

# FORMATION OF A SMALL THREE-DIMENSIONAL DARK SPOT WITH A HIGH UNIFORM LIGHT WALL

Yaoju Zhang<sup>1\*</sup>, Taikai Suyama<sup>2</sup>, Yanyan Wang<sup>1</sup>, Tianzhen Shi<sup>1</sup> and Chaolong Fang<sup>1</sup>

<sup>1</sup> College of Physics and Electronic Information, Wenzhou University,  
Wenzhou 325035, China

<sup>2</sup> Graduate School of Science and Technology, Kumamoto University,  
Kumamoto 860-8555, Japan

\*Author e-mail address: [zhangyaoju@sohu.com](mailto:zhangyaoju@sohu.com)

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Three-dimensional (3D) dark spots or bottle beams surrounded by light are applied in many areas in optics, such as dark-spot optical traps for atoms or as erase beams for super-resolution fluorescence microscopy [1]. Several methods have been used to produce 3D bottle beams that have an intensity null surrounded by light in all directions. A simple method to create a 3D bottle beam is to use a double-ring-shaped radially polarized beam (R-TEM<sub>11</sub>\*) [2]. However, a serious drawback of the R-TEM<sub>11</sub>\* method is that the maximum light intensity surrounding the dark focal spot is much lower at the diagonal direction in light meridian plane than that along the optical axis (see Fig. 1 (a)) and the uniformity of the light “wall” surrounding the 3D dark spot is about 0.355, which is disadvantage for super-resolution fluorescence depletion microscopy and particle trap.

To generate a small 3D dark spot uniformly surrounded by light, we use the incoherent superposition of two cylindrical vector beams: one is a double-ring-shaped radially polarized beam and the other is a single-ring-shaped azimuthally polarized beam. Figure 1(b) shows the intensity distribution in the focal region for the incoherent superposition of the two beams focused by an oil immersed lens with high numerical aperture NA=1.48, where the truncation parameter of  $\beta=1.3$  is used.  $\beta$  is defined as the ratio of the radius of the aperture of the objective to the waist of Gauss beam, its size has an important effect on the dark spot quality. It is seen from Figure 1(b) that the dark spot volume is very small and the light wall surrounding the dark spot is very uniform. If the uniformity  $U$  of the light wall is defined as the ratio of the lowest intensity in the light wall to the highest intensity in the light wall,  $U=0.785$  in Figure 1(b). The generated perfect 3D dark spot is very useful for 3D dark spot microscopy and particle trap.

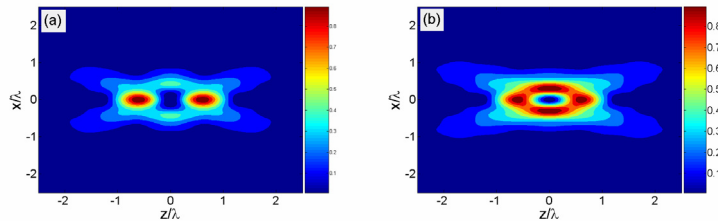


Figure 1: Intensity distributions in the focal region.

## References

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