Superresolution without Evanescent Fields

Fu Min Huang, Tsung Sheng Kao, Nikolay I. Zheludev
Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, United Kingdom

The last decade has seen numerous efforts to achieve imaging resolution beyond that of the Abbe-Rayleigh diffraction limit. The main direction of research aiming to break this limit seeks to exploit the evanescent components containing fine detail of the electromagnetic field distribution at the immediate proximity of the object. Here we propose a solution that removes the need for evanescent fields. The object being imaged or stimulated with sub-wavelength accuracy does not need to be in the immediate proximity of the superlens or field concentrator: an optical mask can be designed that creates constructive interference of waves known as superoscillation, leading to a sub-wavelength focus of prescribed size and shape in a field of view beyond the evanescent fields, when illuminated by a monochromatic wave. We demonstrate that such a mask may be used not only as a focusing device, but also as a super-resolution imaging device.

We report an algorithm for designing a super-resolution imaging mask [1] and also report the first experimental step towards demonstration of the concept: using a simple nano-hole array design we show that it can be used as a focusing device and as an imaging device. Although so far in the experiment we have achieved sub-wavelength focusing [2] and a diffraction-limited imaging [3] our results are important steps towards the demonstration of true sub-wavelength imaging which shall be possible with a more sophisticated mask.

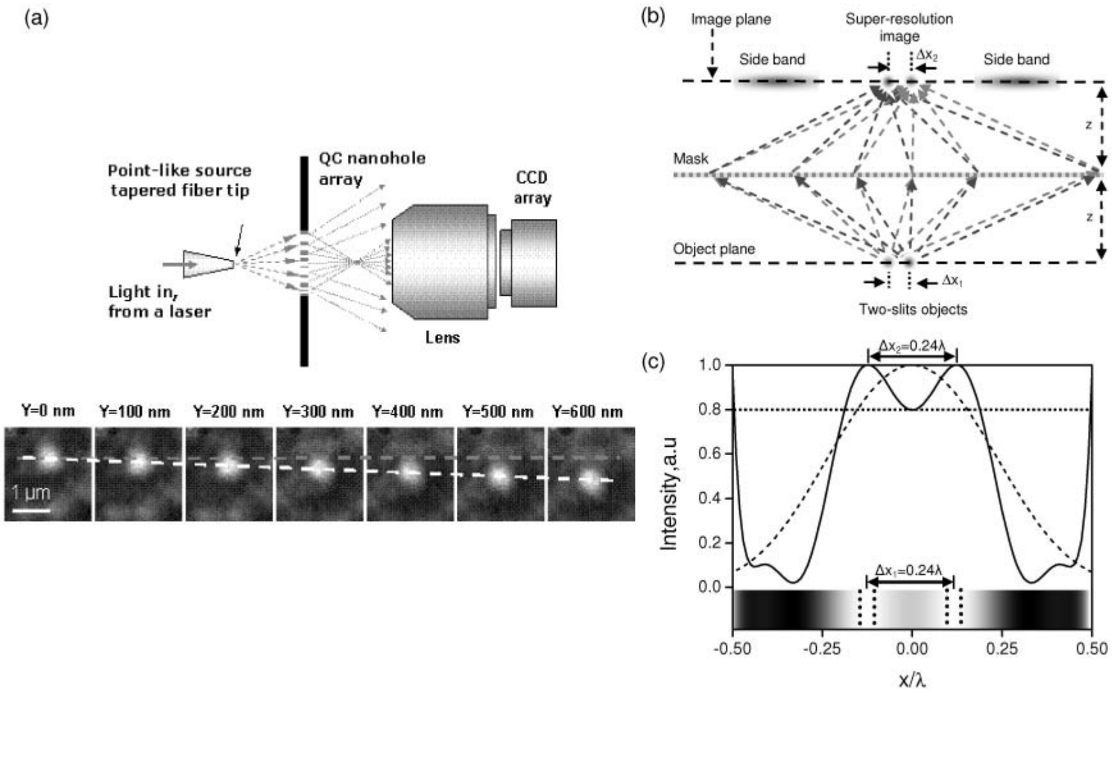

Fig. 1 (a) Nanohole array as a lens. A point light source (λ=635nm) at a few tens of wavelengths away from a nanohole array was imaged into a hot spot on the other side of the array, which was recorded by a CCD camera. Bottom: a series of the CCD images show the motion of the hot spot corresponding to light source moving along the y-direction. (b) Superoscillation mask as a subwavelength imaging device. (c) Subwavelength imaging with a superoscillation mask (modelling). Two nanoslits (each with 0.04 λ width and separated by a distance of 0.24 λ) were clearly resolved by a specifically designed superoscillation mask. Solid line: calculated intensity profile of the imaging field. The intensity distribution is also shown as a gray image at the bottom of the image, where dotted lines indicate positions of nanoslits. Dashed line: the imaging field of a conventional cylindrical lens with NA=1.

References

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978-1-4244-4080-1/09/$25.00 ©2009 IEEE