ESRF	**Experiment title:** Coherent Imaging and Reconstruction of Nanometer-Sized Structures	**Experiment number**: SC-2219
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We performed a coherent diffraction imaging (CDI) experiment on artificial gold structures, using hard X-rays (8 keV) at ID10C. A Si(111) channel-cut monochromator provided the temporal coherence ($\Delta E/E=1.4\times10^{-4}$). Higher undulator harmonics were removed by two highly polished silicon mirrors. Roller-blade slits were used to define a partial coherent section of the beam of 10×10 μm^2 size for the imaging experiments, and the measured net flux through 5×5 μm^2 was 3.4×10^7 photons per second. In order to clean the beam, a second pair of roller-blade slits was used as first guard slits, followed by a pair of conventional tantalum slits. The second pair of guard slits turned out to be key for reducing parasitic slit scattering. A complete suppression of the parasitic scattering was, however, hindered by the limited precision of the slit system. Nevertheless, we were able to record complete coherent diffraction patterns that could be inverted.
The samples consisted of gold structures (200 nm in height and from 2 to 5 µm in diameter) on a 50 nm-thin Si_3N_4 membrane. The diffraction patterns were recorded in SAXS transmission geometry with a direct-illumination CCD (Princeton Instruments, 1242×1152 pixels, 22.5×22.5 μm^2 each) at a distance of 3.3 m from the sample. An evacuated flight tube was used to avoid air scattering. The direct beam was blocked by a beamstop, 1 mm in diametre. Smaller beamstops could not be used, due to the remaining parasitic slit scattering. Figure 1 shows a diffraction pattern from a 2 µm-small DESY logo on a logarithmic pseudo-colour scale. The image is the sum of 200 frames (3 s exposure each), and the legend maximum corresponds to 6800 photons. The square root values of these intensities (1094×1094 pixels, corresponding to a theoretical real-space resolution of 20.7 nm) were fed into an iterative reconstruction algorithm, consisting of a periodic sequence of the so-called error reduction and hybrid input-output algorithm [1]. A circle of 2.11 µm diametre was used as initial (relatively loose) support, which was then iteratively updated using the shrink wrap method [2, 3]. Although the used error metrics did not show a clear convergence a qualitative reconstruction was obtained after 950 iterations, with the DESY logo well recognisable. Overall, the procedure was repeated 50 times, each time with a different initial random number seed. The average of the 4 best runs is shown in Fig. 2 (left-hand side) together with a SEM image of the sample (right-hand side) for comparison. Due to the missing information from pixels covered by the beamstop or corrupted by slit scattering, the reconstruction contains a considerable amount of noise. Furthermore, the intrinsic symmetry of the logo causes a superpostion of the solution and its complex conjugate, i.e. the image rotated by 180°,

which particularly affects the reconstructed DESY letters. Nevertheless, this result presents a major step forward, since it demonstrates the feasibility of CDI with hard X-rays at ID10C.

Apart from this CDI experiment, we also demonstrated Fourier transform holography with hard X-rays for the first time. The object of interest was an artificial gold nanostructure (the letter P), but this time surrounded by 5 dots, producing multiple reference waves [4]. A single Fourier transform of the measured intensities gives the spatial auto-correlation of the overall object, including the cross-correlation between the object and the dots, which directly yields the object shape and its rotated copy, as shown in Fig. 3. From that image a well-defined support can be derived and used as starting point for further iterative reconstruction as described above, in order to improve the resolution [5].

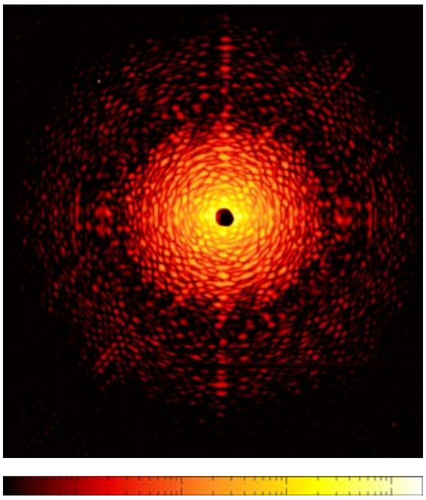

FIG. 1. Coherent diffraction pattern of 2 µm-small gold structure. Logarithmic pseudo-colour scale. Around the beamstop in the centre, there are still some streaks from slit scattering visible. Furthermore, the image suffers from quite a few damaged detector areas.

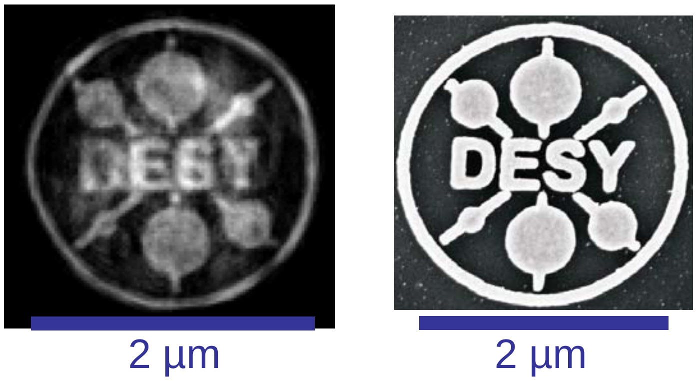

FIG. 2. Left: reconstruction result (average of 4 best runs). Linear grey scale. Right: SEM image of the gold structure.

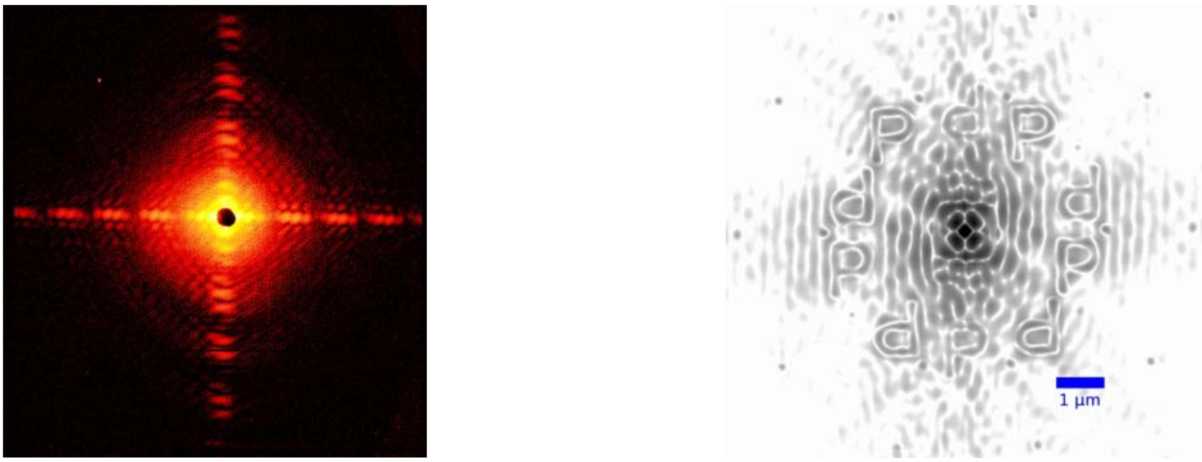

FIG. 3. Left: recorded hologram of a Au nanostructure (letter P) with 5 reference scatterers. Logarithmic pseudo-colour scale. Right: central part of the inverted hologram, imaging the object and its rotated copy 5 times, each. Logarithmic grey scale.

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[4] W.F. Schlotter et al., *Appl. Phys. Lett.* **89**, 163112 (2006).
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