ESRF	**Experiment title:** **Towards x-ray optics with ~10 micro-eV energy resolution**	**Experiment number**: MI-1238
Beamline: ID18	**Date of experiment**: from: 02.06.2016 to: 07.06.2016	**Date of report**: 10.09.2016.
Shifts: 15	**Local contact(s)**: Aleksandr Chumakov	*Received at ESRF:*

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Report:

At present we are witnessing a revolutionary development in x-ray optics changing an emphasis from high-resolution *monochromators* to high-resolution *spectrographs* [1-3]. Spectrographs promise to improve an energy resolution by two orders of magnitude from ~meV to ~10 μeV and to achieve this *without losing* an effective count rate.

In this experiment, we investigated the spectrographic properties of the optics already existing at ID18. This is a high-resolution monochromator with a bandpass of about 0.5 meV (Fig.1).

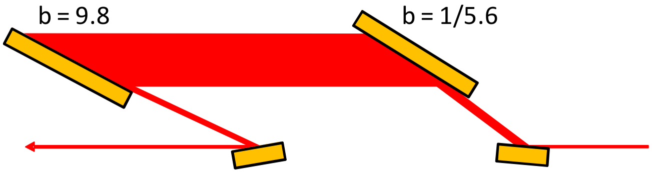

Fig.1. The scheme of the four-crystal high resolution monochromator installed at the ID18. The reflection indexes and the absolute values of the asymmetry parameters are shown.

The available at the ID18 high-resolution monochromator (HRM) was not supposed to be used as a spectrograph, but it provides a noticeable cumulative dispersion rate of D = 137 and the cumulating angular dispersion rate $\Delta\theta/\Delta E = D/E$=9.5 μrad/meV ($E$=14.4 keV). Therefore, it can work as a high-resolution spectrograph using appropriate lenses and a narrow slit downstream. The energy resolution of ~100 μeV is expected for the vertical source size of 30 μm.

We used 1-dimensional cylindrical compound refractive lenses (CRLs) immediately downstream of the HRM, and a slit system at about 15 m downstream of the CRLs. In this scheme, we would expect to obtain the vertical size of the focused beam of about 5 μm for an ideal source, and about 8 μm for the possible effective source size of 30 μm.

The value obtained in the experiment was about 35 μm, i.e., considerably bigger than the expected one. One of the possible reason for this inconsistency is that in the utilized 7/8+1 mode (i.e., not a timing mode) of the storage ring operation, the count rate of the resonance photons is small, and this possibly did not allow us to find an optimal focusing conditions for monochromatic component. Instead, we had to adjust focusing mainly for the beam with an entire energy bandwidth (about 0.8 meV), which is additionally broadened in vertical plane by the dispersion effect. Furthermore, the focusing possibly suffered from the aberrations of the cylindrical CRLs and a finite quality of the HRM crystals.

Nevertheless, we have clearly observed the spectrograph effect and obtained the energy resolution of 0.26 meV (Fig.2). This is by a factor of two better than the nominal energy bandpass of this monochromator.

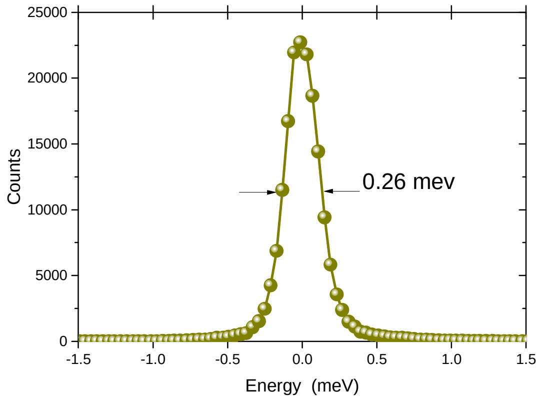

Fig.2. The energy resolution obtained using CRLS and a small vertical slit downstream of the HRM.

Furthermore, we observed the dispersion effect: The vertical displacement of the slit caused the change of the energy within the monochromator bandwidth (left panel of Fig.3). The measured angular dispersion rate (right panel of Fig.3) of 14.4 μrad/meV is considerably higher than the expected one (9.5 μrad/meV). The reasons for this deviation are the subject of further studies.

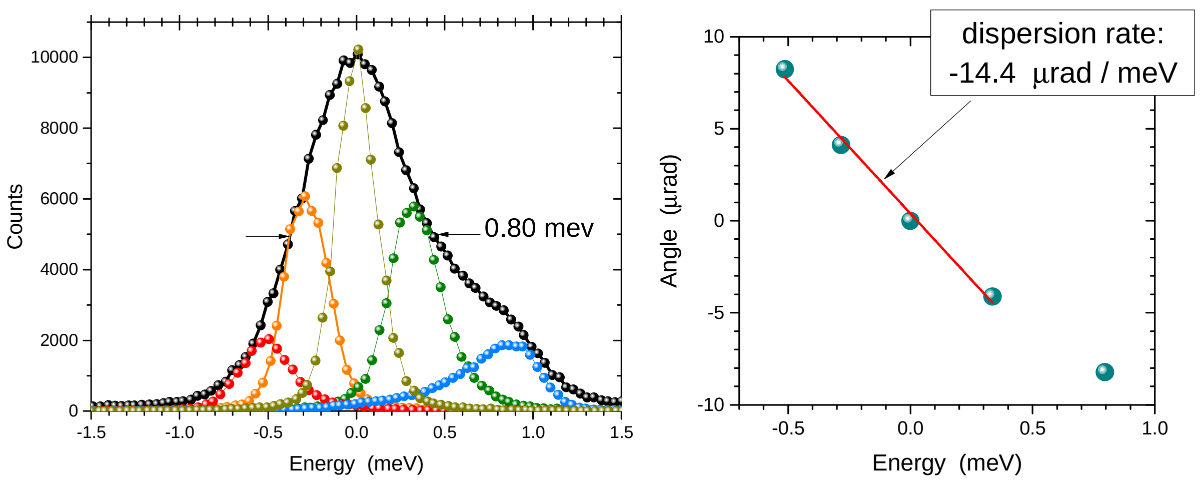

Fig.3. Left panel: The energy bandwidths of radiation selected with various vertical positions of the narrow slit, and the energy bandwidth of the entire radiation measured with an open slit (the black curve). Right panel: the derived angular dispersion rate of the spectrograph.

References

1. Kohn, V.G., Chumakov, A.I., and Rüffer, R. Journal of Synchrotron Radiation, **16** 635 (2009).
2. Shvyd'ko, Yu. Physical Review A. **90**, 053817 (2015).
3. Suvorov, A., Cai, Y. Q., and Chubar, O., to be published in J. Synchrotron Rad.