^{-1} measured using Raman spectroscopy on the spheres and in literature [6,7]. The multiple peaks in the spectra can be attributed to Raman emission within several modes of the cavity around 1633.5 nm.

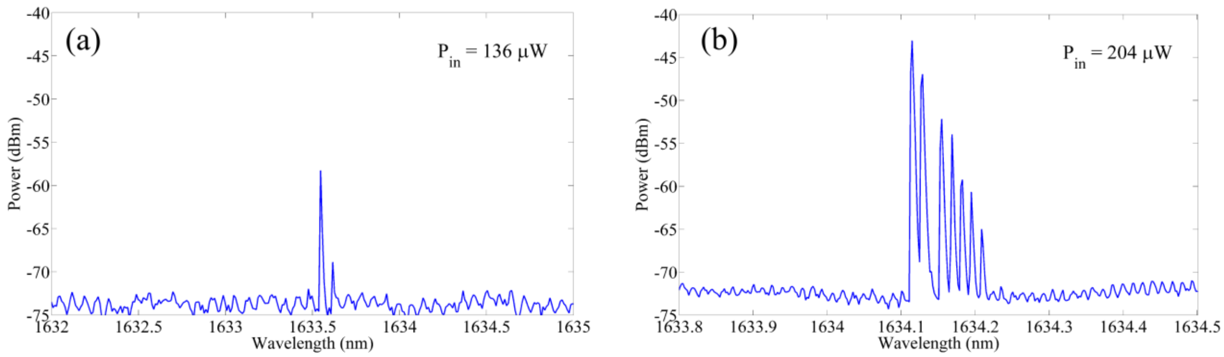

Fig. 2. Raman scattering emission spectra around 1633 nm for a input power of (a) 136 μW and (b) 204 μW.

Raman scattering emission was measured with input powers down to 120 μW. Using the threshold power found in literature [1], considering a Q_L = 5.35 x 10^6 similar to the Raman mode Q_R, an effective volume V_{eff} ~ 1800 μm^3, the Raman gain of g_R ~ 4.4 x 10^{-10} cm/W and an effective index n_{eff} ~ 1.38 corresponding to the fiber mode, we found a theoretical threshold power of 124 μW, close to the measured value. We chose this effective index since it is more likely that the tapered fiber mode couples to higher radial sphere modes with better phase matched conditions.

Because of its high Raman gain, almost 100 times silica Raman gain [6], As_2S_3 can possibly be used as low power Raman source despite the relatively low Q factor of the microsphere. Realizable As_2S_3 microspheres with Q factor of 3 x 10^7 would reduce the threshold power to 18 μW.

4. Conclusion

We presented the first demonstration of Raman scattering emission in high-Q whispering gallery mode As_2S_3 microcavities. Raman emission was observed for microspheres with Q factors below 10^7 and a pump power down to 120 μW. As_2S_3 microcavities based on stimulated Raman scattering could be used as micron size wavelength converters that easily produce light at wavelengths that are inaccessible or technically challenging using conventional approaches.

5. References

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