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A compact, high through-put spectrometer for soft X-ray RIXS studies at ID32

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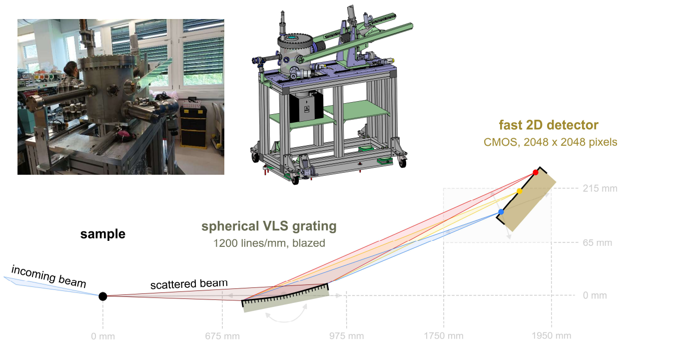
A compact grating spectrometer for soft X-ray RIXS and XES experiments is being built at ID32. The instrument is optimised for very high through-put while still providing a resolving power of 3,000 and better over the entire energy range from 400 to 1600 eV. It can be moved between end stations allowing for a flexible use in several scientific areas. When connected to the existing XMCD end station the spectrometer will enable soft X-ray RIXS studies in high magnetic fields and at low temperatures. In combination with the XAS end station for material sciences at ID32 the spectrometer opens up new scientific opportunities, for instance, in materials science or chemistry. The start of user operation is foreseen for the second half of 2023 and proposals can be put it in for the March 2023 call.

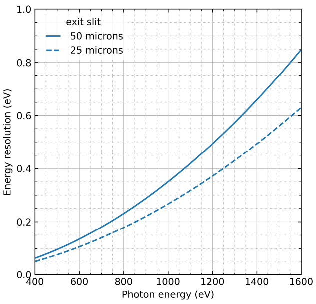
Optical layout & mechanical design

The main objective for the spectrometer design was to create a versatile, highly efficient instrument to cover scientific areas complementary to the existing high-resolution RIXS programme at ID32 [1]. To this end, we adopted a simple, well established optical design based on only one optical element [2], mounted on a mechanical stand that can move between end stations.

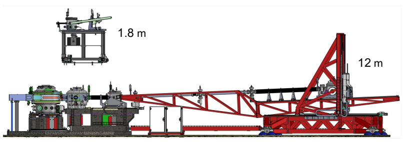


Optical layout and mechanical design of the spectrometer. The simple, compact design and large sample to grating distance allow for a flexible use with several end stations. The spectrometer covers the full energy range of the beamline, i.e. 400 to 1600 eV. A second grating can be added in the future to enhance either through-put or energy resolution.

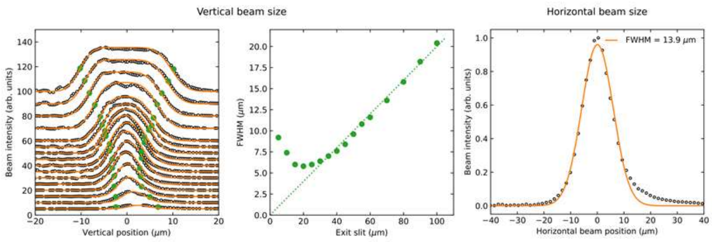
Energy resolution and efficiency



The compact spectrometer will achieve an energy resolution of about 0.25 eV at 930 eV (Cu L_3 edge), a factor 7-8 less than the ID32 high resolution instrument in its low resolution configuration. However, the through-put will be about 30x larger reducing the typical acquisition time of a spectrum from minutes to seconds.



Beam size at the sample

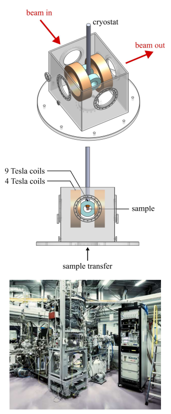


Vertical beam size as a function of the exit slit opening and minimal horizontal beam size measured in the high-field magnet end-station. The horizontal beam size can be varied continuously between 14 microns and more than 1 mm depending on the needs of the experiment without affecting the vertical beam size.

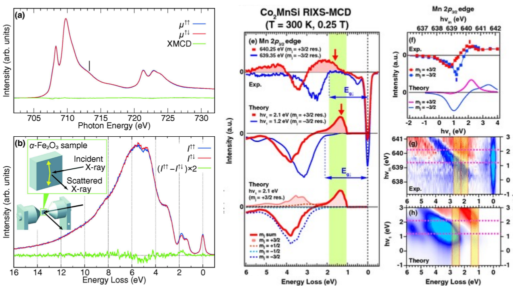
Scientific opportunities

The spectrometer can be connected to several vacuum end stations in order to enable users to exploit it in several scientific areas. The combination with the ID32 high field magnet [3] provides with a new, unique opportunity for RIXS experiments in high magnetic fields which has not been available so far. Even higher fields up to 50 T should become available in 2027 with a new pulsed field magnet setup. Experiments with custom user setups and sample environments may be possible after discussion with the beamline staff.

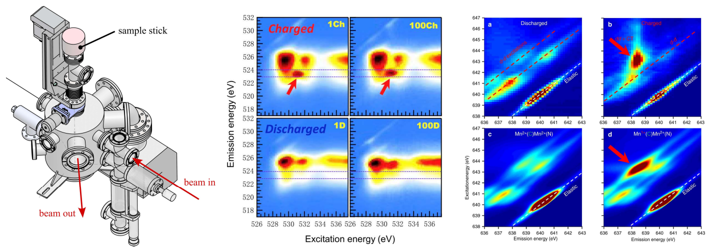
Magnetism and correlated materials



Left: The 9T/4T superconducting magnet end station at ID32 at which the spectrometer will be installed in 90° horizontal scattering geometry. This setup will enable RIXS-MCD and MLD measurements at the transition metal $L_{2,3}$ ($2p \rightarrow 3d$) and rare earth $M_{4,5}$ ($3d \rightarrow 4f$) edges in tunable magnetic fields and temperatures up to 9T and down to 4K. **Bottom:** Demonstration of soft X-ray RIXS-MCD with a permanent magnet setup at SPring-8 BL07LSU [4, 5].

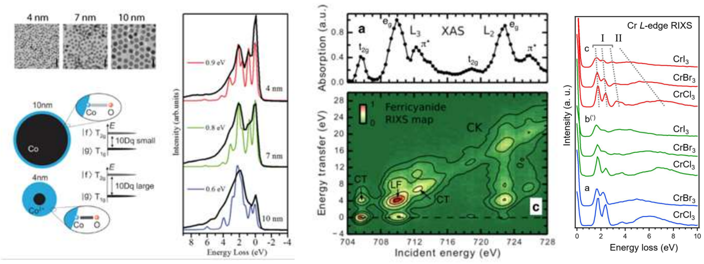


Materials sciences, energy sciences and chemistry



Top left: The XAS end station at ID32 to which the spectrometer can be connected. In combination with the compact RIXS spectrometer it enables efficient automatic collection of RIXS maps for dozens of samples in a row. The standard sample stick for quick XAS screening of dozens of samples could be replaced by user sample setups. **Top right:** Redox activity in lithium and sodium ion battery electrodes followed by O K edge RIXS [6, 7].

Bottom left: Size dependent catalytic activity of Co nanoparticles correlates with a varying energy splitting of the *d* orbitals detected with Co $L_{2,3}$ edge RIXS [8]. **Bottom middle & right:** Key energy scales in transition metal complexes and chromium trihalide (CrX_3) van der Waals materials determined with transition metal *L* edge RIXS [9, 10].



References

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