Shock Compression Physics Panel

D. Kraus – HZDR
N. Hartley – HZDR
C. Spindloe – STFC
R. Briggs – ESRF
S. Pascarelli – ESRF

M. Harmand – IMPMC
G. Fiquet – IMPMC
J. Hund – Schafer
P. Fitzsimmons – GA
Z. Konopkova – European XFEL

EUCALL Workshop on Building a Target Network

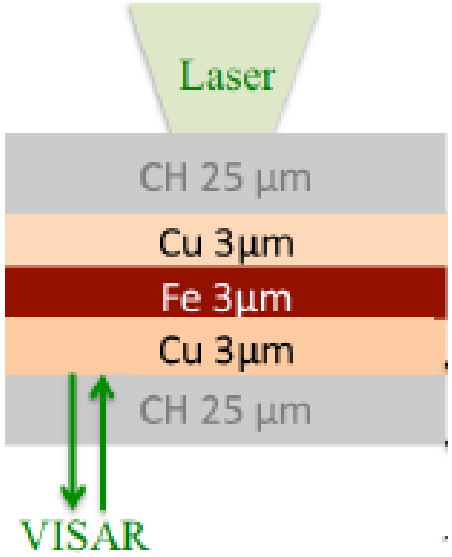
29-31 August 2016

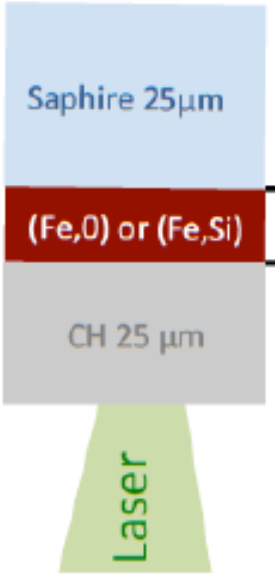
Helmholtz-Zentrum Dresden-Rossendorf

Scope and goals for this panel

- Information exchange on needs at laser vs X-ray facilities
- Make different communities aware of the challenges that exist and their scale
- Suggest next steps to address some of these

Examples of typical targets





- Very similar “target structure” for experiments at XFEL and SR user facilities
- Homogeneous “needs” and “challenges” across the community
- Small differences: choice of materials, thickness (shock confinement time, absorp. requirements)

Agenda

Introductory talk (15’) - G. Fiquet, IMPMC

"Dynamic compression and X-ray diagnostics or the art to design targets matching X-ray probe time resolution"

Discussion (1h30’)

Repetition rate
Prototypical experiments
Target needs, debris
Target production, characterization
Target design, optimization

Repetition Rate

What is the repetition rate in current experiments? 1shot/min to 1shot/10 min

What repetition rate could offer new perspectives and allow to study materials which can't be studied at the moment? Up to 1shot/10 s (0.1 Hz)

What could we do if we were able to accumulate a large number of shots? (would require highly reproducible targets and alignment)

have more data points along the hugoniot/ramp

Increase data collection to study compression pathway very closely (i.e. phase kinetics)

materials with poor scattering properties (i.e. low Z materials, liquids)

accumulate for better statistics for IXS, XRTS, XANES, EXAFS, SAXS

spatially resolved IXS, XRTS

What is the number of shots required to complete a campaign? 100 – 500, higher if rep rate goes up

Do subsequent shots need adjustment (for example in the optical path)? Yes

Prototypical experiments

Can you think of a list of prototypical experiments in shock-compression physics?

Extreme pressure phase diagrams

EOS measurements

WDM research, transition solid ←→ warm dense liquid, planetary physics

Shock melting, structure of liquid

Ramp compression, quasi-isentropic compression, Off – Hugoniot states

Anisotropy of shock propagation

Phase transitions processes (10 – 100 ps time resolution)

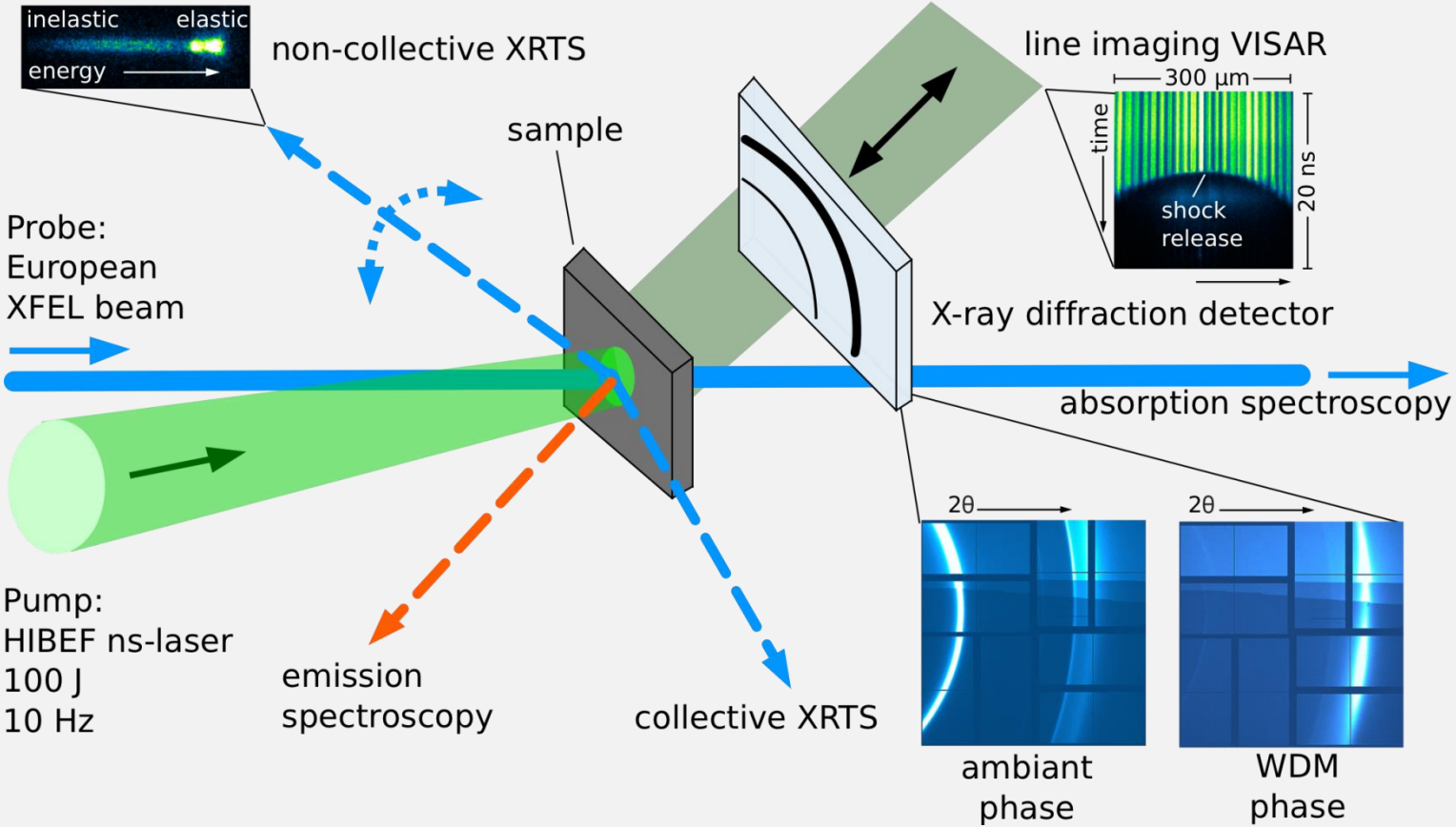
Geometries: Almost co-linear, transverse, various angles between x-rays and the optical laser, two beam counter-propagating shock compression

What do they have in common?

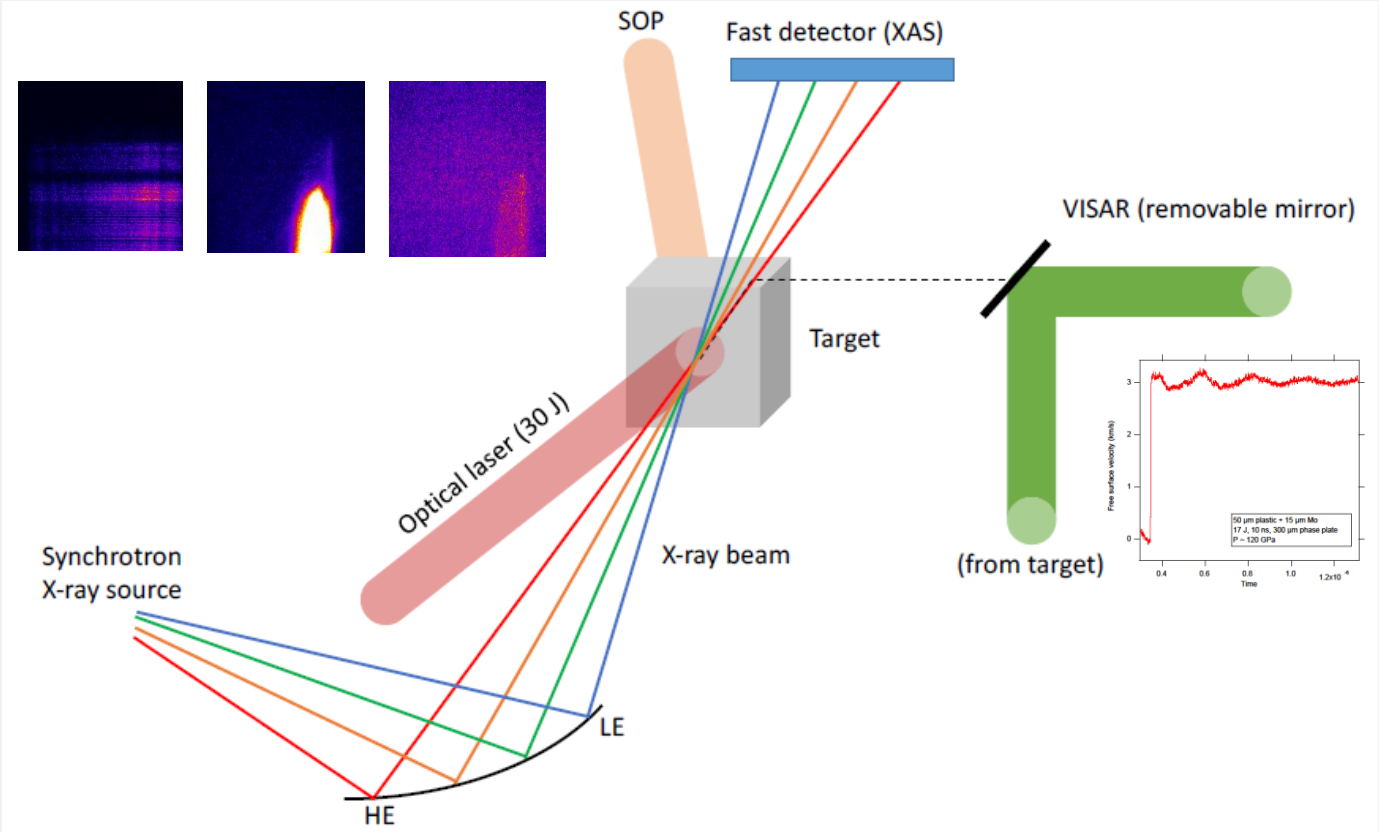
Multiple diagnostics:

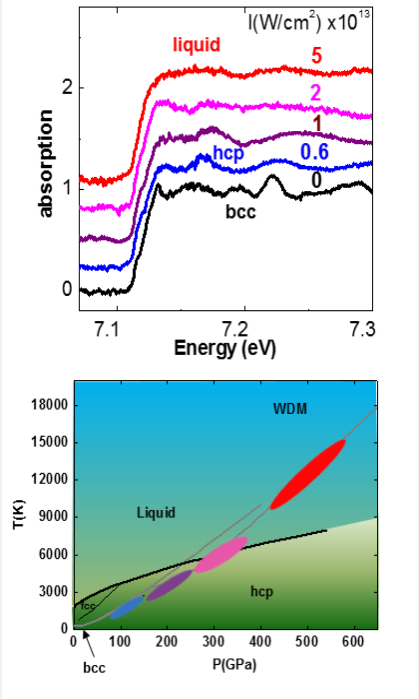
WAXS, IXS/XRTS, SAXS, XANES/EXAFS, imaging, VISAR, SOP

Almost collinear geometry for XRTS, XRD at XFEL



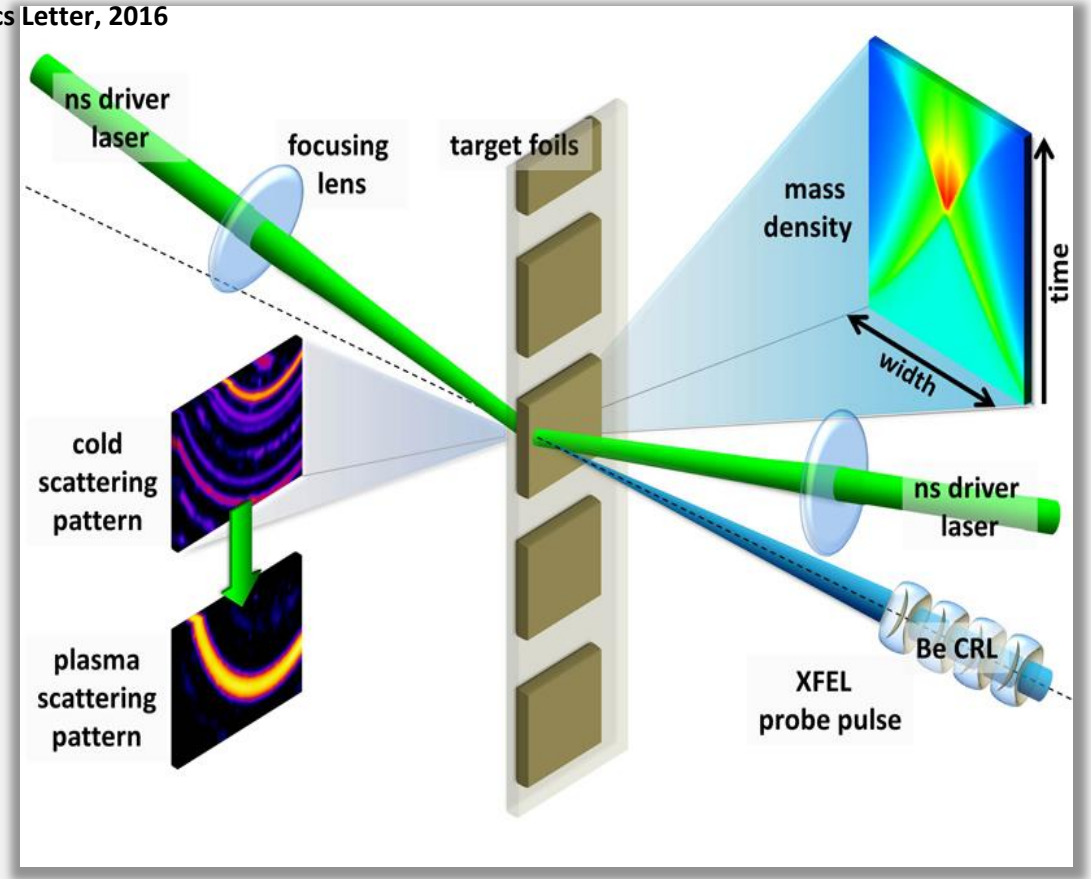
Almost collinear geometry for XAS at synchrotron





Two beam counter propagating shock compression @ XFEL

U. Zastrau, Applied Physics Letter, 2016



Target needs

What are the main target types used for shock compression experiments?

1-200 µm thick single component foils (with thin flash/reflectivity coatings)

Typical dynamic compression targets: ablator, pusher, sample, window (sometimes with glue layers)

Windows: Diamond (single crystal / polycrystalline) / LiF / Sapphire

Samples may be foils but also single crystals

Which requirements should they fulfill (i.e. reproducibility, layer thickness/density, crystalline structure..)?

Few % reproducibility layer thickness, density

Must know initial crystalline phase, orientation, texture, grain size, reflectivity, composition

For user facilities, on which timescales will you need these targets?

2-12 months

(6 months has been typical lead time, quite difficult constraints to get everything done within that time!)

Cost/experiment today: 10k€ - $100k€

Debris

Must targets be protected against shock/radiation/debris/etc. from preceding shots?
optics/diagnostics close to the laser-matter interaction may require protection by rotating debris shields
High-intensity shots can damage neighbouring targets, optics
Debris shielding could be part of the sample holder

Will significant material be vaporized? How much debris is generated?
several µg up to several mg per shot. For 1 hour operation @10Hz: 36 g

Are there possible solutions?

automatically replacing debris collectors

fast exchange of blast shield system to be developed

Would it be possible to mitigate the problem in the target design phase?

Target holder with large enough spacing between targets

Target production

What are the techniques used at the moment to produce these targets? All of them (see target survey); thinner (<30 microns) sample may be deposited, thicker samples must be glued (which is an issue)

- Laser cutting
- Coating
- Surface polishing
- Thermal fusing
- Lithography
- Etching
- Thin glue layers
- Target mounting

What is available?

Many home made targets (where as-purchased rolled foils are glued to plastic ablators with thin glue layers).

Certain companies are available (such as SciTech, Chris Spindloe) who can provide layered targets.

Ion polishing, Coating machines

Equipment for : metals and alloys (ternary systems), oxides and salts, parylene-N deposition

What would be needed?

Higher rep-rates : Targets need to be highly reproducible, will require automization of most techniques
Possibly standard features and procedures for quick alignment.

More time for ‘home made” target preparation

More information needed about other suppliers/possibilities.

careful characterization and documentation of target properties

Are target fabrication costs a significant issue?

immense issue for many of the user groups.

Target characterization

Which properties need to be characterized (density/thickness/crystalline structure/grain size...)?

Required (for each layer in case of multiple layers):

- density
- thickness
- impurities
- If crystalline material:structure, orientation/ texture , grain size
- chemical purity,
- control of the initial phase nature and density,
- quality of contact between sample and transparent windows

How can the reproducibility of target properties be checked?

MEB, XRD, AFM, SEM, TEM, optical microscopes, ..

Must parameters for each individual target be applied to the analysis of results for its shot?

normally not done and with high rep rate may be impossible.

But reproducibility of the targets should be checked at least by a random check of couple of targets from the same batch.

Target design and optimization

What are the main issues?

- Progress needs to be made with hydrodynamic modeling (input of equations of state, phase transition, 2D)
- Reproducibility
- Cost
- Amount of good quality targets at a lower cost + good characterisation
- Design/optimization: Long process, tedious work

Are tools available?

Mostly but lack of time for better control and they are quite spread around so a better communication between facitlites and companies would help a lot

If so, do they need further development?

Some codes for designing and optimizing the experiment specifications (target and laser parameters**)** should become broadly available with good documentation.

Codes need to be made user-friendly

Hydro-simulations for target design