Observation of Brillouin spin-orbit interaction in a silica optical nanofiber

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Spin-orbit interaction (SOI), whereby spin and orbital features of a particle or a wave affect each other, is a ubiquitous phenomenon in many branches of physics, including among others, optics and acoustics [1]. In optics, it has long been known that light carries both orbital angular momentum (OAM) and spin angular momentum (SAM), related to wavefront rotation and circular polarization, respectively, and that they can become coupled by SOI while conserving the overall angular momentum [1]. In acoustics, SOI has been recently reported using elastic spin and angular momenta of transverse acoustic beams [2].

Here we report an opto-elastic spin-orbit interaction in a silica optical nanofiber, whereby a circularly polarized optical mode carrying a SAM of $s = \pm 1$ coherently interacts through Brillouin scattering with a torso-radial (TR21) vortex elastic mode with an OAM of $l = \pm 2$. More specifically, we demonstrate that the backscattered Brillouin signal by the TR21 acoustic vortices undergoes a circular polarization handedness reversal, with a SAM of $s = \mp 1$, due to angular momentum conservation. Figure 1(a) schematically illustrates the Brillouin backscattering in a tapered optical nanofiber (ONF) which results from the coherent interaction between an optical pump wave depicted in blue and an acoustic wave in purple [3]. This gives rise to an optical backscattered Stokes wave (in red) which is shifted in frequency from a few GHz due to the Doppler effect. Among the various acoustic modes of a silica nanofiber, the torso-radial TR21 one is characterized by scalar potential and vector potential components with an OAM with a topological charge $l = \pm 2$, as shown in Fig.1(b). When the pump wave is circularly polarized, because of the angular momentum conservation, the TR21 backscattered wave has an opposite circular polarization. This is shown experimentally in Fig.1(c) where the TR21 signal at 5.4 GHz shows a circular polarization reversal, while the L02 signal at 8.4 GHz due to a longitudinal acoustic mode has the same polarization as the pump. Our observations complete other recent studies about angular momentum conservation in both chiral photonic crystal fibers [4] and in standard single-mode fibers using forward Brillouin scattering [5]. They are relevant not only for further fundamental investigations of SOI in Brillouin scattering but also for potential applications, such as non-reciprocal devices or Brillouin-based optical memories [4].

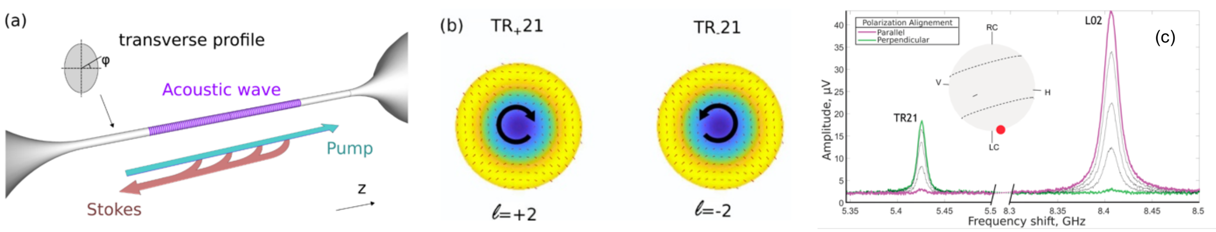

Fig. 1 (a) Illustration of Brillouin backscattering in a tapered silica optical fiber. (d) and (e) are the two degenerated torso-radial TR21 acoustic vortex modes with an OAM $l = \pm 2$. (c) Polarization-sensitive measurements of the backscattered Brillouin spectrum in a 730 nm-diameter silica fiber showing the TR21 and L02 peaks. The pump polarization, depicted on the Poincaré sphere in inset, is set left circular. The TR21 signal shows a circular polarization reversal, while the longitudinal L02 peak does not.

References

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