Coherent diffractive imaging (CDI) and related techniques avoid the use of lossy optics after a sample and instead record the intensity of the diffracted field directly on a pixelated detector [1]. Iterative algorithms are then used to retrieve the phase. So far, these experiments are mainly conducted at synchrotrons and X-ray FELs. In recent years, table-top XUV sources employing high-order harmonic generation (HHG) were shown to generate a photon flux up to $10^{14}$ photons/sec [2] and already demonstrated sub-wavelength resolution using CDI [3]. In this contribution, we focus on imaging of structures with sizes close to the illuminating wavelength using CDI techniques. The resulting high aspect ratio for such small feature sizes gives rise to waveguiding effects which are found to play an important role in image formation and interpretation.

The first among the two CDI techniques used to investigate these effects is Fourier transform holography (FTH). In this modality, a reference wave from a structure close to the sample is used to encode the phase information as an interference pattern on the detector [4]. We used an HHG-based XUV source at 68.6 eV to resolve 23 nm features which are the smallest features ever resolved in a table-top setup. It is observed that waveguiding resulted in modulation of the transmitted light field not existing in the actual sample in addition to damping of high spatial frequencies (Fig. 1(a-c)). The loss of high spatial frequencies results in smoothening of sharp edges thus making the commonly used knife-edge resolution test unreliable. To further investigate this, we used a second variant of CDI, known as ptychography [5], where a sample is raster scanned across a beam to image a larger field of view. The classical Rayleigh criterion is found to be necessary for reliable resolution test for waveguiding-limited scenarios [6]. Using this criterion, we demonstrated a half-pitch resolution of 47 nm– the highest for non-periodic samples on a table-top setup. In addition, the critical difference between ptychographic imaging of periodic [7] and non-periodic structures will be discussed. Reliable imaging of wavelength-scale features using CDI techniques will enable studies from biological samples to investigations of integrated circuits especially for sources in the XUV and soft X-ray.

Fig. 1. (a-c) FTH results. (a) Simulated exit wave from the sample surface showing waveguiding-induced modulation in the profile. (b) Reconstruction zoomed-in on letter ‘P’ from an FTH experiment showing similar modulations and (c) Helium ion microscope image of the sample around the same area as (b). (d) Ptychographic CDI experimental result on a Siemens star sample: reconstruction of a 100 µm² area and zoom-in of the inner-most ring (inset) showing sub-50 nm features being resolved.

References