Beating the Diffraction Limit with Polar Dielectrics: Employing Surface Phonon Polaritons in Low Loss Optical Antennas

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Abstract

Progress in plasmonic research has demonstrated its capability for enhancing many technologies including photodetectors, photovoltaics, and molecular spectroscopy. However, in order to maximize functionality, alternative materials to plasmonic metals that exhibit high optical losses must be explored. In our studies we have demonstrated that plasmonic-like effects can be achieved through phonon mediated collective charge oscillations, called surface phonon polaritons (SPhPs) in polar dielectric materials such as SiC and InP. Recently we showed that localized SPhP nanopillar resonators support extreme sub-diffraction (Åres/200) compression of the free space wavelength, with very low optical losses, resulting in quality factors up to an order of magnitude higher than the best plasmonic devices. Furthermore, the sharp plasmonic-like resonances can be actively tuned and/or turned off through optical pumping of electron/holes carriers.

The use of polar dielectrics to achieve plasmonic like effects is only in the beginning stages of exploration. In particular SPhP in polar anisotropic 2D crystals such as hBN can be exploited as natural hyperbolic materials (NHM). We have exploited the NHM response of hBN within periodic arrays of conical nanoresonators to demonstrate ‘hyperbolic polaritons’, deeply sub-diffractional guided waves that propagate through the volume rather than on the surface of a hyperbolic material. We have identified that the polaritons are manifested as a four series of resonances in two distinct spectral bands that have mutually exclusive dependencies upon incident light polarization, modal order, and aspect ratio. These findings can be extended to produce hyperbolic materials exploiting surface phonon polaritons in layered III-V semiconductors and other 2D materials to extend the optical range and physics. Novel devices and future directions will also be discussed.

Biography

Dr. Joe Tischler obtained his first degree in Physics from the University of Buenos Aires in Argentina in 1994. In 2000 he obtained his PhD degree in Physics from The University at Buffalo (SUNY, Buffalo). That same year he joined the Naval Research Laboratory in Washington DC as an NRC Postdoctoral Fellow working on single dot spectroscopy for quantum computing. In 2003 he joined the Naval Research Laboratory as permanent staff. Dr. Joe Tischler is the Head of the Nano Optoelectronic Section since 2016 and an Adjunct Professor at The University at Buffalo since 2012.

Dr. Tischler’s works on the development of novel nanostructured materials primarily for optoelectronic devices. Such materials include MBE grown III-V semiconductors, chemically grown nanocrystals (quantum dots, nanorods and nanowires), nanophotonic resonators and 2D crystals (graphene, h-BN, MoS2, etc…). Dr. Tischler is working on actual devices that range from far-infrared detectors to photovoltaics.