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Addressing slow drift effects in the SASE3 Soft X-ray Beamline at the European XFEL: performance of an autocollimator-based correction method

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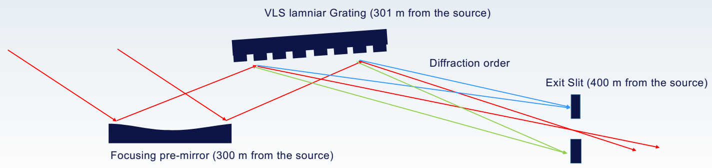
Introduction

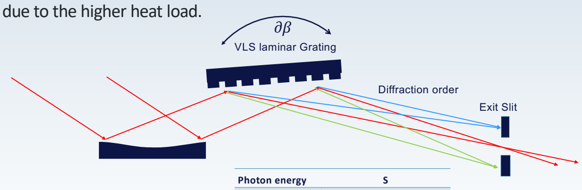
The SASE3 soft X-ray beamline at the European XFEL is equipped with a 100-meter-long-arm monochromator, which delivers to the experiments (SQS, SCS, SXP) pink or monochromatic beam in the photon energy range of 250 eV - 3000 eV [1,2]. Due to the considerable length of the arm (approx. 100 meters), ensuring stability becomes crucial in the short and long timescale. Currently, the system is using an uncooled short grating, that could be a possible reason for the effect we observed.



SASE3 European XFEL Soft Xray monochromator optical scheme

Angular sensitivity

The absence of cooling is triggering a slow drift of the system, which is not entirely captured by the encoders and therefore cannot be corrected. Consequently, this drift results in an undesired drift of the photon energy of the delivered monochromatic beam, causing challenges for high-precision experiments. The effect becomes more pronounced when using multiple pulses and high pulse energies, due to the higher heat load.

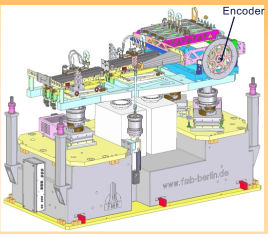


$$\frac{\partial E}{\partial \beta} = \frac{E}{\tan(\theta + \beta)} = S$$

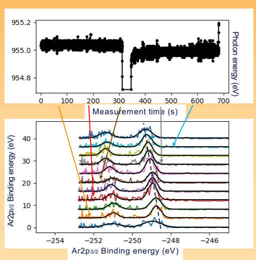
Photon energy	S
1 keV	0.65 eV/microrad
2 keV	1.16 eV/microrad
3 keV	2.6 eV/microrad

Autocollimator-based adjustment

The Sot Xray monochromator is equipped with an high resolution encoder that is measuring the angle of the grating respect to the beam. This reading is converted to photon energy and used during the scan. The absence of cooling is triggering a slow drift of the system, which is not entirely captured by the encoder. If the spectrums are repeated in different times, we can see a drift in photon energy, and this is more severe when using multiple pulses and high pulse energies, due to the higher heat load.



Mechanical structure of the Soft Mono

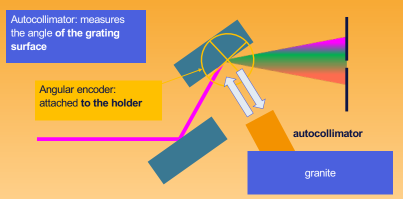


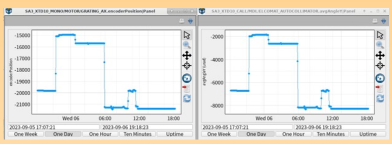
Top: photon energy from the encoder calibration. Bottom: Ar 2p Binding energy spectra using the photon energy retrieved from the encoder acquired at different times

We measured photoelectron spectra, that shows the kinetic energy of Ar2p 1/2 and 3/2 photoelectrons ionized at a certain photon energy. The KE is converted into binding energy knowing the photon energy. From the measurement we see a drift of the binding energy with time, which means the photon energy is drifting.

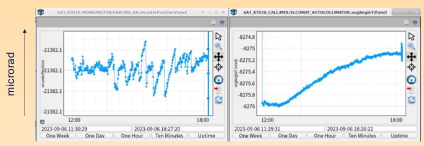
Parameter	Value
Pulse energy	6 milliJoule
Repetition rate	10 Hz
Number of pulses/train	500
Power of incoming beam	30 Watts
Drift in 10 minutes (energy)	0.75 eV
Drift in 10 minutes (angle)	1 microrad

We have installed an autocollimator that directly observes the grating position from outside the chamber, providing an independent measurement of the angle.

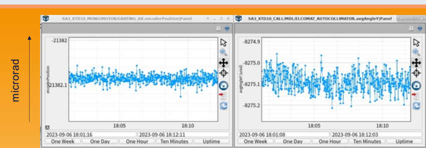




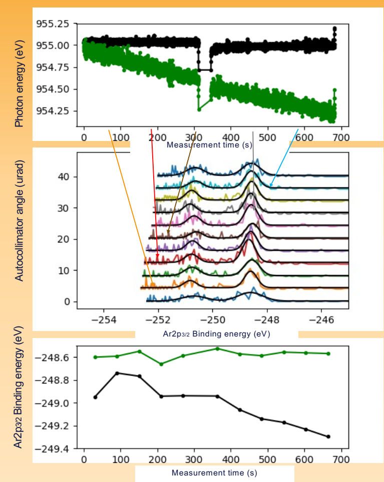
Left: reading from the encoder. Right: reading from Autocollimator



Example of discrepancy between the two readings
Left: reading from the encoder. Right: reading from Autocollimator



Short term fluctuations of encoder (left) and autocollimator (right)



Top: photon energy from the encoder calibration and from the autocollimator calibration. Middle: Ar 2p Binding energy spectra using the photon energy retrieved from the autocollimator. Bottom: Peak position when encoder is used (black) and when autocollimator is used (green)

References

[1] Gerasimova, N., La Civita, D., Samoylova, L., Vannoni, M., Villanueva, R., Hickin, D., Carley, R., Gort, R., Van Kuiken, B. E., Miedema, P., Le Guyarder, L., Mercadier, L., Mercurio, G., Schlappa, J., Teichman, M., Yaroslavtsev, A., Sinn, H. & Scherz, A. (2022). The soft X-ray monochromator at the SASE3 beamline of the European XFEL: from design to operation. J. Synchrotron Rad. 29, 1299–1308.

[2] Daniele La Civita, Natalia Gerasimova, Harald Sinn, Maurizio Vannoni, "SASE3: soft x-ray beamline at European XFEL," Proc. SPIE 9210, X-Ray Free-Electron Lasers: Beam Diagnostics, Beamline Instrumentation, and Applications II, 921002 (8 October 2014)

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