TEXS: high-efficiency in-vacuum tender X-ray emission spectrometer based on eleven cylindrically bent Johansson crystal analyzers

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Photon-in photon-out spectroscopies, namely, X-ray emission spectroscopy (XES), resonant inelastic X-ray scattering (RIXS) and high energy-resolution fluorescence detected X-ray absorption spectroscopy (HERFD-XAS) are getting embraced by a growing user communities, such as in bio-, geo-, chemistry sciences. This is permitted by the availability of an increasing number of high-resolution X-ray emission spectrometers at synchrotron radiation and free electron laser facilities plus in the laboratory. The X-ray energy ranging from 1.5 keV to 5.5 keV, the so-called "tender" X-ray energy range, permits measuring the K-fluorescence of light elements, such as aluminum, sulphur and chlorine, the L-lines of 4*d* transition metals and the M-lines of 5*d* elements and actinides. This energy range is largely unexplored with high energy resolution techniques, mainly because of instrumentation-related challenges.

A high-efficiency in-vacuum tender X-ray emission spectrometer (TEXS) is presented. The main specification consists of covering continuously the tender energy range with high quality standard single crystals, such as Quartz and Silicon or Germanium. This corresponds to a relatively large Bragg angular range, from 85° to 35°. Going away from backscattering requires reducing any angular error in the dispersive direction below 5 μrad. To achieve this stringent requirement, an array of cylindrically bent Johansson-type crystal analyzers of rectangular-shape and a dynamical sagittal positioning have been designed. The ideal point-to-point focusing Rowland circle geometry is kept exact in the dispersive direction and approximated in the sagittal one. Based on a ray tracing study, the optimized size of the analyzers was chosen 25×80 mm^2 (flat side × bent side). Owing to the possibility of working with a nominal bending radius ranging from 500 mm to 1000 mm, the number of analyzers is eleven. This permits a large covered solid angle per energy bandwidth. The expected energy resolution, $\Delta E/E$, is below 10^{-3}. The whole spectrometer is encased in a ≈4 m^3 vacuum vessel with a target vacuum of 10^{-5} mbar. This permits not only removing X-ray absorption from air, but most importantly the possibility to connect the spectrometer directly to the ultra-high-vacuum of the beamline and run a liquid helium cryostat windowless.

The mechanical design permits exact Rowland circle tracking (energy scan) via two core components: 1) a two-axis crystal analyzer table and 2) a three-axis detector arm. The whole array of analyzers is sliding on a flat plate table and sagittaly focused via a "pantograph"-like friction system. The detector is a multi-wire gas flow proportional counter. The mechanics and electronics of the detector were developed in-house and are mounted on the detector arm inside an "inverse vacuum" chamber. The choice of such detector is dictated by a large detection area (50×40 mm^2), high quantum efficiency and low electronic noise in the whole tender X-ray range.

The number of wires is sixteen, permitting a total count rate up to 1 MHz and a sagittal spatial resolution inside the focal spot. By selecting the central wires, it is possible to improve the energy resolution to ≈10^{-4} at the expenses of luminosity. A windowless liquid helium cryostat with multiple samples holder was developed for the spectrometer. A load-lock system for quick sample exchange with the possibility to load cryogenically cooled samples is present.

TEXS is currently installed on the beamline ID26 of the ESRF and its commissioning has permitted to validate the concept and mechanical design. The spectrometer is open to users.