RESOLUTION AND SUPERRESOLUTION

Colin J. R. Sheppard
Istituto Italiano di Tecnologia, Via Morego 30, 16163 Genova, Italy

The term superresolution is often used to refer to achievement of a resolution greater than that given by the Abbe resolution limit[1-4] or the Rayleigh resolution criterion.[5] Many papers have claimed the attainment of superresolution, i.e. resolution beyond that achieved classically, by measurement of the profile of a feature in the image. In this presentation, for simplicity, we concentrate our attention on imaging in coherent microscopes, as assumed in the original Abbe theory.

In particular, we argue that measurement of the contrast of the image of a dark bar on a bright background (i.e. the gap between two bright objects) does not give a measure of resolution, but rather of detection sensitivity.[6-8] We find that the width of a bar that gives an intensity at the centre of the bar of 0.735 times that in the bright region (the same ratio as in the Rayleigh resolution criterion[5]) is $\lambda/(13.9\times\text{numerical aperture})$ for the coherent case with central illumination. This figure, which compares with $\lambda/(\text{numerical aperture})$ for the Abbe resolution limit with central illumination, holds for the classical case, and is therefore no indication that superresolution has been achieved. The contrast in the image of a narrow dark bar on a bright background is thus much greater than might be expected from comparison with the Rayleigh resolution criterion.

Theoretical images for two points, two lines, arrays of lines, arrays of bars, and grating objects are compared, and the effect of changing the number of elements in the arrays studied. These results can be used a reference for experimental results, to determine if superresolution has indeed been attained for different experimental implementations.

1. Abbe, E. (1873). Beiträge zur Theorie des Mikroskops und der mikroskopischen Wahrnehmung. *Arch. mikrosk. Anat. Entwichlungsmech.* 9: 413-468.
2. Abbe, E. and Fripp, H. (1874). A contribution to the theory of the microscope, and the nature of microscopic vision. *Proceedings of the Bristol Naturalists' Society, new series* 1: 200-258.
3. Lummer, D. and Reiche, F. (1910). *Die Lehre von der Bildentstehung im Mikroskop von Ernst Abbe*. Braunschweig: Vieweg.
4. Köhler, H. (1981). On Abbe's theory of image formation in the microscope. *Optica Acta* 28: 1691-17012.
5. Rayleigh, J. W. S. (1879). Investigations in optics, with special reference to the spectroscope. *Phi.l Mag.* **8**: 261-274
6. Rayleigh, J. W. S. (1896). On the theory of optical images, with special reference to the microscope. *Phil. Mag.* 42: 167-195.
7. Rayleigh, J. W. S. (1903a). VII - On the theory of optical images, with special reference to the microscope. *J. RMS*: 447-473.
8. Rayleigh, J. W. S. (1903b). VIII - On the theory of optical images, with special reference to the microscope (Supplementary paper). *J. RMS*: 474-482.