Laser science within a nanoscopic gap

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Lasers have overcome numerous technological limitations in the 50 years since their first demonstration; however, scaling their size below the diffraction limit of light has only recently been achieved [1-3]. Metal-based lasers now create and sustain coherent light well below the diffraction limit, by amplifying surface plasmon polaritons, the collective electronic oscillations of metal-dielectric interfaces.

We first review our recent progress on semiconductor plasmonic lasers. These devices consist of a semiconductor nanowire [1] or square nanocrystal [2] sitting separated from a Silver substrate by a 5 nm insulating “gap” layer. Remarkably, the thickness (diameter) of the semiconductor nanocrystals can be just 50 nm, despite a much larger operation wavelength of about 500 nm. The close proximity of the high permittivity nanocrystal to the silver strongly confines propagating waves light normal to the plane. Meanwhile, the geometry edges provide sufficient feedback to achieve laser action. In particular, we report room temperature operation of the square devices, a key step towards applications.

We go on to discuss the potential for using the “gap” region for probing light matter interactions. While the characteristics of conventional lasers are suited to light transmission over large distances, plasmon lasers are sources of nanoscopic light that is more suited to use within the laser itself. This especially relevant since the sizes of these optical excitations are now tantalizing close to those of solid state electronic wave-functions [4]. Not only does the nanowire laser geometry (eg. Fig. 1a and 1b) generate intense optical fields in the gap region due to the highly localized mode; it also strongly enhances vacuum fluctuations. Indeed, in new experiments we have found that spontaneous emission of Dye molecules, placed within the gap region are greatly accelerated, as shown in Fig 1c [5]. The capability to enhance both real and virtual photons could lead to extremely sensitive implementations of spectroscopy at the nanoscale.

References