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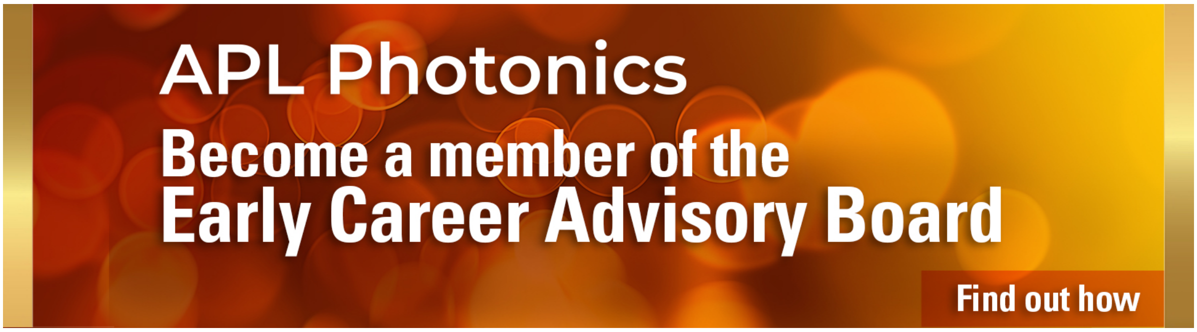

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ABSTRACT

The fields of cavity optomechanics and Brillouin scattering, linked by common underlying physical mechanisms, involve the interaction of light waves with mechanical vibrations at the micro- and nanoscale. Exciting fundamental research in both classical and quantum regimes as well as opportunities for applications in microwave photonics, frequency conversion, narrow-linewidth lasers, optomechanical sensors, electro-optic transducers, coherent light storage, and Brillouin spectroscopy have stimulated significant interest in the last decade. This special issue brings contributions to fundamental aspects regarding the Brillouin interaction such as novel waveguide structures, novel guiding mechanisms, the interplay between Brillouin and other nonlinear phenomena, and applications in sensing and light storage, as well as an introductory tutorial to the research field. Here, we provide a brief introduction to the topics covered in the issue.

The interaction of light waves with confined mechanical vibrations offers a unique link between two different physical domains. It bridges frequencies from megahertz to terahertz and allows exploiting the unique traits of electro-magnetic and mechanical waves across their respective domains. These phenomena have been traditionally studied in the research fields of cavity optomechanics and Brillouin scattering, which recently merge together investigating high-frequency acoustic vibrations and waves interacting with tightly confined optical fields. Current research activities explore these photon-phonon interactions in different resonator and waveguide structures, such as photonic integrated circuits, microfibers and microstructured fibers, whispering gallery mode resonators, suspended mechanical cavities and cantilevers, photonic and phononic crystals, and metamaterials. In this special issue we gather the recent progress on high-frequency optomechanics and Brillouin scattering and present herewith a short overview on the topics covered in the issue.

The rapid progress in both optomechanics and stimulated Brillouin scattering (SBS) has been to a great extent fueled by the development of new resonator and waveguide systems with improved photon-phonon interaction strength and minimized losses. As it regards SBS waveguides, the research emphasis has been predominantly on materials and their combinations rather than on geometric waveguide design. In their study, Håkansson and Van Thourhout[1] take a different route: they use genetic searches to design novel waveguide cross section shapes with optimal SBS gain. This leads to new insights, not only in the most relevant coupling mechanisms, but also in practical designs in silicon which promise unprecedented SBS gain.

A quite different route to control mechanical waves is explored by Arregui *et al.*,[2] which is through the existence of topological states arising at the edge of two types of multilayer stacks experiencing band inversion. Recently, the topic of topological states of matter—made famous in electronic materials—has received wide attention in photonics and acoustics. In their paper, high-frequency (200 GHz) topological phononic modes in nanoscale multilayered III/V systems are investigated using a new optical technique. Their time-resolved pump-probe technique allows us to reveal the properties of the acoustic states through their interaction with light in the structure. It provides a starting point to explore the use of these states and in particular their topologically protected characteristics, for example, in systems where *both* light and sound waves experience topologically nontrivial band structures and interact.

In many systems, the interplay between Brillouin and other nonlinear mechanisms is of significant interest. One example is when two optical waves propagating along an optical fiber interact through four-wave mixing as well as through guided-wave Brillouin scattering, an important case in long-haul communications as well as distributed fiber sensing. In London *et al.*,[3] a clever multitone optical time-domain deposition technique is used to experimentally measure the four-wave mixing spectrum evolution along the fiber length. They demonstrate that asymmetric spectral features, commonly observed in cascaded four-wave mixing processes, are also generated due to Brillouin interaction when the laser's frequency separation matches the frequency of one of the mechanical resonances of the fiber.

In a contribution to the recent field of electro-mechanically induced scattering, Li *et al.*[4] demonstrate a planar integrated device that is able to deflect telecom-band optical beam at a large angle of 60°. They fabricated a pristine device consisting of integrated interdigital transducers, waveguides, and lenses on a 330 nm thick suspended aluminum nitride membrane. Large-angle deflection is important for realizing strong electromechanical Brillouin scattering and this work presents the first step towards achieving an integrated device that can provide a unique combination of fast and continuous beam steering for a range of on-chip applications such as optical spectrum analysis, high-frequency acousto-optic modulators, or delay lines.

Sensing has traditionally been a direct application area for Brillouin physics, with advanced methods targeting remote and distributed sensing using optical fibers being especially powerful. Even though light is perfectly protected inside a fiber core, its interaction with acoustic waves that extend to the outer surface of the fiber cladding allows probing the fiber environment. A practical issue, however, is the role of the protective plastic coating. Diamandi *et al.*[5] present a new model for commercially available fibers coated with polyimide that accurately predicts their observed sensing spectra, enforcing the application range of SBS fiber sensors. Moreover, it invites the question if fiber coatings can even be tailored to optimize specific sensing tasks. Another challenge in Brillouin distributed fiber sensing is the discrimination of temperature and strain effects. It has been tackled with different techniques, such as polarization maintaining fibers or using multiple optical or acoustic modes. Deroh *et al.*[6] demonstrate a very interesting phenomenon in heavily germania-doped optical fibers, where the temperature coefficient becomes negligible in comparison to the strain coefficient. They also show that removing the fiber coating reveals a temperature coefficient of almost zero. This athermal behavior opens new avenues for the field of fiber optic sensing based on opto-acoustics.

Pushing the physics of Brillouin interaction into new regimes is definitely exciting. Godet *et al.*[7] apply very high static strain (up to 6%) in silica nanofibers and measure the evolution of the Brillouin scattering spectrum. Such high static strain pushes the system into a nonlinear Hooke's law regime. Mechanical modes are formed by a specific combination of a shear and a longitudinal wave components, and in this nonlinear Hooke regime, each component's phase velocity changes quite differently with strain. As a result, any individual mode exhibits a particular frequency dependence with strain, as observed experimentally in the evolution of the Brillouin spectrum.

An exciting application for Brillouin is in optical delay lines or optical memories. Light storage using Brillouin interaction in a multiwavelength system is explored in Stiller *et al.*[8] Information contained in two write-lasers separated by as little as 25 GHz is stored in two mechanical waves with almost identical frequencies. Nonintuitively, read-lasers can recover the information in each respective mechanical wave with negligible crosstalk, even when the mechanical waves differ in frequency only slightly, by less than their intrinsic linewidth. A theoretical model is presented showing that, although the mechanical waves have close frequencies, they are still significantly phase-mismatched compared to the interaction length, therefore inhibiting crosstalk.

Finally, the topical issue also includes a tutorial that is dedicated to Brillouin optomechanics in nanophotonic structures.[9] It focuses on the discussion of two major mechanisms that are responsible for both Brillouin scattering and optomechanical effects: the photoelastic effect and the moving boundary effect. The tutorial gives a thorough explanation of both physical phenomena while differentiating intermodal and intramodal scattering and conceptually different platforms as waveguides and cavities. Moreover, an extensive overview on Brillouin coupling in a range of typical microcavities is given. The tutorial not only provides an introduction and overview but also offers simulation files and processing scripts in an accompanying data repository.

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