X-ray Vortices in Coherent X-ray Wavefields

Andrew G Peele
School of Physics, The University of Melbourne, Vic., 3010, Australia

Undergraduate optics courses treat waves as if they are completely coherent and have a well-defined and continuous phase. It is now well accepted that most waves are not coherent and so it is necessary to take partial coherence effects into account. It is less well-established that phase distributions are rarely continuous. Indeed, the visible coherent optics community is only now coming to terms with the phenomena associated with phase discontinuities through the new field of "singular optics". It is to be anticipated that x-ray "singular optics" is also an area of potential importance to the coherent x-ray optics community.

Singularities in the phase of a wavefield arise whenever the field amplitude is zero. In particular, these discontinuities in the phase can always be analysed in terms of a combination of edge discontinuities and vortex discontinuities (where the phase spirals around a point singularity with an integer multiple of 2π increase in the phase for each turn). In the optics community, singular optics has found application in the development of optical vortex solitons and in optical trapping (the optical spanner). It is also interesting to note that a wave structure containing a phase vortex carries orbital angular momentum in addition to the spin angular momentum associated with polarization.

The role of singular optics in coherent x-ray optics is not yet clear. At the University of Melbourne, we are interested in these structures in the context of phase recovery, where discontinuities play a critical role. It can be shown that propagation-based phase recovery is only able to yield a unique solution when it is known that phase singularities are absent. We speculate that singularities also play a significant, but not yet understood, role in methods to recover correlations in the wavefield. Techniques that use only measurements of intensity will fail when there is a rotational symmetry in the phase. The key issue being that the intensity distribution of a vortex wave structure is independent of the direction of rotation of the vortex.

In this context, we have recently begun an exploration of vortex phenomena at x-ray wavelengths. While vortices are expected to be ubiquitous at all wavelengths, we have recently demonstrated the surprising fact that it is particularly easy to create these objects in a controlled way at x-ray wavelengths. I will describe these experimental results and discuss the concepts and role of phase discontinuities in phase recovery methods, as well as in measurements of the phase space properties of a wave.