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Enhanced Stimulated Brillouin Scattering in silicon acousto-optic metamaterials

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Abstract: *We propose a metamaterial based on nanoporous silicon which strongly increases the Stimulated Brillouin Scattering (SBS) response compared to bulk silicon. This paves the way towards a new generation of compact, cost-efficient silicon-based SBS devices.*

Keywords: *Silicon, Brillouin, Scattering, Electrostriction, Optomechanics*

Stimulated Brillouin scattering (SBS), which arises from the interaction between light and sound, has important applications in sensing, novel light sources and microwave-photonics (Kobyakov *et al*, 2010; Eggleton *et al*, 2013). The major platform for integrated optics at $1.55\ \mu$m is silicon, but it suffers from weak intrinsic SBS gain compared to other commonly used SBS materials, such as chalcogenide and silica glasses. This inherently low gain, due to high mechanical losses, combined with the high speed of sound in silicon, makes it difficult to observe photon-phonon interactions in silicon photonics. To overcome this we propose a metamaterial in the form of a cubic array of air holes in silicon (Figure 1a). Early simplified models (Smith *et al,* 2015) demonstrated the ability to control electrostriction in such media. Now, combining rigorous effective medium treatments for both the acoustic and optical problems, we compute the linear wave properties and acousto-optic interaction (Figure 1b) of this metamaterial. We find that this enhances the SBS power gain coefficient by more than a factor of 4 (Figure 1c), at a dilute filling fraction of 20% air. While the increased electrostrictive interaction is the biggest driver, changes in the refractive index, speed of sound, mass density, and the mechanical loss also contribute to the enhancement. In addition, the speed of sound in this metamaterial is lower than in bulk silicon, making it easier to confine the acoustic field. The greatly enhanced SBS gain, combined with the stronger confinement, will enable more compact silicon-based SBS devices.

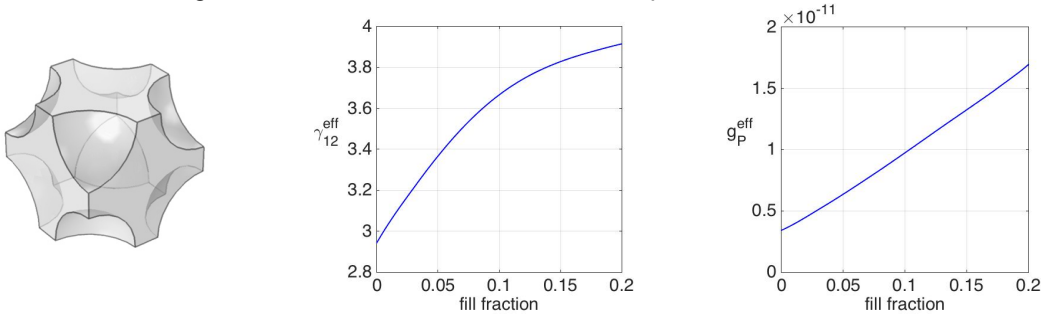

Figure 1 - (a) Unit cell for nanoporous Si; (b) effective acousto-optic (electrostrictive) parameter versus fill fraction; (c) effective SBS power gain coefficient [m W^{-1}] versus fill fraction.

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