# Enhanced Polaritonic Metasurfaces for Second Harmonic Generation in InAs/AlSb Heterostructures

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III–V semiconductors, characterized by their zincblende crystal structures, exhibit naturally strong nonlinear optical responses. To enhance this nonlinearity, multiple quantum well (MQW) heterostructures have been integrated into plasmonic metasurfaces, facilitating electrically tunable second harmonic generation (SHG)[1]. In this research, we leverage InAs/AlSb heterostructures from the 6.1 Å lattice constant family, which feature a large conduction band off-set, enabling the creation of MQWs with significantly enhanced nonlinear coefficients in the short-wave infrared (SWIR). Specifically, our MQW structure achieves a second-order nonlinear susceptibility of 9 nm/V in the SWIR range.

Fig. 1a illustrates the conduction band diagram of the MQW used in the polaritonic metasurface. To achieve intersubband transitions in the SWIR range, the central 2.1 nm InAs layer is n-doped with an electron concentration of $10^{19}$ $cm^{-3}$, and the conduction band off-set exceeds 2 eV.

Fig. 1b depicts the polaritonic metasurface with a metal–insulator–metal configuration designed to enhance local field intensity at both the fundamental (FF) and second harmonic (SH) frequencies. The resonant antenna geometry maximizes the modal overlap between FF and SH modes, significantly boosting SHG efficiency. The SHG intensity scales with the square of the effective second-order susceptibility $\chi_{ijk}^{(2)eff}$ eff, defined as $\chi_{ijk}^{(2)eff} = \frac{\chi_{zzz}^{(2)}}{V_{MQW}}[\int_{V_{MQW}} \xi_{z(i)}^{2\omega}(x,y,z)\xi_{z(j)}^{\omega}(x,y,z)\xi_{z(k)}^{\omega}(x,y,z)dV]$, where $\chi_{zzz}^{(2)}$ is the relevant tensor element of intersubband nonlinear susceptibility, $\xi_{z(i)}^{\omega, or\ 2\omega}$ is the normalized near-field enhancement of the $E_z$ field in the MQW region at FF and SH, $V_{MQW}$ is the volume of the MQW. Fig. 1c and 1d indicate the near-field distributions within the MQW region for TM-polarized FF excitation and TE-polarized SH output. The effective nonlinear susceptibility reaches 11.5 nm/V at a 3 μm wavelength, enabling efficient nonlinear optical processes.

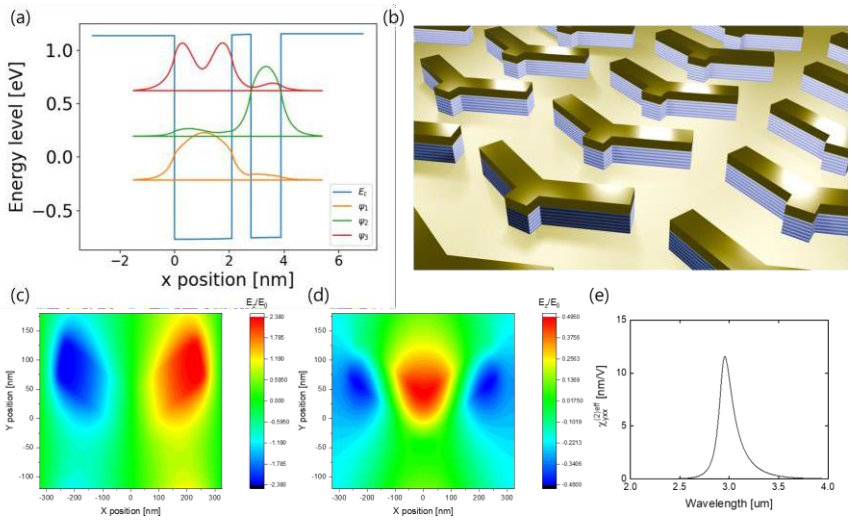


Fig. 1 (a) Conduction band diagram for InAs/AlSb MQW with each energy levels and normalized wavefunctions. (b) The schematics of SWIR polaritonic metasurfaces. The near field distribution of SWIR polaritonic metasurfaces in xy plane for FF (c) and SH (d). (e) The calculated effective nonlinear susceptibility of the SWIR polaritonic metasurface.

**References**

[1] Yu, Jaeyeon, et al. "Electrically tunable nonlinear polaritonic metasurface." Nature Photonics 16.1, 72-78 (2022).