Polaritonic Nonlinear Metasurfaces for Flat Nonlinear Optics

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Nonlinear optical metasurfaces – planar structures made of a large number of sub-wavelength elements with engineered nonlinear optical response – can enable frequency mixing without phase-matching constrains of bulk nonlinear crystals and manipulation of the shape of the output beam via phase control of the nonlinear response of an individual sub-wavelength element. However, efficient frequency mixing in nonlinear metasurfaces requires nonlinear response orders of magnitude higher than that of traditional materials.

Intersubband transitions in n-doped coupled semiconductor coupled quantum wells allow one to quantum-engineer nonlinear response in semiconductor materials and produce very large optical nonlinearities. This large nonlinear optical response can be further enhanced if intersubband transitions are coupled to electromagnetic modes of optical nanoresonators fabricated in the semiconductor heterostructures to form intersubband nonlinear polaritonic metasurfaces. In this presentation, I will share our results on developing metasurfaces that display second- and third-order nonlinear susceptibility values 4-7 orders of magnitude higher than that of traditional nonlinear materials. In particular, I will present metasurfaces designed for efficient mid-infrared second harmonic and difference-frequency generation with second-order nonlinear susceptibility of ~10^6 pm/V with controllable phases of the nonlinear optical response and metasurfaces designed for saturable absorption and power limiting.