ESRF	**Experiment title:** Fourier Transform Holography with Hard X-Rays for Materials Science	**Experiment number**: HS-3552
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Fourier transform holography (FTH) [1] can be used to image objects on the nanoscale and such a result can be used as input for further iterative algorithms for pushing the resolution toward the diffraction limit [2]. This approach seems to be particularly attractive using hard X-rays, which opens the possibility to tackle various problems, e.g. in materials science. Since the feasibility of this concept has been proven recently [3], we wanted to apply the technique to biological samples and determine the structure of cellulose in flax [4].

Coherent diffraction patterns and holograms were taken using 8 keV photons at ID10C. In contrast to recent measurements [3], 3 pairs of guard slits (one pair of roller-blade slits and 2 pairs of ultra-high precision slits with tantalum blades that were provided by HASYLAB) were used to clean the beam from parasitic slit scattering. Without focussing 5.1×10^8 ph/s through the beam-defining roller-blade slits of 10×10 μm^2 were measured.

First, we wanted to make sure that data could be taken with at least the same quality as last time (SC-2219). Indeed, we could record a hologram of a test structure [3] where almost all parasitic slit scattering was suppressed. Figure 1(a) shows this hologram (average of 100 frames, 5 s exposure each), yielding an unprecedented image quality in its Fourier transform, as shown in Fig. 1(b). In order to suppress ringing in its Fourier transform the hologram was multiplied with a 30 pixel-wide (HWHM) filter function for smoothing the beamstop edges in the diffraction pattern. Unfortunately, the high quality in the diffraction pattern could not be achieved again during the whole beamtime which is mainly attributed to instabilities of the beam (for example, at the latest after each refill the guard slits had to be realigned again, starting from scratch).

In order to realise an FTH set-up which can be used for arbitrary samples, i.e. samples that are located on a Si_3N_4 membrane, isolated, but not surrounded by reference dots, a membrane containing single reference dots was mounted on an attocube nanopositioning system, at a distance of less than 500 μm upstream the sample membrane. With the attocube system it should have been possible to position the reference dot next to the desired sample with sub-micron precision. When we tried to position the membrane containing the reference dots, we encountered a severe problem that could not be solved, namely, how to identify the exact position of the reference dot on its membrane. This problem occurred, because the microscope for looking at the sample along the beam direction was not available for our beamtime. We thus had to look at the diffraction of the single reference dots in order to find them and only the biggest reference dot could be identified unambiguously. Figure 2(a) shows the corresponding diffraction pattern (average of 100 frames, 1.5 s

exposure each). As can be seen the parasitic slit scattering dominated in that case, which was a typical situation, unfortunately. Using this big reference dot and an artificial test structure we could see indications for a holographic image, but structure details were not resolved at all.

Thus we tried to image the cellulose in flax using conventional coherent diffraction imaging [5]. To account for the weak scattering of the biological samples the beam was focussed using 2 Be lenses, 300 µm radius each, increasing the flux to 1.3×10^{10} ph/s through 10×10 µm^2. Small pieces of a flax fibre on a Si_3N_4 membrane were prepared using the laser cutter in the microimaging lab with the help of M. Ogurreck. Due to the missing microscope it was, however, not possible to identify pieces smaller than 5 µm at the beamline, i.e. by looking just at the sample diffraction.

Figure 2(b) displays the diffraction pattern (average of 100 frames, 1 s exposure each) of such a big piece where the diffraction of the membrane alone was subtracted. The inset of Fig. 2(b) shows a real space image taken with the optical microscope of the laser cutter. Due to the size of the object, too many fringes were hidden behind the beamstop and a successful reconstruction was not possible.

We conclude that for possible future experiments a microscope looking at the sample position or equivalent means are indispensable in order to find and position small and weakly scattering samples on a membrane. A higher beam stability might be helpful too, particularly for a sustainable adjustment of the guard slits if one wants to collect the whole diffraction pattern at once.

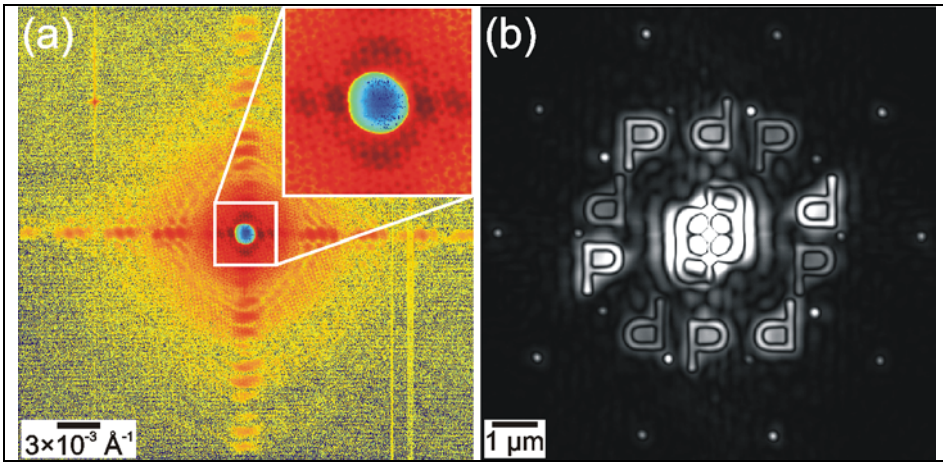

FIG. 1. (a) Measured hologram. Logarithmic pseudocolour scale. Inset: zoom into the region around the beamstop, illustrating the singular case where the beam could be well cleaned using 3 pairs of guard slits. (b) Central part of the modulus of the Fourier transform demonstrating hard X-ray FTH imaging with unprecedented quality. Linear grey scale.

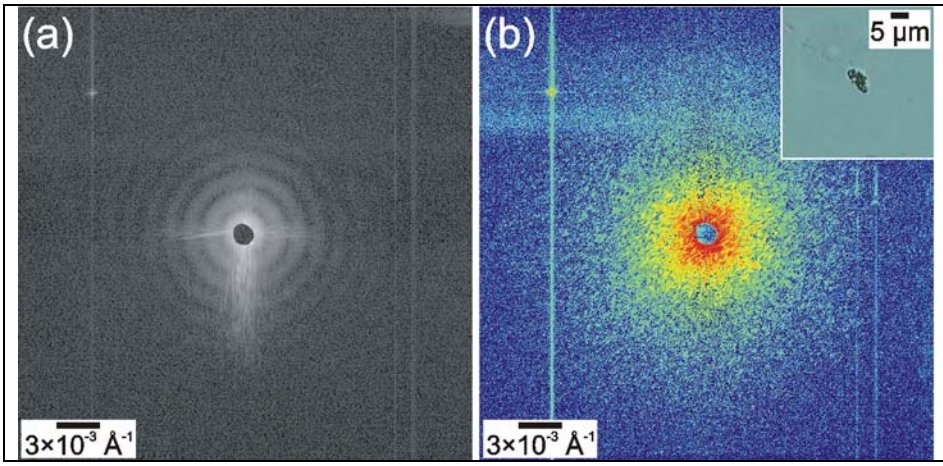

FIG. 2. (a) Coherent diffraction pattern of a single gold reference dot (Ø ≈ 560 nm). Note the dominating parasitic slit scattering. Logarithmic grey scale. (b) Coherent diffraction pattern of a piece of flax (shown in the inset), which had been cut out of a single flax fibre using the laser cutter of the microimaging lab with the help of M. Ogurreck. Logarithmic pseudocolour scale.

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