Quantum Hard X-Ray Microscopy with Undetected Photons

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X-ray microscopes can provide a unique combination between atomic-scale spatial resolution and long penetration depth. However, since the refractive index in the hard X-rays range is very close to 1, the performances of X-ray lenses are limited. For that reason, point-to-point imaging of nanoscale features is very challenging and has never been demonstrated.

We propose and analyse a high-resolution X-ray microscopy and interferometry method based on the concept of undetected photons [1]. The system is based on the large angular magnification originated from the far field correlation of the photon pairs generated by extreme nondegenerate X-ray parametric down-conversion (PDC) [2].

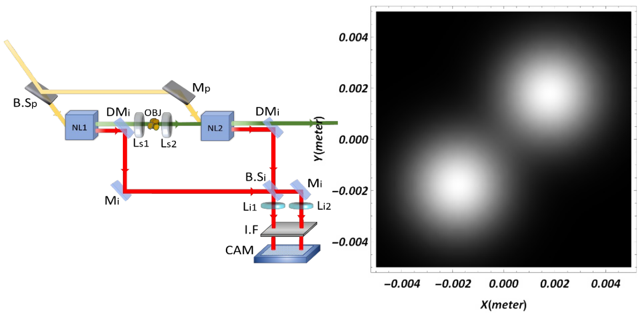

Figure 1: (a) Proposed experimental setup; (b) Visibility distribution on the visible camera of two infinitesimal pinholes separated by 6 nm

The proposed experimental, which its setup is depicted in Fig. 1a includes two nonlinear crystals (NL1 and NL2) configured to generate photon pairs that contains one X-ray photon and one optical photon using the process of hard X-ray to optical PDC. The X-ray photons are focused to a spot on the object and enter NL2. The visible photons generated by NL1 and NL2 interfere to form an image of the object illuminated with the signal photons on the optical detector.

As an example for the possibly achieved resolution we show in Fig. 1b the visibility distribution on the camera of two infinitesimal pinholes separated by 6 nm, for X-ray photons at a 8998 eV, optical photons at 2 eV, and focal lengths of 2 and 150 mm for the X-ray lens and the optical lens respectively The magnification is about 5 orders of magnitude.

In addition to the large magnification that enables the point-to-point imaging scheme, the setup can be used also for very high resolution phase measurements since it provide interferometric information. The main challenge for the implementation of the scheme is the requirement for high degree of temporal coherence that can be mitigated by either using filters or more likely by using the proposed X-ray oscillator laser, which is expected to deliver fully temporal and spatial coherent beams.

References

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