	Experiment title: X-rays in the quantum regime: imaging with true single photons by using an energy resolving two-dimensional detector	**Experiment number**: MI-1378
Beamline: ID01	**Date of experiment**: from: 07/07/2021 to: 12/07/2021	**Date of report**: 18/10/2021
Shifts: 15	**Local contact(s)**: Dr. Tobias Schulli	*Received at ESRF:*

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Report:

This is a continuation experiment for the 2D x-ray quantum imaging demonstration that we tried to perform in 2018 (MI-1337). The source for the single photon quantum state of light is photon pairs that are generated during the nonlinear process of parametric down conversion (PDC). To generate the single photons we used the procedure and configuration of our previous successful experiments [1,2]. In the process of X-ray PDC an incident X-ray photon, that is called pump, interacts with the quantum vacuum field in a crystal and converts into a correlated photon pair. The efficiency of conversion of pump photons into a photon pair is very low, however by using energy and momentum conservation and the fact that the two photons were generated in the same time, we could separate the PDC photon pairs from the background noise.

During the previous beamtime we encountered a few major difficulties. The main problem was the strong background (Compton and fluorescence) that obscured our signal and which we could not over come due to the lack of energy resolution of our 2D detector. In the current beamtime we used the pnCCD detector [3], which has an energy resolution of about 200 eV.

Another significant improvement in the current beamtime was taking advantage of the measured spectrum by the 2D detector to reduce the fluorescence lines by improving the shielding and the flight tube materials. The spectrum is shown in Figure 1 and it is important since part of the fluorescence lines are within the energy range of the photon pairs. Another benefit of the spectrum measurment was the early detection of the saturation of the detector. It could be observed in Figure 1 in the distorted spectrum and elivated Compton tail.

We managed to significantly reduce the measured background by 2 orders of magnitude compared to the previous beamtime, and get about 4 photons per frame (in the range 9.5-11.5 keV before applying energy conservation).

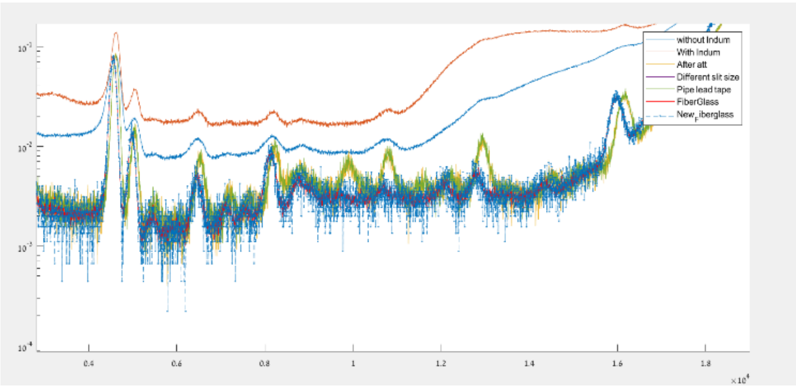

Figure 1 – Measured background spectrum by the pnCCD 2D detector. The data is normalized by one of the peaks. The fluorecence lines became weaker after the improvements – blue dashed line.

Figure 2 – Cumulative image of pairs in the energy range of 9.5 – 11.5 keV that conserve energy with a pump of 21 keV after a few hours of measurements.

However, even the small background that is still present makes it difficult to get directly the desired image – Figure 2. We are in the process of data analysis and the main goal is to exploit the momentum conservation of the photon pairs to reduce the background further. Meanwhile, it is hard to complitly eliminate the background due to the pump beam smearing at the nonlinear crystal (which is a diamond crystal with low absorption).

Beyond improving the data analysis process, there are other methods that we could use to improve the SNR and get cleaner results. We are considering to repeat the experiment with modified parameters for the pnCCD. The main idea is to use binning that will allow us eventually to increase the frame rate. It was 100 Hz during the current beamtime and we want to enlarge it to about 1000 Hz.

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[3] S. Send, A. Abboud, R. Hartmann, M. Huth, W. Leitenberger, N. Pashniak, J. Schmidt, L. Strüder, and U. Pietsch, *Characterization of a PnCCD for Applications with Synchrotron Radiation*, Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip. **711**, 132 (2013).