PHOTON-AVALANCHE NANOPARTICLES FOR SUPER-RESOLUTION MULTIPHOTON MICROSCOPY

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Laser-scanning multiphoton microscopy has become a powerful tool for morphological and functional imaging of cells, tissues and live animals over the decades. One of the advantages is the improved spatial resolution over confocal microscopy; however, the nonlinearity of multiphoton process is limited using conventional fluorescent probes, so that structures below the diffraction limit cannot be resolved in general. We show that using Yb/Tm co-doped upconversion nanocrystals, an anomalous super-linear power dependence have been achieved when the Tm doping concentration is beyond 8% [1]. Specifically, we measured individual nanoparticles of $NaYF_4$:20%Yb,8%Tm and found the intensity of their 455-nm emission follows the 980-nm excitation to the power of 6.2. Our rate equation modelling revealed that the photon avalanche process in these nanoparticles underlies such unusual superlinearity, essentially caused by the intense cross-relaxation among the highly doped Tm emitters [2]. These photon-avalanche nanoparticles have enabled 3D sub-diffraction cellular imaging in a simple confocal configuration using a continuous-wave diode laser source. Furthermore, theoretical simulations have proposed photon-avalanche nanoparticles with even higher order of superlinearity up to the power of 80, to potentially achieve spatial resolution around 40 nm [3]. These results suggest a new avenue to super-resolution multiphoton microscopy without the need of expensive femtosecond lasers, to facilitate biological studies enabled by photon-avalanche nanoparticles.

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