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Numerical Optimization of Plasmonic Bowtie Architectures for Enhanced TMD Single-Photon Emitters

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Two-dimensional (2D) materials such as transition-metal dichalcogenides (TMDs) and hexagonal boron nitride (h-BN) exhibit tunable band structures, strong excitonic effects, and the ability to host quantum emitters, making them promising for quantum technologies [1]. Single-photon emitters (SPEs) in TMDs—engineered via defect creation or strain modulation—offer a route to nonclassical light, though they face challenges including low brightness, limited emission directionality, and reduced photon indistinguishability [2]. Plasmonic structures can overcome these obstacles by increasing emission rates, enhancing stability, and boosting photon collection, while their tunable resonances offer precise spectral and spatial control [3]. In this work, we employ numerical simulations to optimize plasmonic architectures for integrating with TMD-based SPEs. Our results indicate that a plasmonic bowtie geometry is particularly effective, providing spatial overlap between strain-induced quantum emitters and plasmonic enhancement along with polarization control. For sharp bowtie antennas, we observe multiple plasmonic resonances stemming from strong field confinement at the tips. Rounding the tips, however, causes these distinct resonances to merge into a broader peak, due to reduced local field inhomogeneity. Furthermore, adding a 5-nm h-BN layer atop MoS₂ alters the local refractive index and enhances field confinement, effectively reducing the mode volume and markedly increasing the Purcell factor. Variations in the inter-arm gap also play a role; widening the gap leads to a blue shift in the resonances and reduced scattering intensity as the coupling efficiency diminishes. Ongoing investigations aim to clarify the underlying mechanisms and further optimize SPE performance. Overall, our numerical study advances the integration of TMD-based SPEs with plasmonic structures and provides valuable insights for developing scalable quantum photonic technologies.

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