Supersampling Scanning Transmission Microscopy: Unlocking sub-10 nm STXM Resolution

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The SLS 2.0 upgrade comprised an increase in storage-ring energy from 2.4 to 2.7 GeV, and a significant reduction of horizontal emittance, converting the synchrotron to a so-called fourth-generation storage ring [1]. The new machine greatly benefits from an increase in brightness and brilliant flux. This brings major benefits for future experiments, not only for the use of photon-hungry and coherent techniques, but also for routine acquisition of high-resolution imagers in scanning X-ray transmission microscopy (STXM). Within this contribution, we present a newly developed STXM modality that combines this advantage with a paradigm change in how scanning is performed.

The resolution of STXM imaging is fundamentally limited by the size of the focused X-ray beam, usually focused by means of a Fresnel zone plate lens. The resolution cut-off of this method is usually linked to the outermost zone width of the zone plate: the focus size under coherent illumination conditions can be expressed as [2]. The resolution record using direct scanning has been demonstrated as low as 7 nm some years ago [3].

However, we observed already during these experiments that we approach a regime, where the resolution is not merely limited by the beam size, but also by other factors, such as mechanical vibrations. These vibrations, measured as relative positions between the X-ray lens and the sample stage, are typically in the magnitude of three to five nanometers rms on frequencies of several to some hundred Hz. Thus, both pixel-by-pixel and constant velocity line scan modes are inherently limited by these vibrations.

We now present a paradigm change in how we acquire scan images: instead of optimization and avoidance of vibrations, we read out the real sample position with respect to the beam at kHz rates. With this approach, we are not only able to bypass the inherent limitations from mechanical instabilities, but we are also able to reconstruct images using different criteria, such as noise limits, spatial or temporal resolution [4]. Besides, this method also avoids the high overhead times that are common for scanning on the nanometer level. Using experimental data and simulations, we demonstrate imaging resolutions that are half of the outermost zone width of the respective zone plate: with being the diffraction order of the zone plate lens. Future experiments comprise the use of higher diffraction orders to achieve even better imaging resolution, targeting routine resolution below 5 nm.