Tracking of non-repetitive processes with full field hard X-ray MHz rate single bunch imaging

Experimental report from beamtime MI126

P. Vagovic[1,2], T. Sato[1,2], R. Graceffa[1], C. David[3], M. Olbinado[4], A. Rack[4], A. Hovan[5], J. Ulicny[5], M. Sikorski[2], H. N. Chapman[1], A. Meents[1], J. Schulz[2], A. P. Mancuso[1]

[1]CFEL, DESY, Germany, [2]European XFEL, Germany, [3]PSI,Switzerlad, [4]ESRF, France, [5]Faculty of Science, Šafárik University, Slovakia

The aim of the experiment was the experimental characterisation a laser induced sample delivery system to be optimized for serial femtosecond crystallography (SFX) at the European X-ray Free-Electron Laser (XFEL.EU) facility. We have been particularly interested in three regions at the sample injector: visible laser – liquid interaction region, liquid-air interface (Meniscus) just before jetting, and its dynamics during the jetting and the dynamics of the jet itself. For the above-mentioned regions we applied MHz single pulse full field imaging recently developed at ID19 end station. We tested the feasibility of the optical density measurement using single phase grating interferometry. However due to weak signal we could not resolve the self-image (interferogram) at the detector plane using single bunch signal. We could observe clear interference pattern only after integrating signal over several bunches. Which indicates that the signal to noise ratio was not sufficiently high. Nevertheless, we successfully reached major goals. We found the optimal parameters such as the laser power density and shape of the water-air interface and concentration of dye, as well as the conditions under which the very repeatable generation of liquid jet has been achieved. The observed speed of jet was ~125 m/s, which makes such jet an promising candidate for the sample delivery at MHz repetition rate XFELs such as European XFEL. Moreover, by the fine time tuning of the pump laser in sheet capillary we observed the evidence of the shockwave propagating at the speed ~1.5km/s. Although with very weak signal we could see the edge of the shockwave at the distance from the laser impact corresponding to the speed of ~1.5km/s . Just after the shockwave closer to the impact point we see the generation of micro cavitation indicating that the cause of microcavitation was indeed the shockwave. Such observation was not possible with the visible light imaging because such sample is not transparent and strong fluorescence generated at the impact point prevents such observation of microstructure. The results and experimental setup is shown in figure 1.

It would be important to determine the pressure of the shockwave to estimate if the sample in the jet, for example protein crystal, can withstand such pressure. Although it was not possible with single bunch signal to obtain quantitative information (the density) we think it will be possible to do so in stroboscopic mode. In such mode we can even increase the spatial resolution by using higher magnification. Because we achieved good repeatability of the process, we applied for the follow-up experiment to image the density of the shockwave using differential phase imaging in stroboscopic mode.

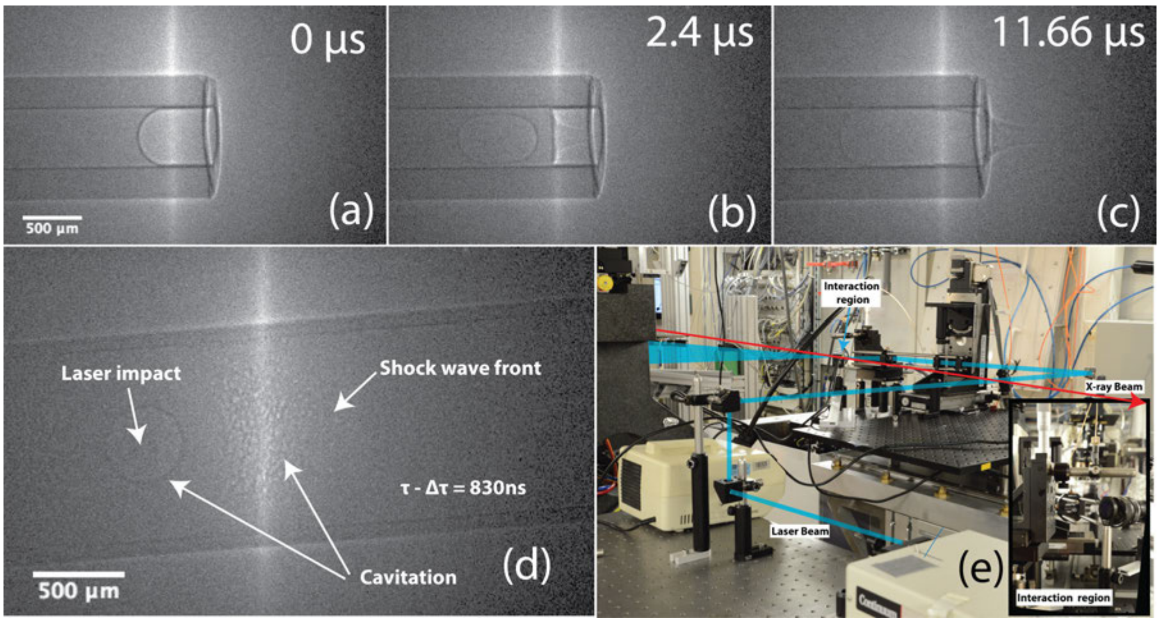

Figure 1. Time evolution of laser induced jet generation event (a,b,c), Observation of shock wave propagating at high speed ~1.5km/s (d) and photo of the setup used for experiment in ESRF ID19 beamline (e).