Enhancing Light Collection Efficiency due to WS_2 Dielectric Nanoantennas on a Metallic Substrate

Sam Randerson
Yadong Wang, Panaiot G. Zotev, Yue Wang, Dominic Hensman, Sharada Nagarkar, Alexander I. Tartakovskii
University of Sheffield, Dept. Physics and Astronomy, Hicks Building, Hounsfield Rd, Sheffield, UK
SRanderson1@Sheffield.ac.uk

Transition metal dichalcogenides (TMDs) have a range of attractive properties allowing them to be used for manipulating light on a scale below its wavelength through a variety of structures and arrays. In particular, they have high refractive indices [1], low losses [2], and can be deposited on a range of substrates owing to van der Waals interactions [3]. Recent works have demonstrated coupling of these modes to single photon emitters (SPEs) in strained TMD monolayers placed over dielectric nanoantennas, thus enhancing their quantum efficiency [4]. However, the directionality of such SPEs still remains low with much of the light lost to the environment. Here, we simulate and fabricate a hybrid metal-dielectric nanoantenna system composed of WS_2 hexagonal monomers and dimers (single and double pillars) on a gold substrate. We show that resonant Mie modes observed in simulated scattering spectra (figure 1a) are reproduced well in experimental dark field spectroscopy (figure 1b), and that the electric field is highly confined at the antenna vertices, as shown in figures 1c and d, which leads to a Purcell enhancement of 119. Furthermore, we demonstrate that light collection efficiency can be considerably increased by a factor of 4 with a gold substrate compared to a SiO_2 substrate in simulation, as in figure 1e. This work opens possibilities for enhanced photoluminescence of coupled emitters, advances in optical trapping, and stronger non-linear effects.

References

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Figures

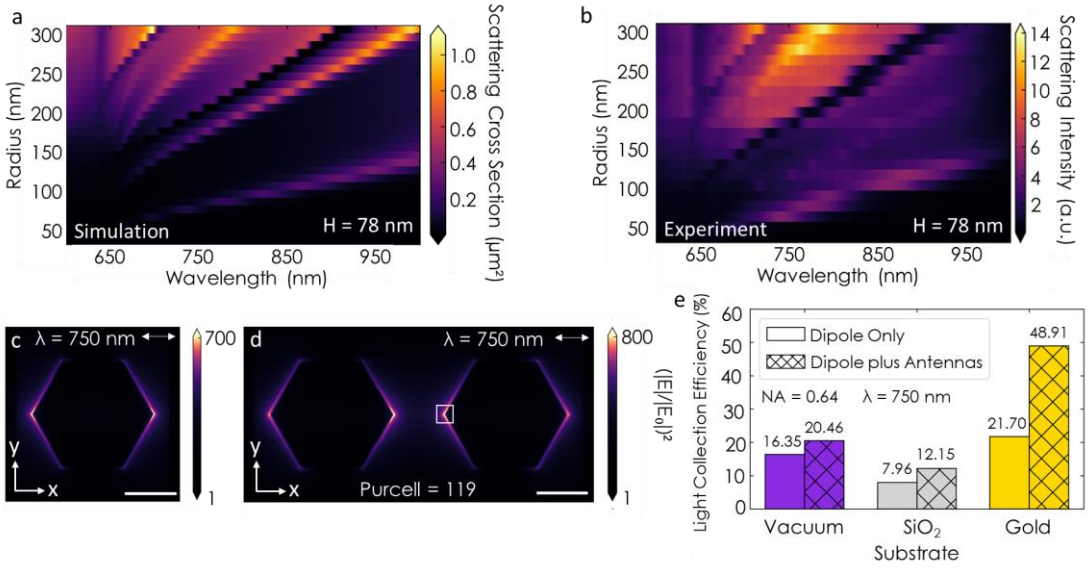

Figure 1: WS_2 hexagonal nanoantennas on gold optical characterisation and simulation. (a) and **(b)** show simulated and experimental scattering spectra of monomers of height 78 nm for a range of radii respectively. **(c)** and **(d)** show the top view of the electric field intensities for a monomer and dimer respectively, each with height 180 nm and radius 120 nm. White double-headed arrow shows excitation polarisation. Purcell factor is from a dipole placed 0.5 nm above the inner dimer vertex, highlighted by the white box, where the electric field is maximised. Scale bars are 100 nm. **(e)** shows the light collection efficiency in simulation of a dipole placed 0.5 nm above different substrates, compared to a dipole 0.5 nm above the inner dimer vertex. The numerical aperture used is 0.64 with dipole polarisation along the dimer axis and wavelength 750 nm.