Super-resolution STED imaging of optical vortices in a high-NA speckle pattern

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Scalar wavefields passing through random media generate random speckle patterns. These patterns contain hot spots but also true zeros of intensity which draw lines in three-dimensional space [1]. These zeros of intensities are surrounded by spiral phase patterns and are thus called optical vortices due to the circulation of the optical current around the nodal line. For optical wavefields of high numerical apertures, the contribution of all three components of the field must be taken into account. In particular, the axial field cannot be neglected. In STimulated Emission Depletion (STED) microscopy for instance [2], resolution is improved by stimulating fluorescence with a donut-shaped beam exhibiting an optical vortex at its dark center. This beam must be circularly polarized in order to cancel the axial component of the field at the center of the donut. Using the opposite “wrong” circular polarization yields a significant axial component resulting in deexciting fluorophores located at the donut center.

Here we study optical vortices in a high-NA speckle pattern thanks to super-resolution STED microscopy [3]. To do so, we first photo-bleach a uniform sample of fluorophores embedded in a polymer matrix with a high-NA speckle illumination pattern having right-handed circular polarization. Then we image the remaining fluorescence by STED microscopy. The same protocol is repeated for left-handed polarization. Results demonstrate sub-diffraction confinement of fluorescence in the sample and sub-diffraction imaging of positively and negatively charged vortices in the speckle pattern. These results are discussed in the context of imaging through scattering media [4] where speckle patterns consistently occur under coherent illumination.

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