Brillouin lasing in barium fluoride whispering-gallery-mode resonators

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In the last few years, several authors have reported low-threshold stimulated Brillouin scattering (SBS) and lasing using ultrahigh quality Q whispering-gallery-mode (WGM) optical resonators [1,2]. This simple technique appears as a very promising solution for applications in telecommunications or microwave photonics and opens up a new mean to develop compact narrow-linewidth lasers and ultralow phase noise microwave signal generators [2]. So far, Brillouin lasing has been demonstrated in silica and calcium fluoride (CaF_2) WGM resonators [1,2].

In this work, we report the first observation of Brillouin lasing in Barium fluoride (BaF_2) mm-size disk WGM resonators. Figure 1(a) shows the scheme of a BaF_2-based Brillouin WGM resonator. The light in such a disk resonator circulates in the equatorial plane through total internal reflection. One billion quality factors can be achieved in such a BaF_2 disk by mechanical polishing [3]. A SF11 prism was then used to couple light into and out from the resonator. The coupling gap was finely controlled using a piezoactuator. To achieve lasing effects using SBS, doubly resonant configurations are usually exploited, as shown schematically in Fig. 1(b). It is therefore needed that cavity resonances exist in both pump and Brillouin gain regimes. However, this usually requires an ultimate control on resonator geometries in the single WGM regime. Here, we overcome this requirement by using a group of transverse WGMs. As a result, we have been able to observe Brillouin lasing in three handily polished BaF_2 resonators with different geometries and Q factors. Figure 1(c) shows a typical feedback cascaded Brillouin spectrum. The pump and second-order Stokes were also observed in the feedback direction. The measured frequency shift is in an excellent agreement with our estimated Brillouin frequency shift of 8.27 GHz and it clearly differs from the cavity FSR which is about 5.5 GHz. The inset of Fig. 1(c) shows the corresponding RF beat spectrum. The free running beat signal centered at 8.223 GHz with a 20 dB linewidth of 27 kHz was observed, showing that the Brillouin linewidth of the WGMs is well below the natural linewidth in bulk fluoride (about 12 MHz). Narrow-linewidth single and multiple Brillouin radiations with frequency shift ranging from 8.2 GHz up to 49 GHz have also been observed [4]. BaF_2-based Brillouin WGM resonators can thus find strong potential applications for high-coherence lasers and microwave photonics.

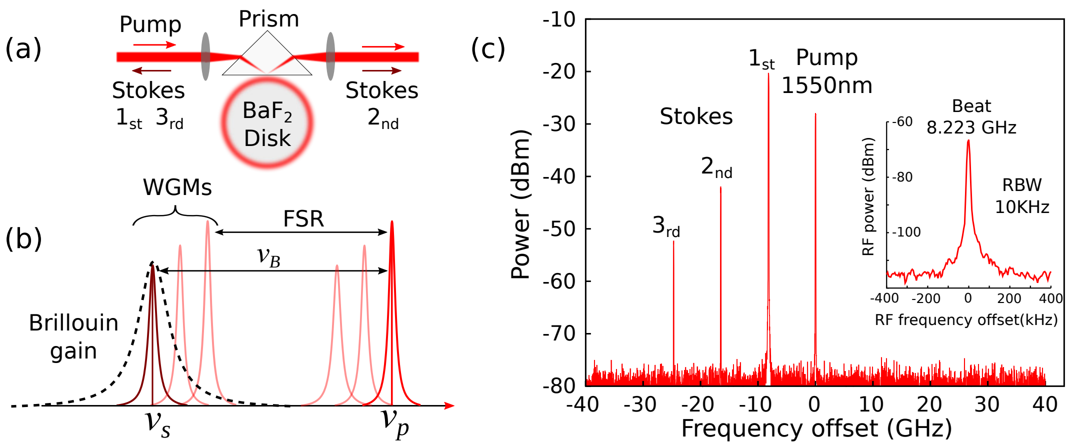

Figure 1: (a) Scheme of a BaF_2 Brillouin WGM disk resonator coupled by a prism, showing pump (red) and Stokes waves (Brown). (b) Scheme of the doubly resonant configuration using different WGMs. The dotted line designates Brillouin gain band and the solid Lorentzian lines and vertical lines show cavity resonances and laser lines, respectively. (c) A typical backward cascaded Brillouin lasing spectrum of the WGM resonator. The inset shows the RF spectrum of the beat note.

References

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