Luminescent Up-conversion in Engineered Colloidal Quantum Dots

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Two-photon microscopy plays a major role in the world of bio-imaging, due to properties such as optical sectioning, improved spatial resolution and easy signal separation. However, two-photon fluorescence typically requires the use of high peak power light sources, which can be problematic for some applications. An appealing alternative to conventional two-photon microscopy is offered by photon up-conversion processes in which a higher energy photon is generated due to promotion of an electron from an intermediate metastable state. Markers having such metastable state effectively enable two-photon imaging with dramatically reduced excitation powers. Although it has already been demonstrated, for example, in rare-earth doped nanocrystals [1] and photochemical reactions based on triplet-triplet annihilation [2], quantum dots (QD) combine great color tunability together with good photo-stability, making them a good candidate for two-photon microscopy.

We present a colloidal compound fluorophore engineered for efficient up-conversion, produced by wet chemical synthesis [3]. The fluorophore consists of a Te doped CdSe core, separated by a CdS tunneling barrier from a second, undoped, island of CdSe, which effectively forms a double-QD nanoparticle. The band structure of this fluorophore is of a double quantum well for holes in the valence band, while an excited electron in the conduction band is completely delocalized. This structure enables two-color emission centered around 690 nm and 570 nm from the two quantum wells. When exciting at a wavelength between the two emission-lines (here, 680nm), one-photon absorption can occur at the lower energy well forming an exciton. Upon two consecutive such absorptions (before the first exciton decayed), a hot hole is created, which can rapidly cool down to the higher-energy well and later recombine with the electron to emit an up-converted photon. We have observed up-conversion from this fluorophore both in colloidal solution and in single particle level and studied their up-conversion mechanisms and efficiency.

Quantum dots’ color tunability of the above configuration makes it a unique tool for efficient two-photon microscopy. With further improvement of the efficiency of this process, low power excitation sources, such as widely available CW lasers, should suffice for two-photon imaging.

References:

