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IT-1-P-2476 Effect of a phase plate on TEM imaging

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The type of phase plate that has been most widely reported (eg [1]) consists of a plain disc of material such as carbon, of controlled thickness, with a central hole to pass the direct beam. Images made with this type of plate show bright outlines or halos around certain features [2, 3]. Analysis of geometrical imaging has shown how these halos occur. It is necessary to consider the response to all spatial frequencies that are present in a typical object. In principle this can be done straightforwardly by Fourier transforming the object phase to find its spatial frequency distribution at the back focal plane (BFP), multiplying by the response of the phase plate and further transforming to find the image distribution.

The response has been found [4] for a weak phase object consisting of a circular disc of radius b, centred on the microscope axis. The phase plate is assumed to advance the phase of components with angular frequencies greater than a value q_0 , defined as

$q_0 = 2 (pi) r_2 / \lambda f$

where r_2 is the radius of the central hole in the plate for the direct beam, λ is the electron wavelength and f is the focal length of the lens. The resulting image intensity is shown in figure 1 for a phase advance of (pi)/2 and a range of values of $B = q_0 b$. The object is imaged with little overshoot when B is less than about 1. Reported results [5] agree with this transition value for B.

The step changes at radius b are always imaged fully but as B increases, the low-frequency components are progressively lost from the image and for B > 1, the mean intensity across a step falls to the background value. The full range of the step is maintained, so the intensity changes from +(half the range) at radii just less than b, to –(half the range) just outside the step. Thus a bright halo or outline is produced just outside the boundary r = b, for objects with B > ~1. The darker central patch for B = 8 agrees with observation [3]. The maximum object diameter that corresponds to B_{max} , the maximum B for accurate imaging, is

$2b_{max} = 2B_{max} / q_0 = \lambda B_{max} f / (pi) s_2$

where s_2 is the radius of the hole needed to pass the direct beam. To increase the size of object that can be imaged accurately, it will be necessary to reduce s_2 or increase the focal length of the objective lens.

References

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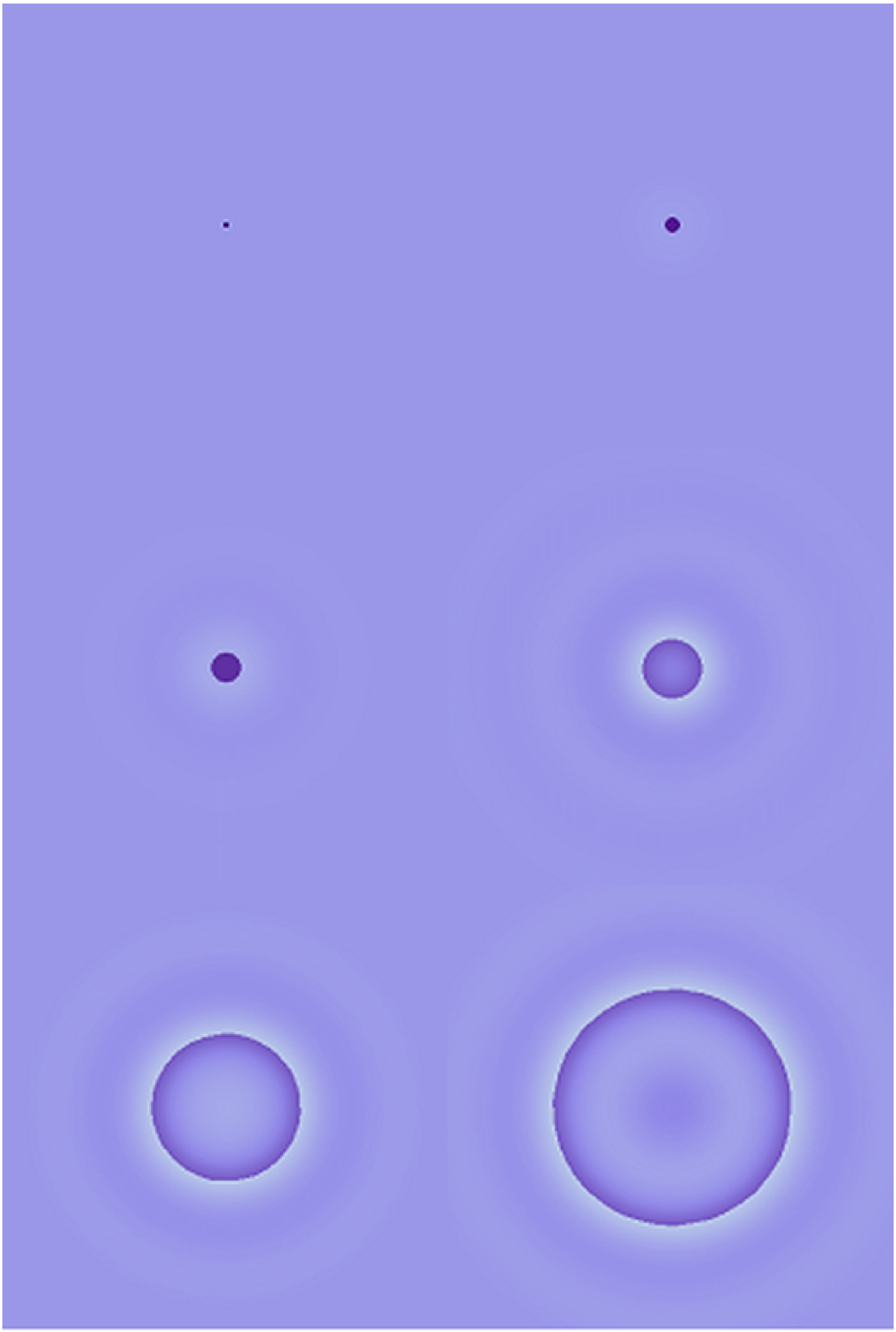

Fig. 1: Figure 1. Image intensities produced by a (pi)/2 phase plate with fixed q_0 for uniform disk objects with a range of diameters 2b. Responses are shown for values of B = q_0b (increasing from top left) of 0.2, 0.5, 1, 2, 5 and 8.