Imaging clusters dynamics

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Light induced dynamic with X-ray pulses
Two aspects

- Light induced expansion dynamics
  - Short time scale, fs-ps,
  - Long time scale, ps-ns

- Collective cluster oscillations, fission, fs-ps time scale

Size selected clusters

together with B. von Issendorff, Freiburg
I. Cluster dynamics induced by intense x-ray pulses

- **Beginning of the pulse**
  - Outer ionisation: Few electrons are removed from cluster

- **During the pulse**
  - Inner ionisation: Nano plasma formation

- **After the pulse**
  - Disintegration, relaxation, recombination
  - Energy, size, power density

Simultaneous light scattering and ion spectroscopy on individual clusters FLASH (DESY)

Morphology of very large xenon cluster

Analysis with 2D-Fouriertransform

<table>
<thead>
<tr>
<th>Growth by Coagulation</th>
<th>Experimental scattering pattern</th>
<th>2D-projection</th>
<th>2D-fouriertransform</th>
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</thead>
<tbody>
<tr>
<td>(a)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>R=32 nm</td>
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<td>(b)</td>
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<tr>
<td>R=75 nm</td>
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<td>(c)</td>
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<td>R=200 nm</td>
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</table>

- Imaging growth by coagulation, Soler, PRL49, 1856 (1982)
- non-spherical clusters ("Hailstones")
- clusters >1µm

Clusters are often individuals

Time resolved imaging of exploding clusters

- Study how ultrafast ionization dynamics influence scattering process
- Scattering sensitive to both, changes in electronic and geometric structure

IR pump + FEL probe pulse (LCLS), CAMP
Experimental layout

IR laser: 50 fsec, 2 mJ, $2 \times 10^{15}$ W/cm$^2$

XUV pump XUV probe

Delayline for soft x-rays (autocorrelator)

Universität Münster, Zacharias BESSY

FLASH, 93 eV

ion spectra

Geometrical wavefront splitting
3D geometry of the beam paths

top view - fixed arm

side view - variable arm

2 nm Xe clusters, destroyed after ~2 ps

20% pump

80% probe

Very long delay: Results from FLASH 93 3V, Comparison with simulations

Timescale: 1000 – 1500 ps - moderate NIR intensities

Simulation with Gunnier-approach


Density fluctuations in an expanding nanoplasma?
With two X-rays pulses at SQS

- First (weak) pulse shape of initial cluster
- Second pulse imaging of the cluster dynamics

- surface melting and explosion, fs-time scale
- Cluster expansion, ps time scale
Collective oscillations/dynamics in nanoparticles

Size selected

Damping?

Approved DFG project with B. von Issendorff
Size selected nanoparticles and two/three light pulses

- first (very weak) X-ray pulse
- IR pulse induces vibration by heating
- second X-ray pulse, imaging as a function of delay
- Two x-ray pulses, initial shape of clusters

New regime of cluster dynamics
Damping on the nanoscale
# Parameters wish list

<table>
<thead>
<tr>
<th>Parameters wish list</th>
<th>Day 0</th>
<th>Nice to have</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental techniques</strong></td>
<td>Scattering / spectroscopy</td>
<td></td>
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<tr>
<td><strong>Source properties</strong></td>
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<td></td>
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<tr>
<td>Energy range</td>
<td>500</td>
<td>500 eV- 2000 eV</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>50 fs or less</td>
<td>&lt; 30 fs</td>
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<tr>
<td><strong>Device properties</strong></td>
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<tr>
<td>Maximum Temporal delay</td>
<td>5 ps</td>
<td>30 ps or more</td>
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<tr>
<td>Pulse intensity ratio</td>
<td>1:3</td>
<td>1:1- 1:50</td>
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<tr>
<td>2 Colors</td>
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<td>yes</td>
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<tr>
<td>Symmetric delay around t=0</td>
<td></td>
<td>no</td>
</tr>
<tr>
<td>Spatial separation behind sample</td>
<td></td>
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<tr>
<td>Add your suggestions</td>
<td>Small focal spot, good overlap</td>
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</table>
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And thank you for your attention!