Extreme nanophotonics within subnanometer plasmonic gaps

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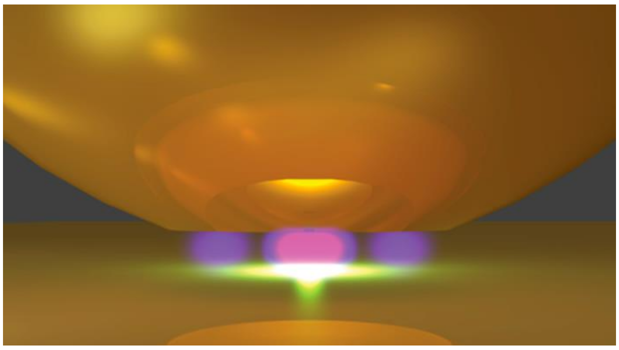

Fig.1 Schematic of a nanoparticle-on-mirror plasmonic nanocavity[1]

Light is being squeezed into smaller and smaller space. Traditional photonic devices such as waveguides have minimum size of microns limited by the wavelength of light due to diffraction effects. Single metal (especially noble metals such as gold, silver, copper and aluminium) nanoparticles can confine light into spots in the range of a few tens to a few nanometers, limited by the size of nanoparticles. Further confinement of light can be achieved with closely spaced nanoparticles with subnanometer gaps so called plasmonic nanocavity, which can confine light into extremely small space below 1 nm^3 [2]. The extreme confinement also brings about extreme enhancement of the local optical fields within the gap, which can be up to 100~1000 times stronger in magnitude (10^4~10^6 enhancement in intensity) than the incident field. Such extreme confinement of light opens avenues for 'extreme nanophotonics', which have significant applications in a wide range of areas, including imaging (e.g., scanning near-field optical microscopy), sensing (e.g., singe molecule detection), data storage (e.g., heat-assisted magnetic recording), energy (e.g., plasmonic enhanced photovoltaics and light emitting diodes), nonlinear optics (e.g., higher harmonic generations) and quantum optics (e.g., plasmon enhanced single photon emitters). Ultimate plasmonic nanocavities are also the ideal platforms for exploring a rich set of fundamental science, such as single molecule chemistry, hot electrons, cavity quantum electrodynamics, and nano thermodynamics etc.

In this project we aim to develop robust plasmonic cavities with tuneable and well-defined sub-nm gaps for a systematic investigation of extreme nanophotonics. This will be achieved with the so-called nanoparticle-on-mirror (NPoM) geometry (Fig.1) composed of a metal nanoparticle sitting on top of a reflective metal substrate ('mirror') separated by a sub-nm spacer [2]. The nanoparticle couples strongly to its image particle inside the metal substrate, in analogue to a pair of dimer particles, generating extremely strong optical fields within the gap. Atomically thin films of 2D materials will be used as the spacing layer to create ultimate sub-nm gaps. Thanks to the pioneering gold-assisted exfoliation technique developed by our group which can exfoliate large-size monolayers of 2D materials on Au substrate [3], we will be able to construct a wide variety of plasmonic nanocavities with variable sub-nm gap sizes by using different 2D material spacers, opening opportunities for unprecedented detailed investigation on fundamentals of extreme nanophotonics, to shed light on many unsolved questions and to exploit it for applications, such as enhancing the light-matter interaction of 2D materials.

1. Sigle, D.O., et al., ACS Nano, 2015. **9**(1): p. 825-30.
2. Baumberg, J.J., et al., Nat. Mater, 2019. **18**(7): p. 668-678.
3. Velicky, M., et al., ACS Nano, 2018. **12**(10): p. 10463-10472.