TRIXS end-station at FLASH for ultrafast high-resolution soft X-ray spectroscopy.

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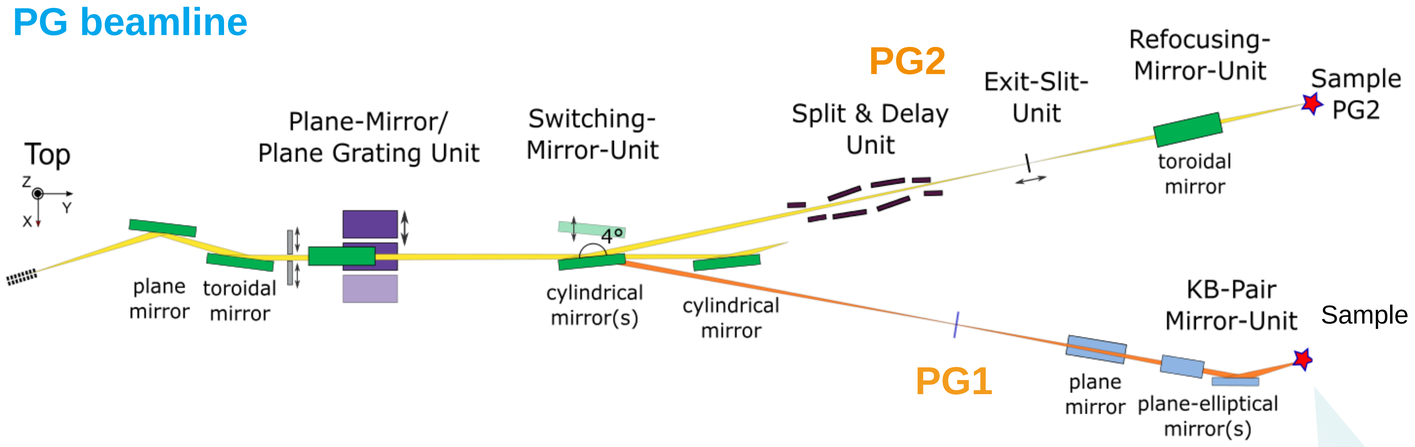
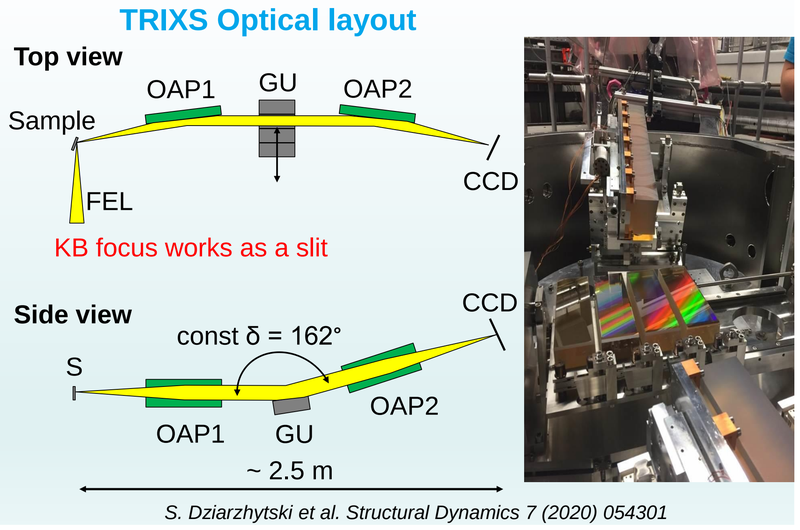
*The **t**ime-**r**esolved **i**nelastic soft **X**-ray **s**cattering spectrometer (TRIXS) of the PG1 beamline at the free-electron laser Hamburg (FLASH) was developed for studies of ultrafast processes with high energy and time resolution in condensed matter by means of femtosecond pump-probe IXS technique. Its spectral range spans from 40 eV to 210 eV and covers M-edges of the 3d transition metals and N-edges of rare earth elements. With its high spectral resolution (40 - 100 meV), the high brilliance of FLASH, high collecting efficiency, FEL synchronised optical laser and overall time-resolution of about 180 - 250 fs, this endstation is especially suitable for dynamic studies. Within the FLASH 2020+ project variable gap and polarization undulators will be installed at FLASH1. A new sample chamber for time-resolved RIXS, XAS and reflectivity measurements has already been built and installed to provide users an opportunity to benefit from the FLASH upgrade and to enhance the capabilities of the endstation. Several time-resolved RIXS measurements employing this new setup have already been successfully carried out and further experiments are planned. New control system and machine-learning-based alignment as far as stabilization algorithms will provide a better user interface and even more stable operation. Design, features and performance of the TRIXS are presented here.*

PG beamline



TRIXS Optical layout



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Experimental Parameters

General Parameters

N_{ph} on sample per pulse (total 5 kHz)	≤ 10^{10}
Focal spot size on sample H x V, μm²	10 x 5* *(PG mono slit width dependent)

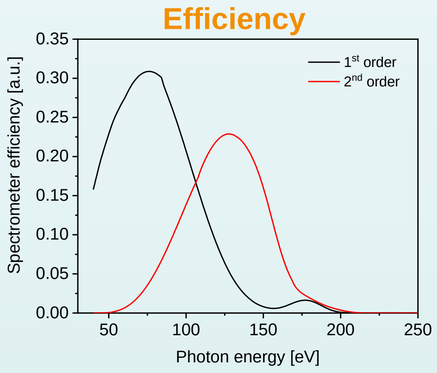
For tr-RIXS using TRIXS spectrometer

Spectral range, eV	36 - 210
Spectral resolution, meV	35 - 160
Time resolution FWHM, fs	170 – 300** (**energy resolution dependent)
Throughput	~5E-5
Optical laser	1030 nm + 2nd, 3rd and, 4th harm., ~70 fs fwhm; ~50 mJ/cm² fund.

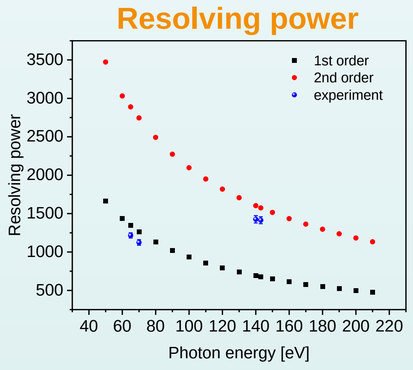
For XAS & Reflectivity

Spectral range, eV	36 – 210 (fund.), up to 700eV with HH in SASE
Resolving power E/dE	7000 – 12000
Θ-2Θ range	30-260°
Azimuthal range	0-360°

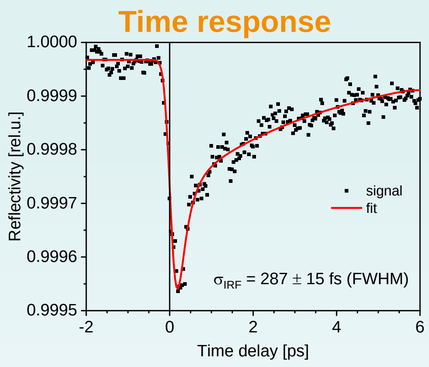
Efficiency



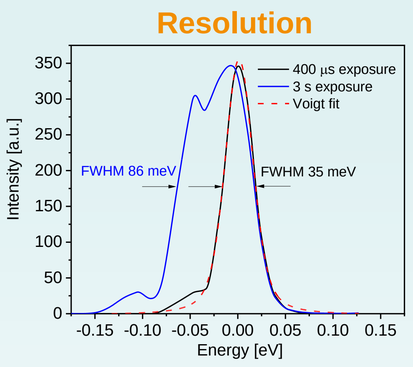
Resolving power



Time response



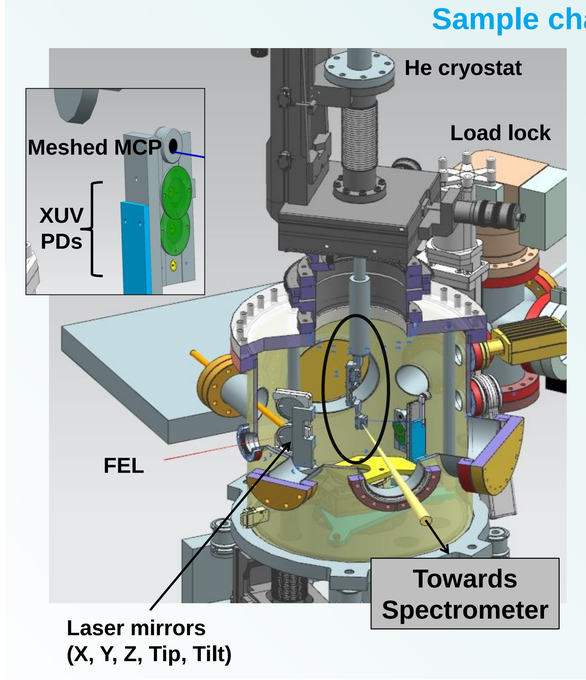
Resolution

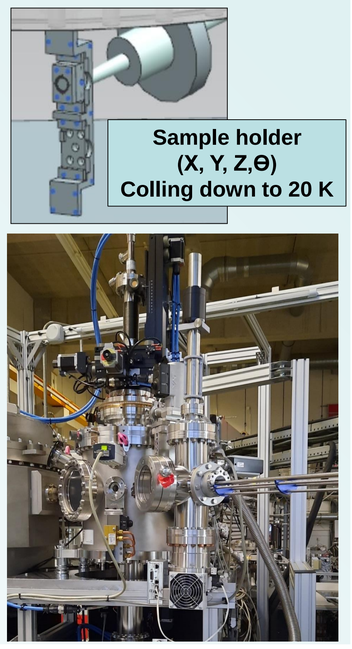


Machine learning based alignment

Misalignment, mm			TRIXS image at a given distance (caustics), mm						
Y	Z	X	-1	-0.5	-0.25	0	0.25	0.5	1
0	0	0.1							

Sample chamber

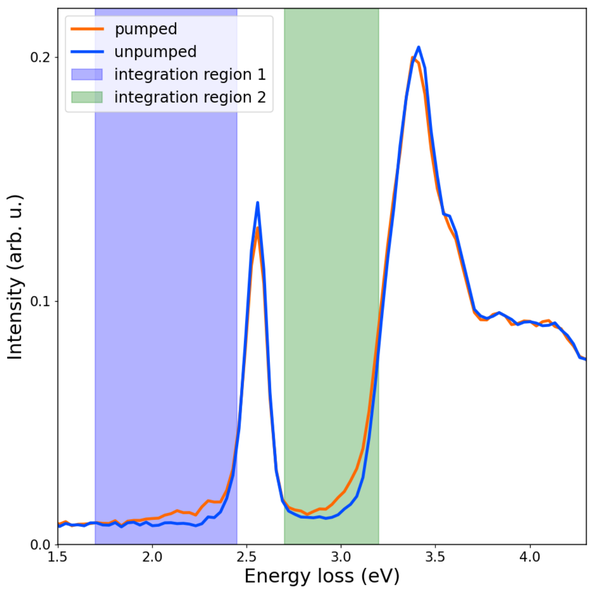


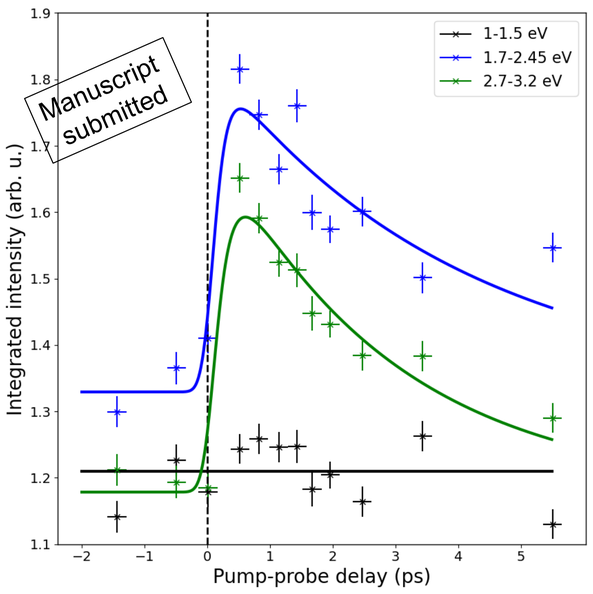


User experiment

Time-resolved RIXS of Tb near $N_{4,5}$ edge of ~147 eV

Courtesy of N. Thielemann-Kühn





Summary and outlook

- ✓ **Possibility of sub-ps time-resolved RIXS, X-ray reflectivity and XAS (TFY, TEY) in a single endstation**
- ✓ **Interface studies are possible that will open path for exploring spectroscopy of different heterostructures**
- ✓ **With the temperature of about 20 K, there is possibility to explore phase transitions dynamics**
- ✓ **New optical scheme and detection are being discussed**
- ✓ **The possibility of introducing adjustable magnets (mangle) for XMCD research is being considered**

Acknowledgements

- *FLASH Group, J. Schunck, R. Engel, S, Marotzki*
- *FLASH FS-LA, DESY MEA2, DESY M-division*
- *Prof. M. Rübhausen (Uni HH, CFEL)*
- *Dr. N. Thielemann-Kühn et al. (HZB)*

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