ESRF	**Experiment title:** Probing the dependence of the valence electrons in silicon on strain by using x-rays into ultraviolet parametric down-conversion	**Experiment number**: HC-3539
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Shifts: 15	**Local contact(s)**: Andrew Fitch, Catherine Dejoie	*Received at ESRF:*

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Report:

Introduction:

The aim of the experiment was to measure the influence of strain on the efficiency of the effect of Parametric Down Conversion (PDC) of X-rays into UV. The PDC effect is an interaction of an input beam (that is called Pump) with the quantum vacuum fluctuations in a nonlinear medium. During this process, an X-ray incident photon is converted into two photons, an UV idler and an X-ray signal, such that both energy and momentum (phase matching) are conserved. For each pair of signal and idler there is a nonlinear coefficient that depends on medium parameters. The experimental idea is to illuminate the crystal by an X-ray beam and to measure the efficiency of the outgoing radiation at angle and energy that satisfy phase matching and energy conservation. The nonlinear coefficient dependence on the photon energy represents various crystal properties for different energy ranges. Moreover, because of the periodicity of the crystal, the Fourier components of the nonlinear coefficient for different reciprocal lattice vectors are measured. The uniqueness of the nonlinear coefficient in UV wavelengths is its dependence mainly on the valence electrons distribution. We measure only the outgoing X-ray photon (the Signal) but since the effect is nonlinear, its efficiency depends on the interaction of the UV photon (the Idler) with the valence electrons. Because of energy conservation of the signal and the idler photons with the incident photon, measuring a signal photon with specific energy probes the interaction of the corresponding idler photon. In addition, we use the reciprocal lattice vectors of the crystal for the phase matching, therefore this effect allows atomic scale resolution probing of valence electrons. The strain should change the charge distribution of valence electrons and therefore change the efficiency of the effect.

Experimental setup and procedure:

The main experimental steps were changing the strain, finding the new Bragg angle and performing a set of measurements. The setup is shown in Fig. 1. Each set of measurements included deviating from the Bragg angle in the Theta axis and scanning with the 2-Theta arm in a range that covers the solutions to the phase matching. In addition, for each Theta angle, we changed the angle of the analyzer to measure the spectrum of the outgoing beam from the sample. The photon energy of the outgoing beam (the Signal) is lower than the

incident beam by the energy of the Idler photon (which is not measured). The range of Idler energies that we measured was 3-50 eV.
The incident beam had a photon energy of 23.5 keV, the sample was a Silicon single crystal. We worked in Laue geometry and the diffraction was from (220) plane.
We induced strain in the sample by compression with the beamline's 5kN stress rig by Admet.
The diffractometer at the beamline has only two axes and the Admet stress rig is too large to be mounted on a goniometer head. The beamline scientist and the staff managed to setup two cradles and to align the sample within the stress rig relative to the beam.

<u>Results, experimental difficulties and conclusions:</u>
We succeeded to measure the PDC effect while applying force in the range 0-300 N. The effect is seen in Fig. 2 as a wide peak in the 2-Theta scans. For each offset from the Bragg angle, a 2-dimensional data set was measured.
However, the Adment stress rig was unstable during the experiment and we could not collect enough data to get pronounced results. Few times during the experiment the applied force increased unpredictably till it broke a few samples and we had to align the setup again. At different occasions we found that suddenly the load was released completely or changing during stages in which it had to be fixed. Also, at some stage it even was not stable enough to align the sample due to its movements. Probably it was something with the wiring to the controller or the load sensor – the beamline scientist tried to fix it a few times and we tried to operate it differently, however these problems appeared again and enforced us to repeat measurements.
From the sets of measurements that we managed to complete, we did not find the expected increase in the efficiency of the PDC effect. We believed that maybe the increase in efficiency is not pronounced enough since the strain is uniform instead of changing gradually along the crystal. Therefore we tried to improve the SNR by inserting a slit before the detector to separate beams with different angles (according to the phase matching, different energies have different angles). It turned out that it was possible to insert the slits only after the analyzer. It is one bounce analyzer, therefore different energies are diffracted with different angles. The consequence was that the energy range was limited by the slit. We tried to move he center of the slit between measurements, however, since it was combined with the instability of the stress rig, we could not get a satisfactory data set.
This beamline is not optimized for these kind of experiments, but it has the stress rig, which was crucial for our measurements. Unfortunately this stress rig did not function in a way that allowed as to get the data we needed.
We intend to proceed with this type of experiments. The next time we WILL induce strain gradient (by bending) and use an analyzer that diffracts perpendicular to the diffraction plane. Using a 2D detector could also help in aligning the bent sample.

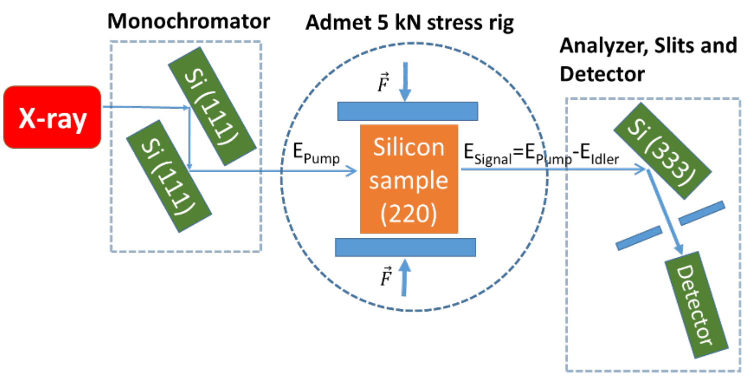

Figure 1 – The experimental setup

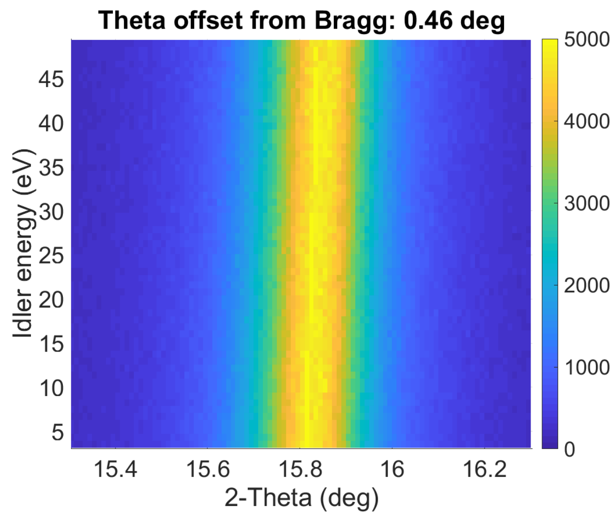

Figure 2 – A typical 2-dimensional scan. A 2-theta scan (horizontal axis) was performed for each analyzer value (vertical axis). The analyzer angles are presented in the corresponding Idler energy. The count rate is denoted by the color.