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Simulations of von Hamos X-ray spectrometer based on segmented-type diffraction crystal

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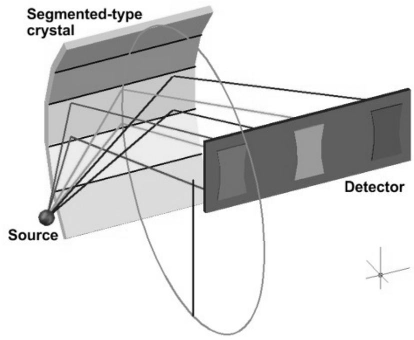
Wavelength-dispersive spectrometers use the diffraction of X-rays on a crystal to spread out the incident radiation with respect of its wavelength. The dispersed X-rays, detected by a position sensitive detector, give thus precise information on their wavelengths, which is the main concept of a high-resolution diffraction X-ray spectroscopy. The wavelength-dispersive spectrometers can be equipped with flat [1], bent [2,3,4] or bent/ground [5] crystals. The bending of the crystal results the improvement of the spectrometer efficiency, but causes also worsening the energy resolution because of the deformation and waviness of the curved crystal. To avoid deformations caused by crystal bending, the diced or segmented-type crystal can be use, which is easy to implement for any spectrometer geometry.

An example of a device with diced crystal is the developed von Hamos spectrometer based on a segmented-type diffraction crystal and CCD detector [6] installed on SuperXAS beamline at Swiss Ligth Source laboratory in Villigen. It is dedicated to X-ray emission spectroscopy, in particular resonant inelastic X-ray scattering (RIXS) studies for X-ray energies about 10 keV. The design and performance of this spectrometer was preceded by a computer simulation of its properties. The calculations were compared with experimental results of X-ray elastic scattering for photon beam energies in the range 8-10 keV [6]. In this spectrometer a continuously bent crystal is replaced by a segmented crystal consisting of flat segments, which are tangent in the focusing plane to the bending circle of a crystal in a standard von Hamos geometry. This arrangement leads to quasi-focusing of X-rays and enlargement of observed distribution in focusing plane on the detector, but in the dispersion plane, the X-ray are diffracted always on a flat-crystal segment.

In the present work the main properties (resolution, efficiency) of a von Hamos spectrometer with a segmented-type crystal were studied for low energy X-rays of about 3 keV. Such spectrometer is planned to be used the EBIS facility at the Institute of Physics of Jan Kochanowski University [7] to study with a high-resolution the X-rays emitted from highly charged ions. In order to determine the spectrometer properties, the Monte-Carlo ray-tracing simulations, which combine the laws of optics with dynamical theory of crystal reflectivity and X-ray diffraction, were developed [8].



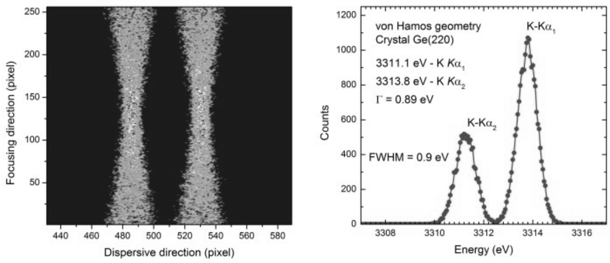


Figure 1. (*Top*) Scheme of the von Hamos geometry with a segmented-type diffraction crystal. (*Left*) 2D-distribution of photon hits in a plane of CCD detector, simulated for a potassium $K\alpha_1$ and $K\alpha_2$ X-ray. (*Right*) Simulated profile of X-rays obtained by projecting the 2D-distribution on a dispersive direction in a plane of a detector.

Using ray-tracing simulation technique the influence of various spectrometer parameters, as crystal/segment size, bending radius defining arrangement of crystal segments, X-ray source size, spatial resolution of the detector, on the spectrometer resolution was studied in details. Some examples are shown in Fig.1. Systematic results of the simulations will be presented and discussed.

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