A liquid-jet system for scattering from liquid water

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The ability of modern synchrotron and XFEL light sources to produce highly intense coherent X-ray beams in the µm and sub-µm range offers the possibility to image soft condensed matter on ultrasmall length and ultrafast time scales. This allows accessing a variety of coherent X-ray diffraction techniques, e.g. X-ray Photon Correlation Spectroscopy (XPCS) and X-ray Cross Correlation Analysis (XCCA) [1, 2, 3].

The highly intense beam and the vacuum requirements in such experiments imply constraints on the sample, e.g. radiation damage of the samples or the walls of the sample container may affect the sample structure. One possibility to overcome this problem is a steady streaming injection system that produces a thin liquid-jet in vacuum.

Liquid-jets offer the possibility to study disordered samples in the fluid phase by a very fast steady-streaming [4]. We designed a liquid-jet setup which is capable of producing a homogeneous thin liquid-jet of diameter down to 1 µm.

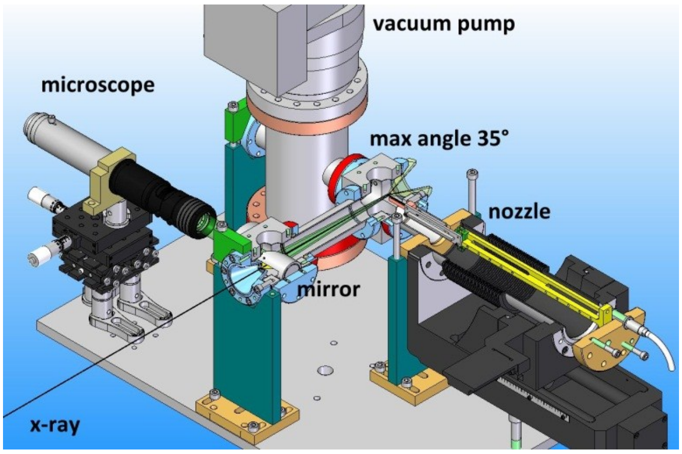


Figure 1: Sketch of the setup. The X-ray beam illuminates the jet from the lower left corner.

In this experiment we studied the wide angle X-ray scattering (WAXS) structure of liquid water as a prototypical application of our liquid-jet setup, see figure 1. We used an inline microscope and a mirror in the optical axis of the X-ray beam to align the thin liquid-jet to the X-ray beam. The mirror used to realize the inline geometry has a hole (diameter: 2.5 mm) letting the X-ray beam pass. We used Pilatus 300k detector at a sample-detector-distance of 7 cm at beamline P10. Due to the small thickness of the jet we performed the measurements with a focused x-ray beam of 3 µm x 3 µm. The beam energy was set to 8 keV.

A typical measurement is depicted in figure 2. The structure factor of liquid water located at 2 Å^{-1} is clearly visible in the WAXS geometry. Therefore, we were able to study the influences of nozzle and jet parameters on the scattering intensity, see figure 3. We analyzed the scattering intensity at the structure factor peak in dependency of the liquid pressure and of distance to the nozzle exit. The data are normalized to their exposure time. The incoming intensity on the focused area was 10^{11} photons per second. The scattering intensity is an indication for the amount of scattering material in the X-ray beam. The intensity as function of the nozzle distance is continuously

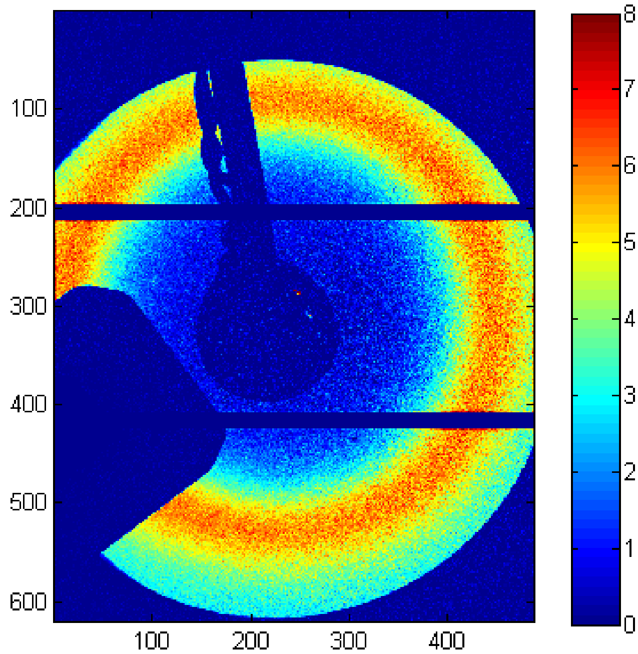
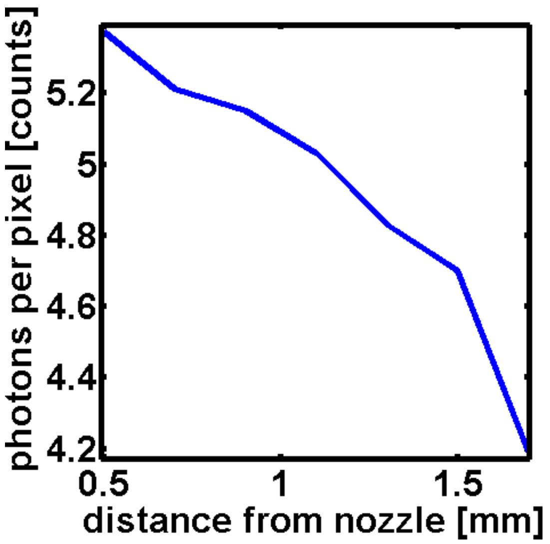


Figure 2: Typical WAXS measurement of the structure factor of liquid water at 2 Å^{-1} .The scattering pattern is polarization corrected.

decreasing, which indicates a constant spread of the liquid-jet. A break up of the liquid-jet is not clearly visible over the measured range. The increase of intensity as function of liquid pressure indicates a swelling of the liquid-jet with higher liquid pressures. The low intensity measured below 4 bar of liquid pressure is in line with our predictions for scattering intensities of a liquid-jet with a diameter of around 1 µm.



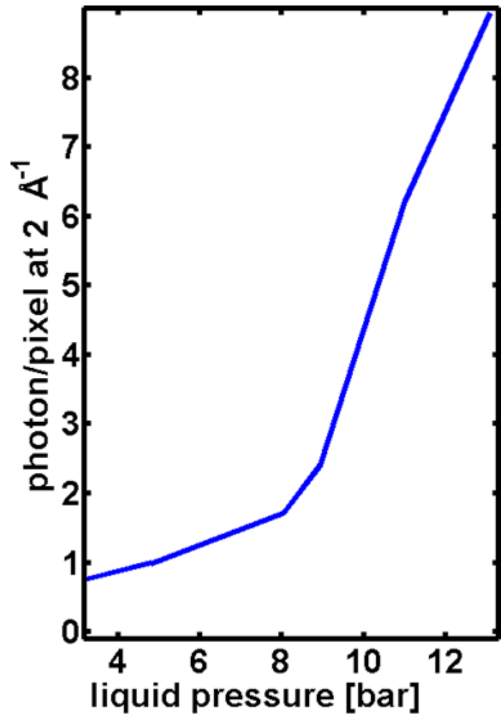


__Figure 3:__ Left: Measured number of photons per pixel at the structure factor peak as function of the nozzle distance. Right: Measured number of photons per pixel at the structure factor peak as function of the liquid pressure.

References

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