Atomic resolution phase-shifting electron holography

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Aim

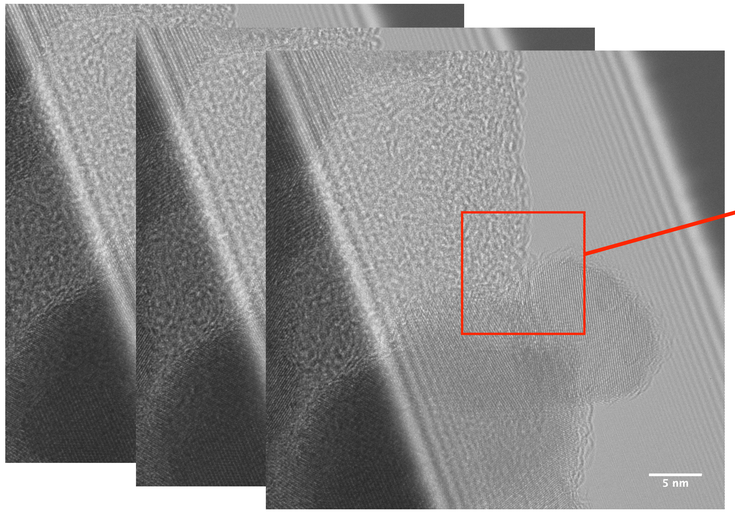
Combine a series of holograms of the same area of a sample to get improved resolution and lower noise than can be obtained from individual holograms.

Requirements

A series of 3 or more holograms of the same sample area.

The sample must not change or damage during the series (but drift is OK).

In each hologram the position of the fringes must be shifted with respect to the specimen by a different amount (the phase-shift). The phase-shifts between each hologram do not have to be the same.



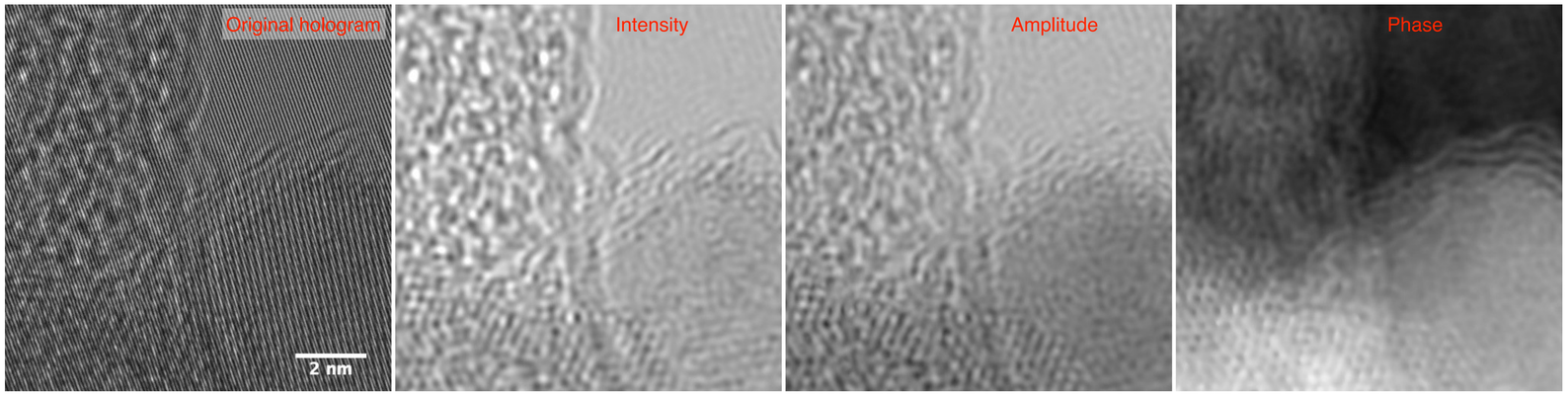
Three holograms from a series of 26 of CeO_2 nanoparticles on holey carbon taken with the FEI Titan "Pico" at 80kV. The biprism voltage was 75V, giving a fringe spacing of 0.1nm.

References

Q Ru, G Lai, K Aoyama, J Endo and A Tonomura, Ultramicroscopy **55** (1994) 209-220.

T Suzuki, S Aizawa, T Tanigaki, K Ota, T Matsuda and A Tonomura, Ultramicroscopy **118** (2012) 21–25.

Conventional reconstruction from a single hologram

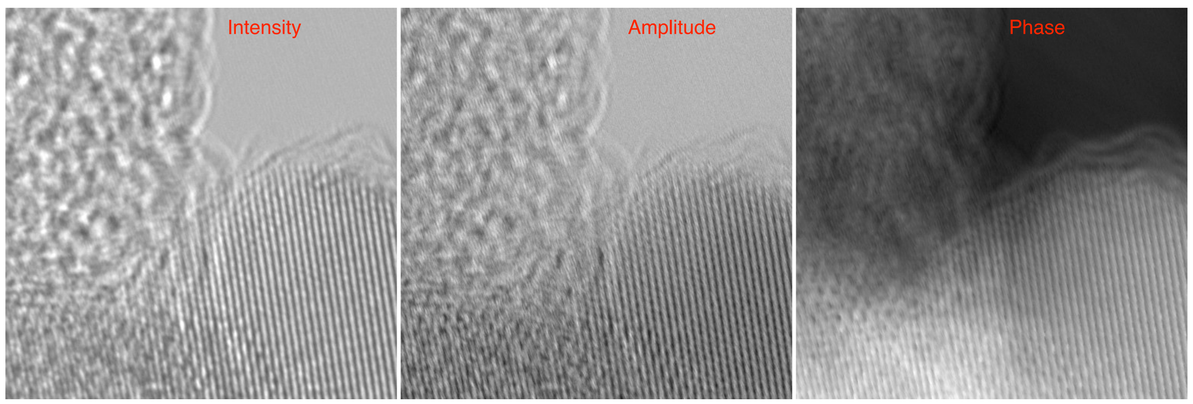


Intensity, amplitude and phase reconstructed from a single hologram in the series using a conventional Fourier aperture. The aperture limits the resolution to 0.3 nm, which is 1/3 of the hologram fringe spacing.

Phase-shifting reconstruction from 26 holograms

Intensity, amplitude and phase reconstructed from a series of 26 holograms entirely in real space using the method of Ru et al and Suzuki et al.

No reference hologram was used.



Is phase-shifting worth the effort?

Sample changes are a problem: they cause artefacts such as the fine fringes visible in the carbon and at the edge of the CeO_2 particle.

Fewer Fresnel fringes: the movement of the hologram fringes necessary for phase-shifting also smooths out the effect of Fresnel fringes.

Fewer camera artefacts: likewise any drift of the specimen with respect to the CCD camera smooths out phase defects in the camera fibre-optics.

Improved phase resolution: combining multiple holograms gives a corresponding reduction in phase noise while still allowing short exposures to reduce the effect of specimen drift.

Improved spatial resolution: the resolution of the phase-shifting reconstruction is not limited by the hologram fringe spacing. Thus all the CeO_2 lattice fringes are visible, unlike for the reconstruction from a single hologram.