ESRF	**Experiment title:** Intensity distribution for the 8-beam case of Si-888 in backscattering	**Experiment number:** MI-589
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Report:

A silicon crystal brought into exact backscattering condition for the 888-reflection yields not only the backscattering Bragg reflection, but additional reflections which reduce the intensity of the former. This phenomena has to be taken into account e.g. when storing photons by successive Bragg reflections [1, 2] between two parallel crystal slices or even when designing a Fabry-Perot interferometer.

In our experiment [3] photons of the exact backscattering energy for the 888-reflection (15.8163 keV) fell perpendicularly onto a perfect silicon wafer. The necessary monochromacy (3.7 meV) and divergence (10 μrad) were available at the backscattering spectrometer ID 28 at the ESRF. A sample chamber holding a detector system consisting of eight avalanche photodiodes and integrated amplifiers has been built. The detectors were suitable as well for time-integrated as for time-resolved photon storage experiments.

In addition to the forward and back diffracted reflections, six further reflections are excited simultaneously in the exact backscattering point of the Si-888-reflection. These eight reflections represent the vertices of a cube in reciprocal space.

The reflection profiles obtained in various angular scans can be explained by cuts of the eight reciprocal lattice points with the Ewald sphere. Let the ϕ-axis be perpendicular to the scattering plane of the 080-reflection and the θ-axis be perpendicular to both the ϕ-axis and the incident beam (Fig. 1 (left top)). The scattering plane of the reflections 000, 888, 080 and 808 contains the axis of the θ-scan, resulting in line widths of some 200 arc seconds in the θ-scans. However, the reflections 008, 800, 880 and 088 occur only in a small angular range of a few arc seconds around θ.

The intensities of the eight reflections were scanned in the θ-ϕ-space. In addition the energy of the impinging photons was varied around the critical backscattering energy by a factor 10^{-6} by detuning the temperature of the monochromator. The scans in angle-energy-space show a quadratic relation for $E(\theta)$. The Taylor expansion of $E(\theta)$ at $\theta = 90°$ provides (see Fig. 1 (left bottom)):

$$E(\theta) = \frac{hc}{2\,d\sin\theta} \approx \frac{hc}{2\,d} \cdot (1 + \frac{1}{2}(\Delta\theta)^2)$$

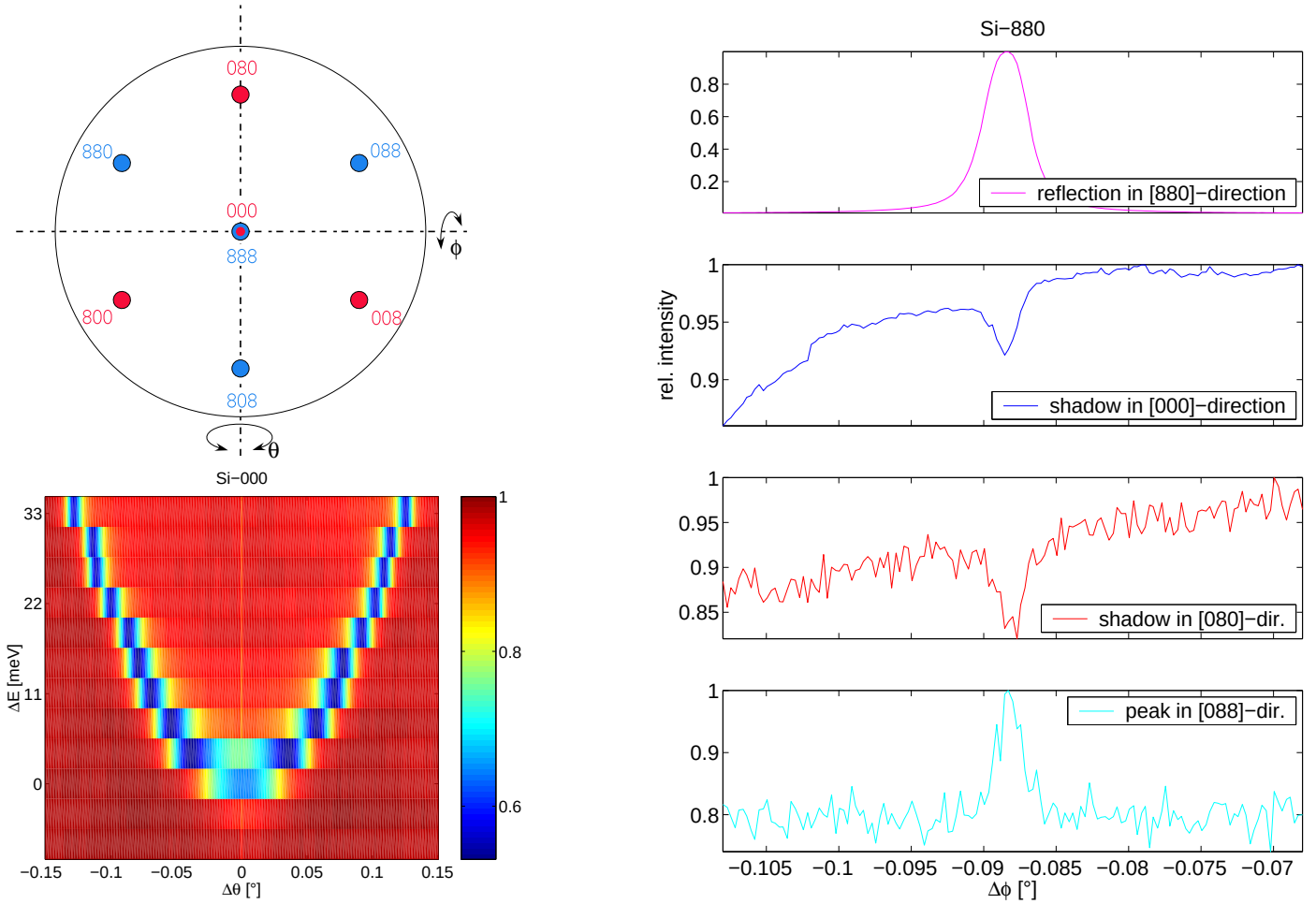

Fig. 1: (left top) *Representation of the beam directions for the 8-beam geometry, viewed towards the beam. The four reflections diffracted into the backward hemisphere are shown in blue, the four reflections diffracted into the forward hemisphere are shown in red.*
(left bottom) *Scan in the angle-energy-space of the forward reflection Si-000. In this representation the minima in intensity caused by the simultaneously excited Si-888-backscattering reflection lie on a parabola. The sharp line at $\theta = 0°$ is due to the reflections Si-008, Si-800, Si-880 and Si-088 being much sharper in the θ-scan than the Si-888, Si-080 and the Si-808-reflections. The widths of the reflections correspond to the cutting angles between the Ewald sphere and the pathways described by the reciprocal lattice points during the scan.*
(right) *Scan of the Si-880-reflection. The peak is shifted by $-0.088°$ because the energy and the ϕ-angle were slightly detuned with respect to the backscattering case. Symmetrically thereto, the Si-088-reflection shows a peak at $\Delta\phi = +0.088°$, the Si-080 at $\Delta\phi = 0°$. However, these peaks lie not in this enlarged cut-out figure. The simultaneously measured intensities of the directions [000] and [080] decrease at the peak position of the 880-reflection referring to the ϕ-scan. Note, that the intensity in the [088]-direction increases. This demonstrates coupling between the 880- and the 088-reflection.*

The intensities observed in angular scans show qualitatively the coupling of the reflections through interference of their wave fields (see Fig. 1 (right)). A quantitative account can be given by the dynamical scattering theory.

References:

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