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1D-Full Field Microscopy of Elastic and Inelastic Scattering with Transmission off-axis Fresnel Zone Plates

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Resonant inelastic X-ray scattering (RIXS) is a powerful X-ray spectroscopy technique capable of investigating electronic properties of materials and molecules. Using soft X-rays, it becomes especially sensitive to the electronic structure of matter due to sharp transitions [1]. Combining this successful technique with imaging opens up a variety of new possibilities for sample characterization because electronic information can be obtained with spatial resolution. This allows for investigations of inhomogeneous materials including interfaces and defects.

Conventional RIXS instrumentation relies on reflecting gratings for analyzing the emitted light from the sample by dispersing it across a detector. For RIXS imaging this requires a time-consuming point by point raster scan of the sample in order to finally obtain a complete image of the sample with the corresponding spectroscopic information [2]. We report on the use of a new zone plate based RIXS analyzer scheme, which has already been successfully tested for RIXS imaging [3]. An off axis part of a Fresnel zone plate (FZP) is used as analyzer and replaces the conventional reflection grating. This setup exploits the fundamental advantage of an X-ray optic that has imaging capabilities. While dispersing the emitted light across one axis of the detector, it acts as a focusing element for the other axis, making it possible to combine 1D microscopy with spectroscopy (e.g. RIXS). Moreover and in contrast to point by point scans (necessary for conventional RIXS setups), line by line scans allow for a much higher throughput.

This concept was applied to a Siemens star test sample with 500 µm diameter made from SiO_2 on an iridium-coated silicon substrate. The sample was scanned in 82 steps using a 1 mm long x-ray line focus having a width of down to 10 µm and a photon energy of around 550 eV. At each step, a line of the sample was imaged onto the detector and its corresponding energy dispersion was recorded (Fig. 1a). Here, the zone plate analyzer was focused on the elastic line of the emission ensuring that this will give a sharp detector image. Combining these 82 slices of the sharp elastic line allows for reconstructing the RIXS image of the Siemens Star test pattern (Fig. 1b).

The upgrade of this analyzer scheme in terms of instrumentation was the parallel usage of a second off axis FZP, which makes it possible to focus a second energy from the sample to the detector. The second FZP can be moved individually from the first one, which allows for two-color spectroscopy combined with imaging. Here, contributions of two different emitted X-ray energies produce a sharp image on the detector. This scheme, which is sketched in Fig 2, was successfully implemented and tested at the P04 beamline at PETRA III (DESY). With this advanced analyzer scheme, not only elastic and inelastic scattering information at two energies can be detected but also two times the solid angle of radiation is

collected in total.
This setup was used for two-color spectroscopic imaging of an artificially structured sample consisting of electroplated gold and the organic negative-tone resist nLOF (Fig 3a). This lined test sample was excited with a line focus of 300 eV resulting in two emission lines: The inelastic scattering signal of C as well as the elastic scattering, which is predominant in Au. With the two-color scheme, both contributions to the spectrum could be imaged in parallel in focus showing contributions from 3 μm lines (Fig 3b and 3c).

The use of off-axis transmission FZPs for RIXS imaging greatly enhances the throughput and allows for a two-color scheme, where two emission energies can be analyzed at the same time. Imaging a spatially resolved region of the sample in terms of spectrometric data at the detector could find application in many experiments at synchrotrons and FELs, while the two color scheme might be very interesting for in-situ experiments with complex materials, where more than one absorption edge is of interest.

References:
[1] L Ament *et al*, Rev. Mod. Phys **83** (2011), 705–767.
[2] T Warwick *et al*, J. Synchrotron Radiat. **8** (2014), 736-743.
[3] F Marschall *et al*, Scientific Reports **7** (2017), 8849.
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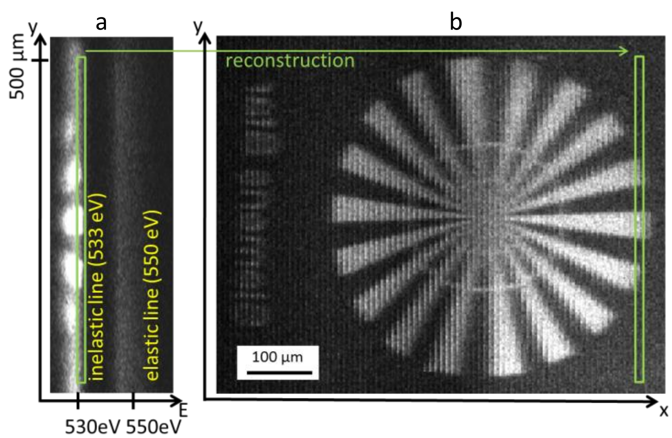

Figure 1: A Siemens star test pattern with 500 μm diameter made from SiO_2 was illuminated with a line focus at a photon energy of 550 eV. a) RIXS signal obtained at the detector with 15 s exposure time. Here, structures can only be resolved in the inelastic line at 533 eV, where the zone plate was focused. b) Reconstruction of 82 detector images showing 3 μm structures (pixel-size limited)

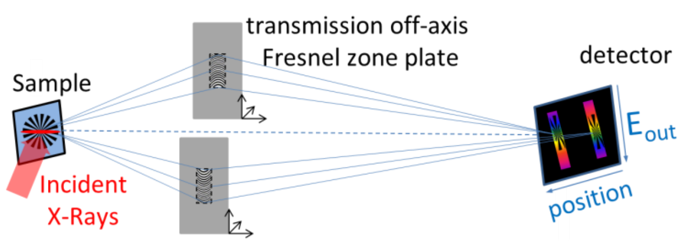

Figure 2: Sketch of the two-color imaging spectroscopy setup: Two independent transmission off-axis Fresnel zone plates are used to collect and disperse the emitted light from the sample on two different lines at the detector. Two separate spatially and spectrally resolved images of different emission energies can be obtained at the same time.

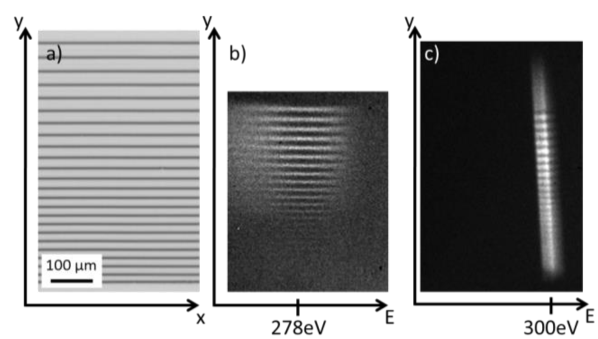

Figure 3: A line test sample consisting of polymer and Au structures imaged a) by light microscopy, b) in a RIXS setup focused on the inelastic peak at 278 eV and c) in a RIXS setup focused on the elastic peak at 300 eV. Note the contrast reversal between the stronger inelastic carbon signal of the finer polymer lines in b) and the stronger elastic signal arising from gold in c).