

# THE ADVANCED PHOTON SOURCE

## AN ENERGY-RESOLUTION RECORD FOR RESONANT INELASTIC X-RAY SCATTERING

Resonant inelastic x-ray scattering (RIXS) is a powerful technique for studying electronic excitations in a wide variety of new and complex materials, offering momentum- and energy-resolution and potentially even analysis of scattered polarization. Since its inception in the 1990s, the development of RIXS instrumentation and scientific subjects have benefited from a closely intertwined evolution; improvements in energy resolution and throughput, spurred by specific scientific cases, have in turn made new subjects of study feasible. In the continued quest for substantially improved energy resolution, a novel prototype RIXS flat-crystal spectrometer was recently tested at X-ray Science Division beamline 27-ID-B at the Advanced Photon Source (APS). The spectrometer established a new record resolution for RIXS below 10 meV, together with a promise to do even better soon.

The new spectrometer at (Fig. 1) uses a multi-layer-based collimating mirror and successive flat-crystal optics. With flat crystals one can largely avoid figure errors and strain, which often are the limiting factor for traditional curved crystal spectrometers. Furthermore, the additional variable of crystal asymmetry allows tailoring the angular acceptance and degree of beam collimation of a flat crystal, and ultimately the resolution and efficiency of the assembly. Lastly, but very importantly, flat crystal assemblies provide the opportunity to include polarization analysis of the scattered beam efficiently and without loss of energy resolution.

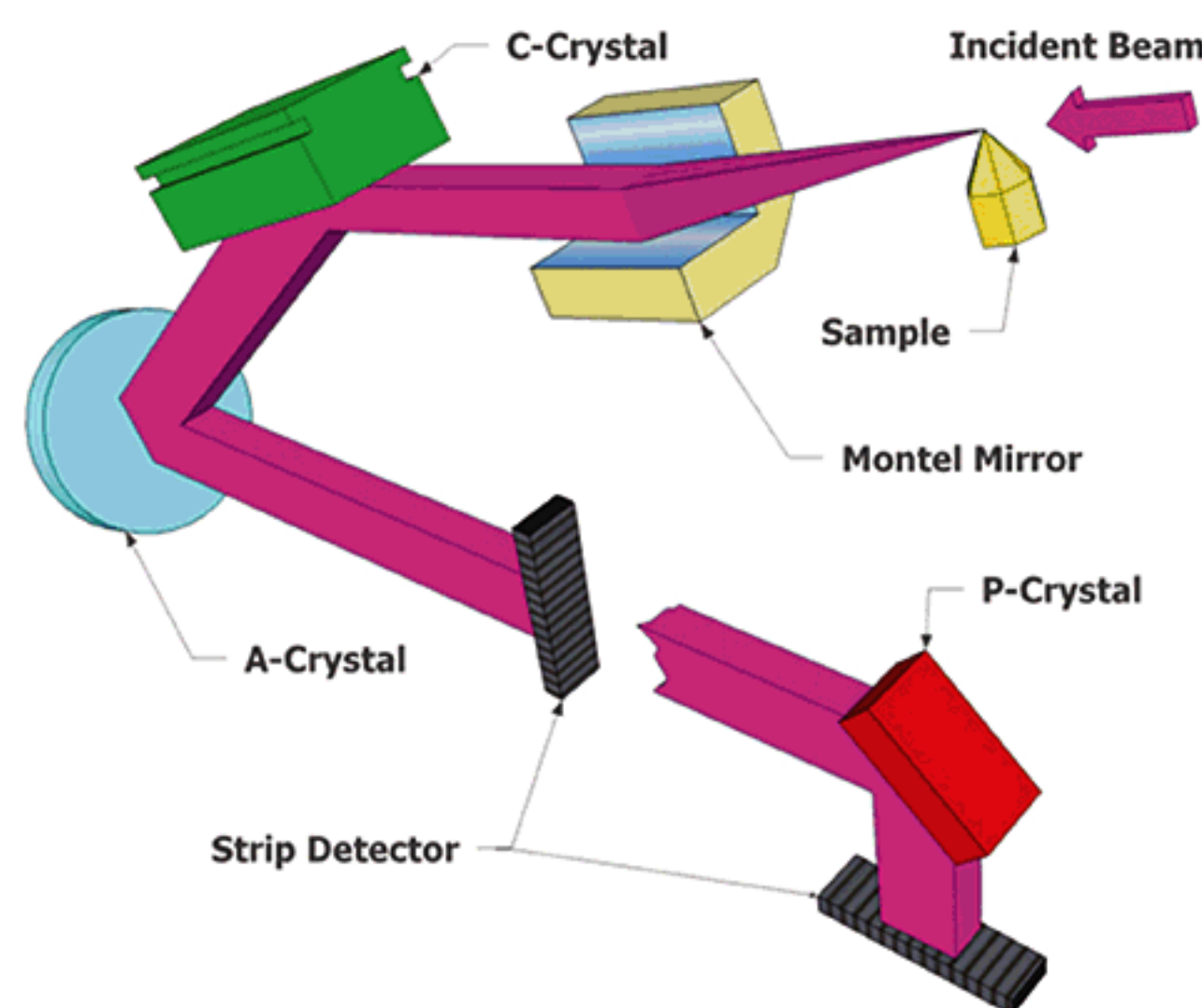


Fig. 1. Schematic rendering of the new flat-crystal RIXS spectrometer.

While polarization is necessary to attain a complete picture of the physics in an inelastic scattering event, routine polarization measurements have not been accomplished thus far in any RIXS measurement with better than a few hundred meV of resolution. The problem with flat crystals, however, is their minuscule solid angle x-ray acceptance. With the advent of advanced multilayer mirrors, collimators can now be devised that offer an acceptance comparable to curved analyzers, while collimating to a degree palatable for flat crystals.

The prototype spectrometer was designed for measurements at the Ir L3 absorption edge (11.215 keV). Scattered x-rays emanating from the sample are collected by a parabolic Ru/C Montel mirror. The pre-collimated exit beam is further collimated by the highly asymmetric Si(111) C-crystal. A near-backscattering Quartz(309) A-crystal followed by a position-sensitive detector performs the

high-resolution spectral analysis. For polarization analysis, a Si(444) P-crystal with a Bragg angle of close to  $45^\circ$  is inserted in the setup as necessary.

In a first set of demonstrations this instrument has achieved an overall energy resolution of 9.7 meV, a new record for any hard x-ray RIXS measurement. Furthermore, in the present case, the overall resolution was limited by the available high-resolution monochromator. Given an intrinsic analyzer resolution of only 3.9 meV, using a monochromator with matching band pass would result in an overall resolution of 5.5 meV. Such a monochromator is currently under development.

The flat crystal spectrometer design can easily be expanded for other absorption edge energies of scientific interest, by choosing an appropriate combination of crystals and multilayer mirror.

*See:* Jungho Kim<sup>1</sup>, D. Casa<sup>1</sup>, Ayman Said<sup>1</sup>, Richard Krakora<sup>1</sup>, B.J. Kim<sup>2,3,4</sup>, Elina Kasman<sup>1</sup>, Xianrong Huang<sup>1</sup>, and T. Gog<sup>1\*</sup>, "Quartz-based flat-crystal resonant inelastic x-ray scattering spectrometer with sub-10 meV energy resolution," *Sci. Rep.* **8**, 1958 (2018).

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