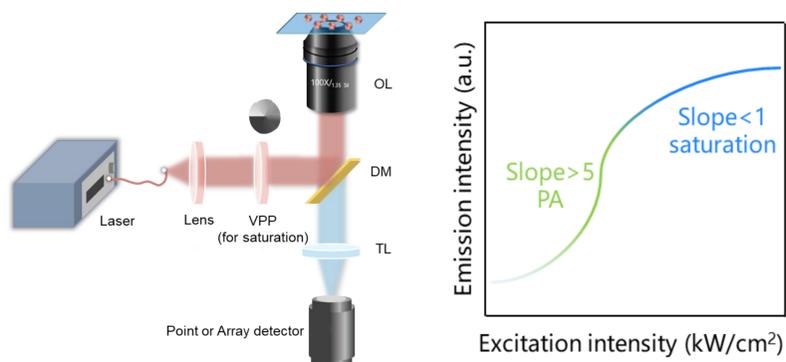


Super-resolution imaging enabled by nonlinear optical response of upconversion nanoparticles

Chenyi Wang, Zizhao Wen

* Corresponding Email:Chenyi Wang@m.scnu.edu.cn

Graphical Abstract



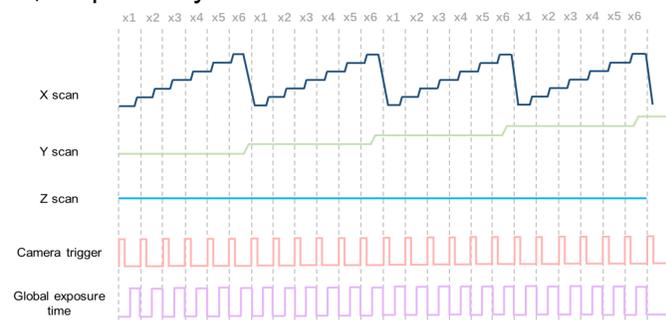
Abbreviation

1. VPP: vortex phase plate; 2. DM: Dichroic Mirror; 3. TL: Tubelens 4. PA: Photon Avalanche 5. UCNPs: upconversion nanoparticles 6. ETU: Energy transfer Upconversion 7. EMU: Energy Migration Upconversion

Methods

Instrument Control

The microscope achieved synchronous control of all equipments through 3 analog output signals and 2 digital signals by the data acquisition card for programming to control the piezoelectric sample scanner and the external triggering of detectors, respectively.



Results & Discussion

1. Energy transfer pathways in UCNPs

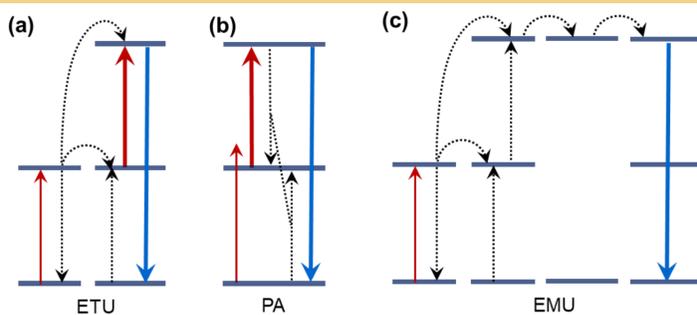


Fig.1 Energy transfer pathways about optical nonlinear response in UCNPs, including ETU, PA and EMU.

2. Full-spectrum photon avalanche effect

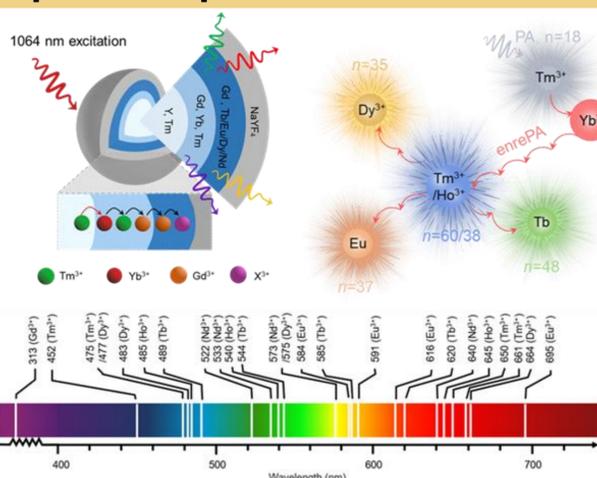


Fig. 2 The extreme optical nonlinear response enabled by elaborately designing the core-shell nanostructure, realizing full-spectrum photon avalanche effect in visible range.

Results & Discussion

3. Super-resolution imaging

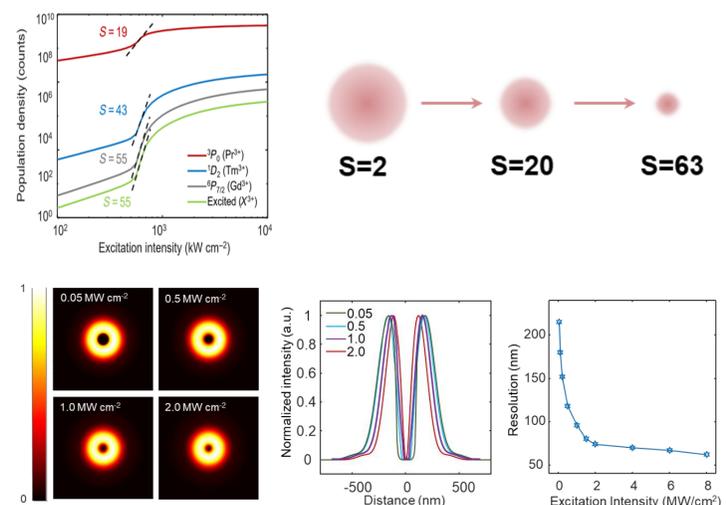


Fig. 3 Super-resolution imaging can be realized by utilizing the photon avalanche effect under the irradiation of a Gaussian beam and emission saturation effect under the irradiation of a doughnut-shape beam with relatively high power.

Conclusions

Based on a confocal optical system, we present series new strategies, including tandem photon avalanche (TPA), energy-relay photon avalanche (enrePA) and emission saturation effect to achieve optical nonlinearity from up to 63rd-order to lower than 1st-order. Furthermore, multi-color super-resolution imaging has been realized with a resolution of about 50 nm. Our work provides simple and universal methods to engineer nanoprobe with much better performance, triggering a wide range of cutting-edge applications.

Reference

- Chen C, Wang F, Wen S, et al. Multi-photon near-infrared emission saturation nanoscopy using upconversion nanoparticles[J]. Nature communications, 2018, 9(1): 3290.
- Wang C, Wen Z, Pu R, et al. Tandem Photon Avalanches for Various Emitters with Optical Nonlinearity up to 41st-order through Interfacial Energy Transfer [J]. Advanced Materials, 2024, 36(2): 2307848
- Wang C, Wen Z, Pu R, et al. Giant Optical Nonlinear Response up to 60th-order induced by the ytterbium energy relay mediated photon avalanches [J] (Laser & Photonics Reviews, accept) (IF=11, Q1)