Imaging of clusters by single shot scattering of soft X-rays radiation from the FLASH

E. Eremina[1], C. Bostedt[1], M. Hoener[1], H. Thomas[1], T. Möller[1], H. Wabnitz[2], M. Kuhlmann[2], E. Plönjes[2], T. Laarmann[3], A.R.B. de Castro[4]

[1]Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany
[2]HASYLAB at DESY, Notkestr. 85, 22607 Hamburg, Germany
[3]Max-Born-Institute, Max-Born-Str. 2A, 12489 Berlin, Germany
[4]Brazilian Synchrotron Source LNLS, IFGW UNICAMP, Campinas SP Brazil

Imaging of non-periodic structures, such as macromolecules and nanoparticles is one of the most attractive perspectives for the upcoming X-ray FELs [1]. The underlying idea is to record diffraction patterns which allow the reconstruction of the sample structure before the sample is destroyed by the intense pulse.

A new 2D detector was built for such imaging studies and time-resolved investigations of clusters by single shot scattering. It consists of a CsI coated MCP detector coupled to a phosphor screen and a CCD camera. The incident FEL beam passes through a 3 mm center hole of the MCP detector. Electric and magnetic fields are applied around the interaction region in order to deflect the charged fragments from the clusters. A schematic view of the detector system is shown in fig.1.

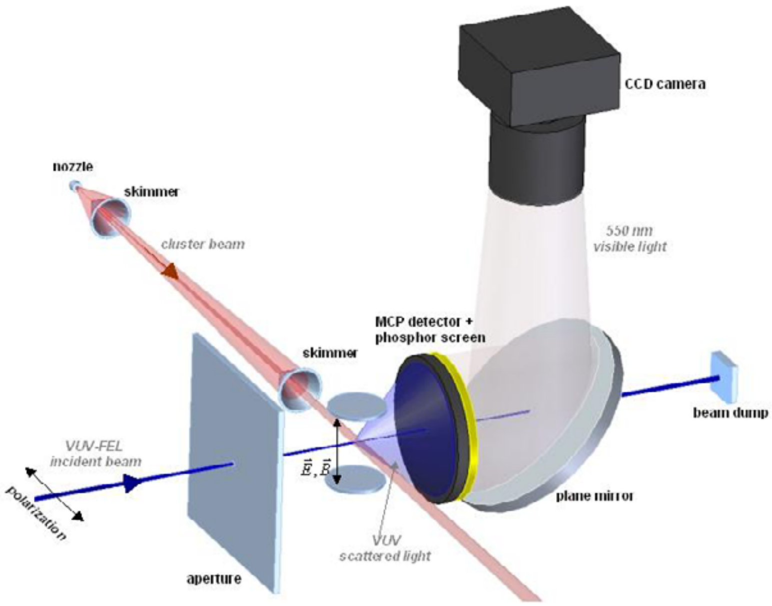

Figure 1: Schematic view of the imaging detector system.

Initial experiments on cluster imaging were performed at a wavelength of 32 nm. Large Ar clusters were produced with a LN_2 cooled nozzle at temperatures of 100 K to120 K and pressures up to 5 bar. On average less than one hundered clusters were in the focal volume. Single shot scattering patterns of clusters almost free of artefacts from electrons and ions could be observed.

From the time of flight mass spectra obtained previously [2] we could conclude that the ions ejected from the cluster move with about 10^4 m/s. As a result, the ions stay at their positions within

0,3 nm during the exposure to the soft x-ray pulse. Thus, the scattering pattern represents the shape of the clusters before radiation damage takes place.

A model calculation based on Mie-scattering theory yields good agreement with the experimentally observed angular distribution of soft x-rays scattered by Ar clusters. Spherical clusters with a sharp edge are assumed in the simulation. An ensemble of clusters with a typical lognormal size distribution has been taken into account. From the width of the intensity distribution of the scattered light the radius of clusters produced under different expansion conditions could be derived with uncertainty of 10%. The cluster radii range from 8nm to 32 nm. Fig.2 shows an example of scattering on Ar clusters for two cluster size distributions with different average radii.

The intensity of the FEL beam was sufficient to record scattering patterns when the FEL beam was attenuated to 1 %. This result is a basis for the next time-resolved investigations of fragmentation and explosion dynamics of rare gas clusters exposed to intense x-rays. Two separated FEL pulses of the first and third harmonic will be used as the pump and probe correspondingly. The fragmentation of clusters induced by the first-harmonic pulse at a wavelength around 30 nm can be studied with time-resolved scattering of the third-harmonic at 10 nm.

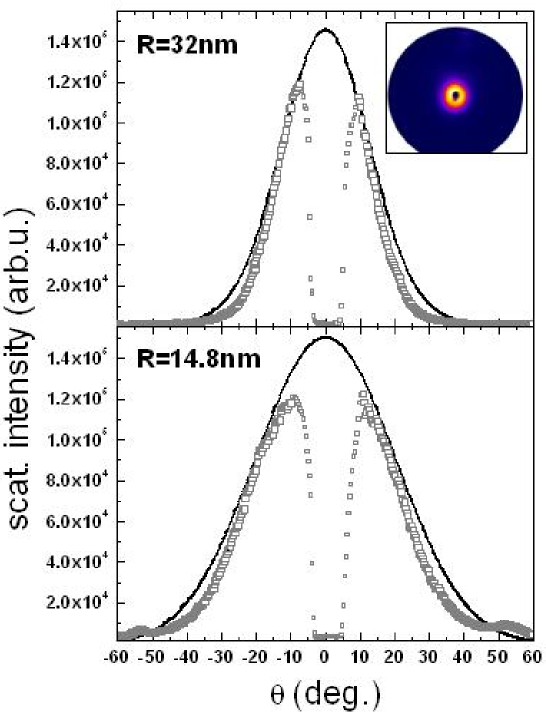

Figure 2: Angular dependence of soft X-rays scattered by Ar clusters with the mean cluster radius 32nm and 14.8 nm. Black curve is a calculation, open squares are experimental results. The insert shows a 2D scattering pattern.

We kindly acknowledge the financial support by BMBF 05 KS4TC/1.

References

[1] R. Neutze, R. Wouts, D. van der Spoel, E. Weckert, and J. Hajdu, Nature 406, 752-757 (2000)

[2] C. Bostedt, M. Hoener, H. Thomas, A.R.B. de Castro, E. Eremina, H. Wabnitz, T.Möller, in preparation