	Experiment title: Conditions of photon storage in a crystal resonator	Experiment number: MI - 476
Beamline: ID28	**Date of experiment:** from: 13.12.2000 to: 17.12.2000	**Date of report:** 1. 3. 2001
Shifts: 15	**Local contact(s):** Michael Krisch	*Received at ESRF:* 2. 3. 2001

Names and affiliations of applicants (* indicates experimentalists):

K.-D. Liss*, ESRF
M. Mitschke*, ESRF, Kristallographie und Strukturphysik, Erlangen
R. Hock*, Kristallographie und Strukturphysik, Erlangen
A. Magerl*, Kristallographie und Strukturphysik, Erlangen

Report:

Photon Storage

The experiment is a continuation of a previous time resolved study on the storage of X-ray photons between two silicon crystal plates cut from a monolithic block as sketched in figure (1) with the 888 Bragg peak around exact back reflection geometry (15.816 keV) [1-3]. The sample sitting in a vacuum chamber found a very stable environment with a temperature variation of less than 0.05 °C in 10 hours, which allowed for temperature scans of the monochromator, and thus an exact determination of the wavelength corresponding for exact backscattering. The monochromator at ID28 is oriented in near backscattering position and yields an energy resolution of 3.7 meV. The excitation of the 888 reflection is an 8-beam case and the present study takes multiple beams into account.

The time characteristics of the forward reflected 000 beam and of one further reflection (880 forward / 00-8 backward traveling beam) were determined for their dependence on the deviation in angular setting and on a detuning of the wavelength of the exact backscattering position, the latter by a temperature variation of the monochromator. Further the storage of photons as a function of the crystal thickness was evaluated for the forward reflected beam.

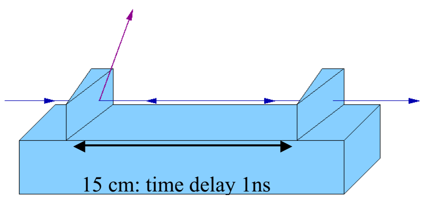


Figure (1): The X-ray cavity consists of a pair of vertical plates cut into a monolithic silicon crystal, with the [111] orientation along the surface normals. The plates are slightly wedge shaped to vary the effective crystal thickness between 50µm and 700µm by a horizontal translation perpendicular to the axis of the beam.

The time resolution was obtained by a silicon avalanche diode and triggered to the storage ring in single bunch mode. The rise time of the photo diode from 10% to 90% of the peak height was about 120 ps. The electronics were set to produce stroboscopically the time delay between a photon signal (start-trigger) and the bunch-clock signal (stop-trigger).
Figure (2) shows that photon storage occurs over the entire reflection width, but the storage efficiency is significantly higher close to the exact backscattering position. Photons traveling up to 30 times inside the cavity were observed. If the thickness of the crystal slabs is varied (see figure 3), maximal photon storage is observed when the plate thickness corresponds to the Pendellösung length of 283 μm. Note the slight increase in intensity for the thickness values of 350 μm and beyond which is related to an unintended increase of the temperature difference between monochromator and sample (2 °C). Further the sudden plunge in the storage capacity at a value of 150 μm likely originates from a slight misorientation of the crystal. The ratio of the intensities for successive bounces is proportional to the reflectivity (including absorption and multi-beam diffraction losses). A quantitative evaluation shows an increase in reflectivity for higher bounces which we attribute to a progressive removal of the high angular components of the primary beam at the wings of the Darwin profile. Also the off axis 880 reflection shows well developed delayed reflections with the apparent decay time being some 20% longer than the decay time for the direct beam. The angular acceptance for this beam represents only a small elliptical region within the much more extended area of the 888 reflection. This region appears to be constantly refilled, which may indicate the presence of strong non-planar wave components.

Fig. 2: Scan in θ

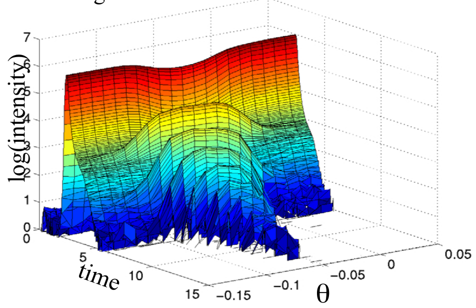
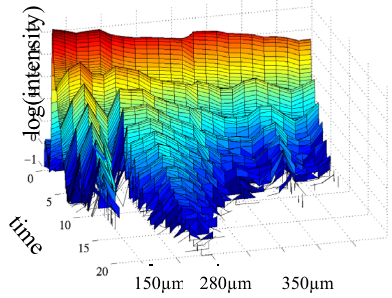


Fig. 3:



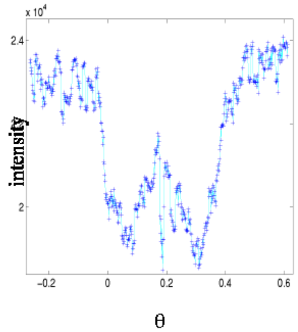


Figure (4): Rocking scan with a cavity as shown in figure (5).

Interference Effects

Rocking curves of a crystal with a gap reduced below the coherence length of 320 μm at ID28 were also measured. We observed a fine structure in the rocking curve indicating the presence of interference effects caused by the reduced gap width. We conclude that photon storage and Fabry-Pérot effects are possible even for exact backscattering geometry in a multi-beam case. At present a more complete solution of the 8-beam case needs to be developed in dynamical theory.

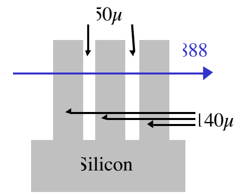


Figure (5): A 520µm plate of silicon (dimension in other directions: 1mm x 30mm) is cut twice to produce gaps of sufficient thinness.

[1] K.-D. Liss, R. Hock, M. Gomm, B. Waibel, A. Magerl, M. Krisch, R. Tucoulou, *"Storage of X-ray photons in a crystal resonator"* Nature, (2000). **404**(6776): p. 371-373.

[2] K.-D. Liss, R. Hock, M. Gomm, B. Waibel, A. Magerl, M. Krisch, R. Tucoulou, *"Storage of X-ray photons in a crystal cavity"* ESRF Highlights, (2000). **1999**: p. 104-105.

[3] K.-D. Liss, R. Hock, M. Gomm, B. Waibel, A. Magerl, M. Krisch, R. Tucoulou, *"X-ray photon storage in a crystal cavity"* Proceedings of SPIE, (2001). **4143**: p. 78-88.

http://www.esrf.fr/exp_facilities/id15a/science/resonator/index.html