Development of a New Soft X-ray Ptychography Spectro-Microscope at the Swiss Light Source (SLS)

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The availability of high-brilliance X-ray sources, such as X-ray free electron lasers (XFELs) and the worldwide upgrade of synchrotrons to the 3rd generation level, have triggered a paradigm shift in X-ray microscopy. Due to the provision of high fluxes of coherent light, a broad development and diversification of X-ray microscopy techniques based on diffractive imaging [1,2] is taking place. The advantages of these techniques are the possibility to reconstruct the phase and amplitude of the imaged object and to go beyond the resolution of conventional X-ray microscopes towards the limit given by the wavelength of the employed X-ray irradiation.

At the Swiss Light Source (SLS), the feasibility and the advantages of this technology have already been demonstrated in the hard X-ray energy range [3–5] with the help of several in-house developed instruments, such as OMNY and flOMNI [3,6]. The applicability of diffractive imaging techniques to magnetic materials has also been demonstrated at the SLS [5] and in other synchrotrons worldwide [7,8]. However, for the imaging of thin magnetic systems, the soft X-ray energy range (500 – 2000 eV) is highly relevant, since the L_2 and L_3 edges of the 3d transition metals are situated in this regime offering a high-contrast X-ray magnetic circular dichroism (XMCD). We are currently developing a new soft X-ray microscope based on diffractive imaging at the SLS with the goal to provide wavelength-limited spatially-resolved maps of the spectroscopic and magnetic response of a broad variety of materials. This contribution shall provide the details about the current status, the technical conception and the future design of this instrument.

The first step towards the realization of an experimental station has already been carried out. A preliminary setup has been assembled, including the vacuum chamber, the supporting frame, 5D girder movers, precise motor stages as well as the electronics and the data infrastructure. The high coherent X-ray flux necessary for such kinds of imaging techniques as well as the full polarization control are provided by the two Apple undulators at the SIM beamline of the SLS. As a unique characteristic of the setup, an in-house developed low-noise charge integrating hybrid pixel detector [9,10] will be incorporated, offering a high detective quantum efficiency (DQE) as well as a large dynamic range with single-photon counting capability in the soft X-ray energy range.

Four silicon sensors with different entrance window thickness were characterized in our chamber in to achieve an optimized photon efficiency in the soft X-ray regime. With the help of these tests, a new detector prototype with improved DQE is currently commissioned and will be permanently installed as a part of our setup. An avalanche photo diode (APD) is also available, providing a setup with two imaging modes, a ptychography mode and a scanning transmission X-ray microscopy (STXM) mode. The first measurements on micro- and nanostructured magnetic samples will be presented.

In summary, we present the most recent development of our setup as well as the first measurement data

taken in STXM and ptychography mode on different test structures together with the highlighted future impact for the scientific community. With the development of a new spectro-microscope based on ptychography, we aim at providing a unique tool for ultimate resolution imaging and spectroscopy using soft X-rays, which will be the basis for a dedicated user-friendly end-station in the future taking full advantage of the upcoming upgrade of the SLS to a diffraction-limited light source. This will allow us to shed light on many topical materials systems, such as spin textures, nanocomposite materials as well as electronic and magnetic nanodevices [11].

[1] J. Miao *et al.*, Science **348** (2015), p. 530–535.
[1] F. Pfeiffer, Nat. Photon. **12** (2018), p. 9–17.
[3] R. Dierolf *et al.*, Nature **467** (2010), p. 436–439.
[4] M. Holler *et al.*, Nature **543** (2017), p. 402–406.
[5] C. Donnelly *et al.*, Nature **547** (2017), p. 328–331.
[6] M. Holler *et al.*, Sci. Rep. **4** (2014), 3857.
[7] X. Zhu *et al.*, PNAS **113** (2016), E8219.
[8] D. A. Shapiro *et al.*, Nat. Photon. **8** (2014), p. 765–769.
[9] J. H. Jungmann-Smith *et al.*, J. Synchrotron Radiat. **23** (2016), p. 385.
[10] M. Ramilli *et al.*, J. Instrum. **12** (2017), C01071.

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