ELLIPTICALLY POLARIZED CYLINDRICAL VECTOR BEAMS IN SINGLE-MOLECULE HIGH-APERTURE LASER-SCANNING CONFOCAL FLUORESCENCE MICROSCOPY

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Previously, we have demonstrated that the task of visualization of arbitrarily oriented single quantum emitters (SQEs) can be solved efficiently by means of laser-scanning confocal fluorescence microscopy (LSCFM) using an elliptically polarized cylindrical vector excitation beam (EPCVB) for SQEs located in a homogeneous medium [1] and inside the planar optical antenna providing 99% fluorescence collection efficiency [2]. In the present work, we theoretically explore the visualization of arbitrarily oriented SQEs located in a polymer film supported by a glass substrate and generalize the applicability of the EPCVB-based LSCFM technique for the visualization of SQEs near different planar interfaces. We consider SQEs of two types: linear dipole emitter and 2D-dipole emitter (a couple of two incoherent mutually orthogonal dipoles). The efficiency of arbitrarily oriented SQE visualization is described using the approach of comparing the dimmest and the brightest orientations [2].

Here, we demonstrate numerically that, using EPCVB-based LSCFM technique, the image intensity difference between the dimmest and the brightest molecules dispersed in a 100-nm-thick polymer film and oriented arbitrarily can be reduced down to 30%. Next, it is derived analytically that for 2D-dipole emitters located in the same plane parallel to layers of a planar layered structure under investigation, the image intensity orientational dependence can be completely excluded by using the azimuthally polarized CVB in LSCFM. Figure 1 shows a series of LSCFM images of 2D-dipole emitters located under a 20-nm-thick polymer film on a glass cover slide as an example. The numbers in Fig. 1 represent the polar angle (in degrees) that assigns an emitter's orientation and the images are normalized to the intensity maximum of the brightest emitter. The intensity maximums of the images are not orientation-dependent.

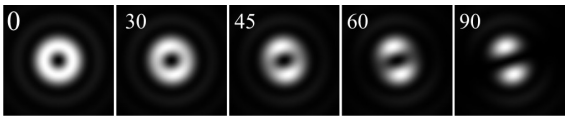

Figure 1: Simulated LSCFM images of 2D-dipole SQEs of different orientations.

The suggested technique can be directly applied for the visualization of arbitrarily oriented single dye molecules in thin polymer films. Potentially, it can be combined with super-resolution microscopy methods to perform super-resolution imaging of arbitrarily oriented single molecules.

[1] S. Boichenko and E.F. Martynovich, "Complex cylindrical vector beam excludes the orientation dependence of the intensity of scanning fluorescence images of single molecules," *JETP Letters*, **97**, 52-56 (2013).
[2] S. Boichenko and K. König. "Extremely high efficiency in arbitrarily oriented single molecule fluorescence imaging," // *J. Opt. Soc. Am. B,* **32**, 601-605 (2015).