ESRF	**Experiment title:** Coherent scanning X-ray diffraction microscopy with reflective focusing optics	**Experiment number**:
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Report:

The goal of the experiment MI-978 was to establish a recent method for ptychographic coherent diffractive imaging (PCDI) with a scanning setup [1] at the nano-imaging endstation of ID22. For this, a coherent hard x-ray beam of 17.5 keV, as produced by the installed Kirkpatrick-Baez (KB) mirrors was used. In particular, there were five main objectives:

1. Use PCDI reconstructions of the object to improve the resolution beyond the constraints imposed by the focusing optics.
2. Employ the simultaneous illumination function retrieval capabilities of our PCDI approach for characterization of the wave field produced by the focusing optics, which had not been done with reflective optics before.
3. Demonstrate diffractive imaging with a relatively large energy bandwidth of 2 %.
4. Utilize the relatively high X-ray energy of 17.5 keV to enable investigation of thick specimens previously barely studied by diffractive imaging methods.
5. Use the possibility to combine PCDI scans with fluorescence measurements to obtain multi-modal images.

The beginning of the experimental run was dedicated to optimizing the conditions for the PCDI experiments, especially by trying to tweak the coherence of the beam by using slits both in the front end and upstreams from the KB optics and by characterizing flat field and taper distortion of the FReLoN camera prior to the actual experiments. The focal spot produced by the KB system was optimized using fluorescence scans.

For the first PCDI experiments, a Siemens star test specimen (Xradia X50-30-2, gold structures of ~180 nm thickness with smallest features of 50 nm in size) was used (see Figure 1(a) for a reconstruction). Its strong scattering allowed for first reconstructions of the incident

wave field, which confirmed the results of the fluorescence characterization of the focal spot size (see Figure 1(b)). The results on the test specimen successfully demonstrate the first three objectives.

Further investigations were done on a 200 µm thick chip with copper-based integrated circuits (IC), magnetotactic bacteria (*Magnetospirillum gryphiswaldense*) and silicon nanorods. The measurements of IC chip nicely demonstrated the possibility of obtaining additional information by simultaneous fluorescence measurements. For the low-contrast specimens, an additional cleanup pinhole had to be mounted to reduce parasitic scattering from the mirror surfaces, which was drowning the signal from the specimens and unnecessarily reducing the accessible dynamic range of the detector. Despite these efforts, this data remains very challenging to reconstruct (partly requiring specialized approaches [2]) and the analysis is still in progress. Since they also require longer exposure times, an observed drift of the focal spot, probably due to effects of changing heat load on the KB mirrors, had major effects on the quality of this data, but can probably be compensated with novel scan position refinement procedures included into the reconstructions process.

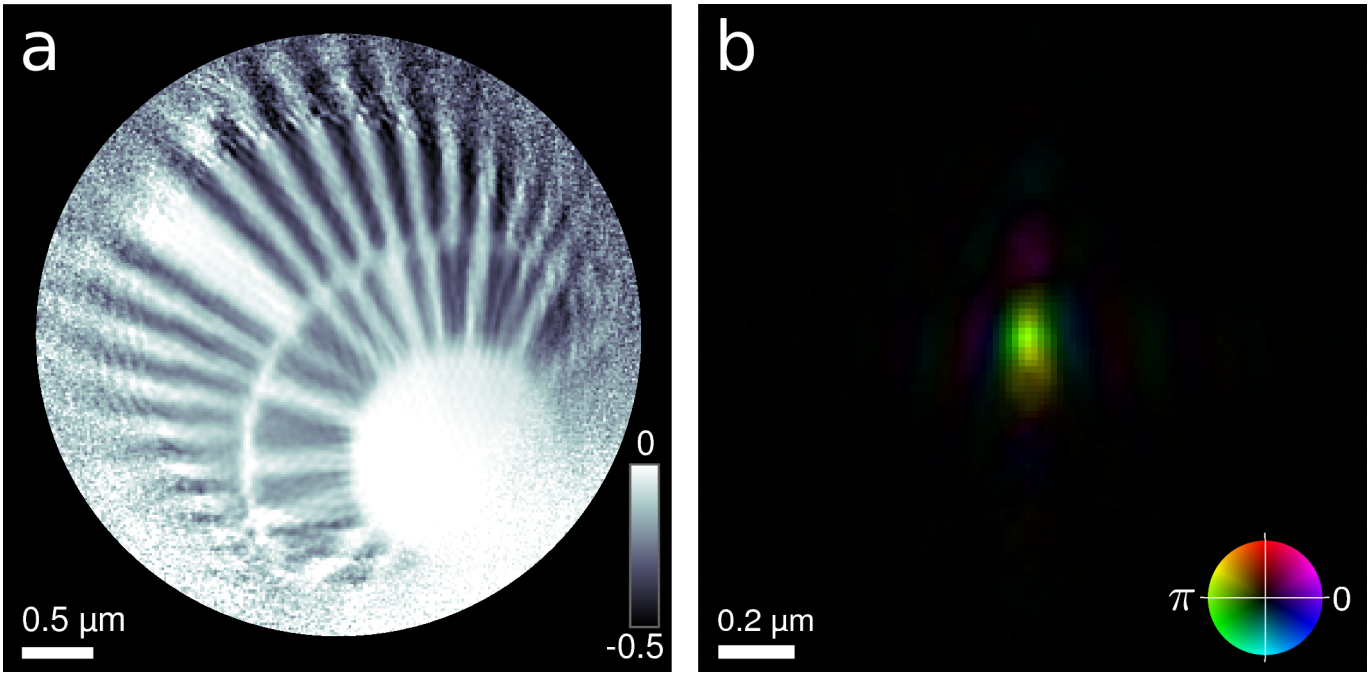

Figure 1: Results of PCDI reconstruction of the test specimen: (a) Reconstructed phase shift of the object (linear color scale in radians). The 50 nm lines and spaces of the inner ring are resolved, corresponding to a more than two-fold improvement of resolution compared to the focal spot size. Some distortions due to drift during the scan are visible. The scan points were located on concentric circles to suppress artifacts inherent to reconstruction from a rectangular scan grid [2]. (b) Reconstructed illumination function showing the wave field produced by the KB system in the focal plane. The reconstructed focal spot is consistent with values from independent fluorescence scans, which gave a extensions of about 200 nm (vertical) and 140 nm (horizontal).

References:

[1] P. Thibault, M. Dierolf, A. Menzel, O. Bunk, C. David, F. Pfeiffer, *Science* 2008, 321, 379-382.

[2] M. Dierolf, P. Thibault, A. Menzel, C. M. Kewish, K. Jefimovs, I. Schlichting, O. Bunk, F. Pfeiffer, *New Journal of Physics* 2010, accepted for publication.