Optical Superresolution without Evanescent Waves

Fu Min Huang and Nikolay Zheludev,
Optoelectronics Research Centre, University of Southampton, SO17 1BJ, U.K.
Tel.: +44 2380592699, Fax: +44 2380593142
fmh@orc.soton.ac.uk, www.nanophotonics.org.uk/niz

Abstract: We show that arbitrarily small localization of light of prescribed profile can be created within a finite area of space using a mask illuminated by a monochromatic plane wave, without evanescent waves.

About fifty years ago Toraldo Di Francia demonstrated that propagating waves can generate arbitrarily small localization of light in far-field by showing a practical example of a pupil design that can achieve that. Recently Berry and Popescu [1] have shown that an optical grating can create a sub-wavelength localization of light beyond the near field and linked this to the theory of superoscillation. Examples of subwavelength localization of light generated by nano-hole array grating waves have been experimentally demonstrated recently by our group [2, 3], while in a separate work we demonstrated that such arrays could be used as imaging devices [4].

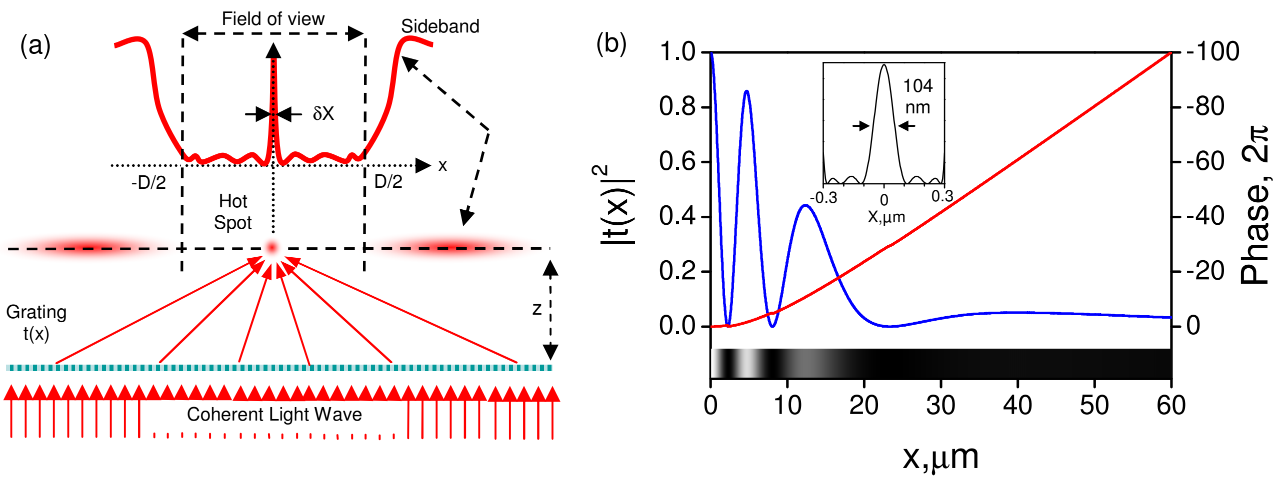

Fig.1 (a) Optical superoscillation. Arbitrarily small field features within a finite area of space [-*D*/2, *D*/2] can be generated by a mask upon illumination by a plane wave. Graph (b) shows intensity and phase profiles of a mask creating a field distribution (insert) with FWHM=104 nm at a distance of z = 10 µm away from the mask, when illuminated with a plane wave at λ =500nm.

In this paper we develop the concept of superoscillation further and show that subwavelength localization of light of prescribed profile in the far field can be achieved without evanescent waves. We show that arbitrarily small field localization can be created within a finite area of space using a phase-intensity mask illuminated by a monochromatic plane wave. We have developed a rigorous mathematical procedure for designing such a mask based on the use of prolate spheroidal wave functions and demonstrate examples of masks generating substantially subwavelength localizations (Fig.1). We also show that the mask can be used as a lens for the purpose of subwavelength imaging.

1 M. V. Berry and S. Popescu, J. Phys. A: Math. Gen. **39**, 6965-6977 (2006).
2 F. M. Huang, Y. Chen, F. J. Garcia de Abajo, and N. I. Zheludev, Appl. Phys. Lett. **90**, 091119 (2007).
3 F. M. Huang, Y. Chen, F. J. Garcia de Abajo, and N. I. Zheludev, J. Opt. A: Pure Appl. Opt. **9**, S285-S288 (2007).
4 F. M. Huang, T. S. Kao, V. A. Fedotov, Y. Chen, and N. I. Zheludev, Nano Lett. **8**, 2469-2472 (2008).