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The Diamond I13-2 Transmission X-ray Microscope: Current Status and Future Developments

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The Diamond beamline I13 "Imaging and Coherence" has been designed to allow investigations of samples over multiple length scales. The beamline with its two independent branches [1] is operational since 2011. The I13-1 coherence branch employs coherent diffractive imaging and ptychography to go beyond the optical resolution limit [2]. The I13-2 Diamond-Manchester Imaging branch is equipped with a microtomography set-up [3] and an endstation for a transmission X-ray microscope (TXM). The layout of the I13 experimental endstations is shown in Figure 1.

The TXM endstation of the DIAMOND I13-2 beamline [4] allows three-dimensional resolutions of below 100 nm and will be upgraded to allow investigations with a 3D resolution of 50 nm. The accessible energy range of 8 – 15 keV is well suited to cover a large range of materials and thicknesses. The instrument is designed for a large field of view and large working distances to allow easy accommodation of sample environments.

The layout of the beamline is shown in Figure 1. The experimental hutches are situated 220 m from the source. The imaging branch experimental hutch has a total length of 15 m available for experiments. An undulator source creates a beam of 12 x 6 mm² (FWHM) in the experimental hutch. Two monochromators are available, fitted with Si-111 crystals and multilayer systems, respectively. The multilayer monochromator (MLM) is equipped with three different coatings allowing access to different X-ray energies and bandwidths.

A horizontally bendable mirror can be used for collimation or focusing to increase the available flux. The flux gain can reach a factor of 5, depending on the diameter of the condenser optics. An additional flux gain can be achieved with planned CRLs for further collimation of the beam profile.

The current TXM experiment is located on a dedicated sample stage on the microtomography set-up. All components are mounted in air and evacuated flight tubes are installed between the components. With the exception of the condenser and detector, every component is mounted on a joint base to increase the relative stability and minimize drifts. Two detector systems are available: A Hamamatsu C12849-101U camera with a 1:1 fiber-optic plate and a sCMOS chip with 6.5µm pixel size and a pco.4000 with 9.6µm pixel size and a microscope optics with variable magnifications (ranging from 1.25x to 4x).

The upgraded endstation is currently in its design phase. A massive joint base for all components will reduce vibrations and a full thermal enclosure for the experiment will improve thermal stability and

minimize drifts. The vacuum system will be extended to the sample position and the condenser optics will be mounted in vacuum to maximize the available flux for the experiment.

The X-ray optics used for the I13-2 TXM are designed and fabricated at the Paul-Scherrer-Institut (Switzerland) using state-of-the-art nanolithography tools [5]. A beam-shaping condenser lens [6] is used for illumination and a Fresnel zone plate used as objective lens. Phase contrast imaging can be performed using Zernike phase rings. Zernike phase contrast (ZPC) gives a much stronger signal for thin or weakly absorbing samples.

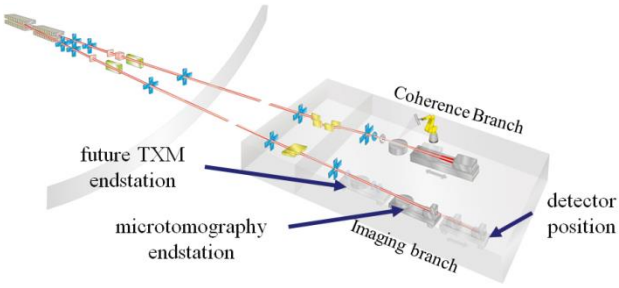

Figure 1: The layout of the I13 experimental endstations.

Figure 2 shows an example projection of a glass capillary with some gold nanodots (diameters 50–500nm) attached on the outside. The images have been acquired using the Hamamatsu C12849-101U camera with 180 ms exposure at an energy E= 11.5 keV and an effective pixel size of 122 nm. Figure 3 shows a reconstruction of the sample using the gridrec algorithm with Shepp-Logan filter [7] for the different contrast modes and clearly demonstrates the benefit of using ZPC.

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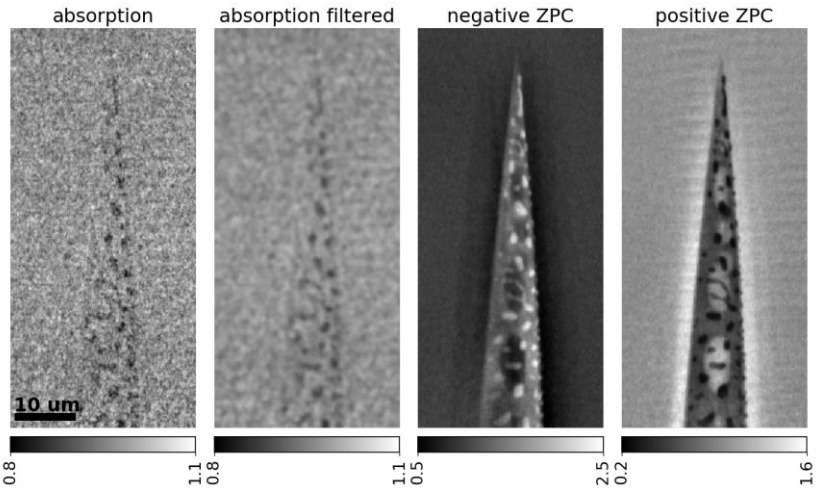

Figure 2: Normalized exemplary projections for different contrast modes. All images were acquired with the same exposure time and a similar number of photons/pixel.

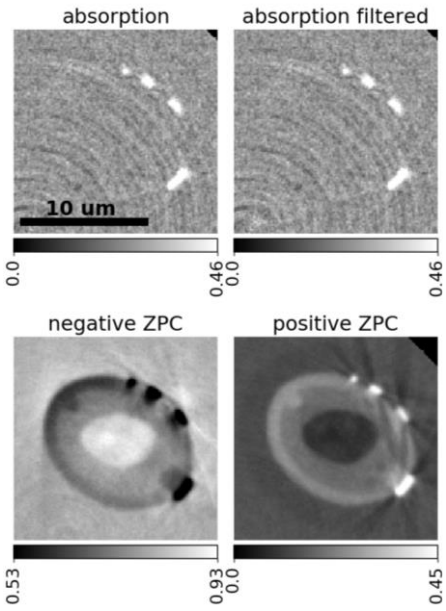

Figure 3: Reconstructed slice of a gold/glass capillary sample for different contrast modes.

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