A new accurate orbital angular momentum spectrometer for electrons

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The introduction of electron vortex beams in electron microscopy has resulted in new research directions that are related to the measurement of orbital angular momentum (OAM). Examples include measurements of magnetic and plasmonic dichroism, spin polarisation, and vertical magnetic fields [1].

Whereas the preparation of OAM states (i.e., vortex beams [2,3]) has been studied comprehensively, here we show how a new electron-optical configuration that is based on the use of two nanofabricated holograms can be used to analyze the OAM of an electron beam directly. In contrast to previous work [4], we demonstrate an OAM sorting concept that has the potential to separate discrete OAM states more efficiently, due to the lateral tiling of three copies of the same beam.

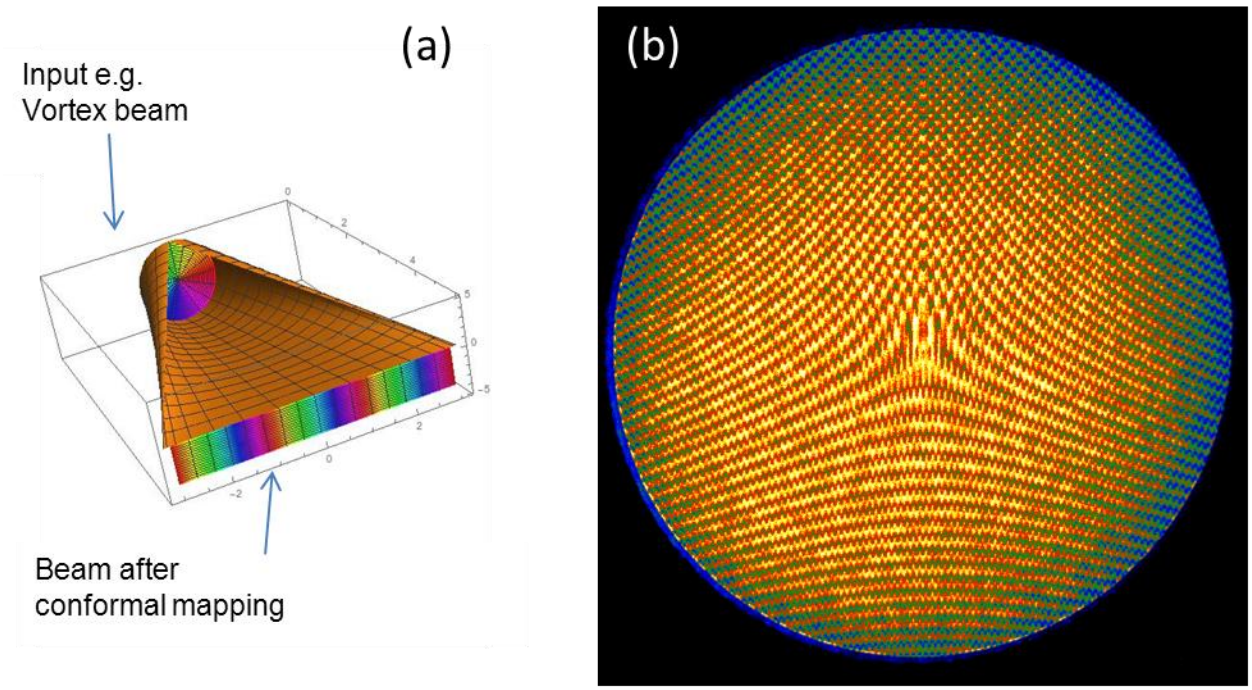

Fig 1 a) Schematic diagram illustrating conformal mapping by a Fan-out OAM sorter. b) Main hologram of a Fan-out sorter.

Figure 1a shows a schematic diagram of the new sorter, which is inspired by a similar concept in light optics [5][6]. In this scheme, a nanofabricated hologram (Fig. 1b) is used to perform a conformal mapping of an electron wavefunction from Cartesian to log-polar coordinates.

Figure 2a shows the experimental evolution of the electron beam. In the diffraction plane, three copies of the same beam are tiled to form a wavefunction, which diffracts in a well-defined direction that depends on the OAM of the beam.

This approach provides one of the most accurate methods for OAM measurement, with a potential cross-talk of below 1%. Preliminary OAM spectra obtained using this device are shown in Fig. 2b for a set of calibrated vortex beams. The results show narrow peaks for positive vortex beams, but also large tails resulting from hologram imperfections that can be improved in the future.

The importance of this concept is that it allows electrons to be visualized in a different basis, in which difficult experiments become easy. Its development and extension will be carried out during the QSORT project (www.qsort.eu).

In order to demonstrate the application of the sorter in materials science, we have used it to measure the magnetic dipole moment of a magnetic pillar. In the OAM basis, this becomes an amplitude measurement, which does not require an external reference wave. Applications in imaging include the reconstruction of sample symmetries.

OAM states also provide a manageable degree of freedom for quantum experiments, offering a similar role to polarization in light optics. The use of the device to perform quantum measurements of single discrete states is therefore also possible, although such measurements have so far only been performed with relatively poor efficiency.

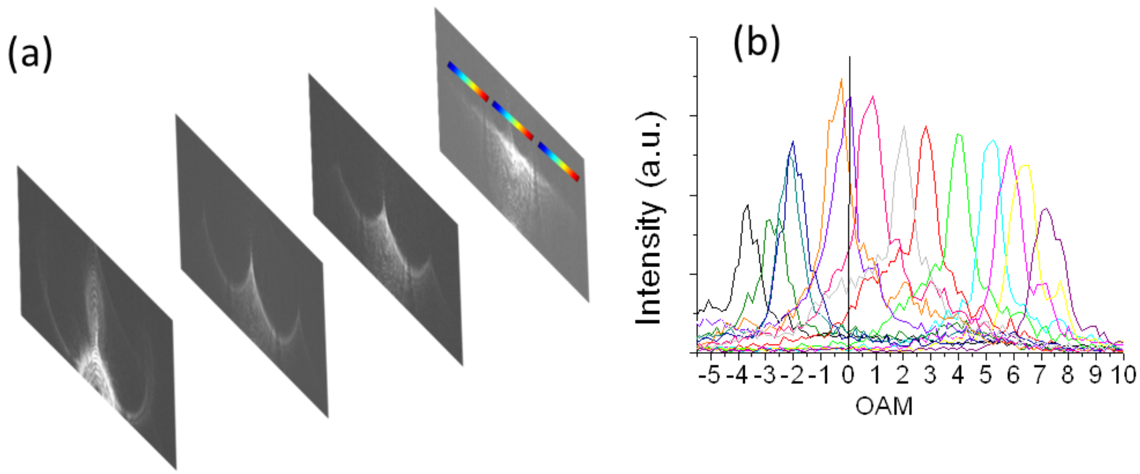

Fig.2 a) Beam evolution in a sorter. b) Experimental OAM spectra for various vortex beams

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