Electron Transport and Isochoric Heating Panel

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EUCALL Workshop on Building a Target Network

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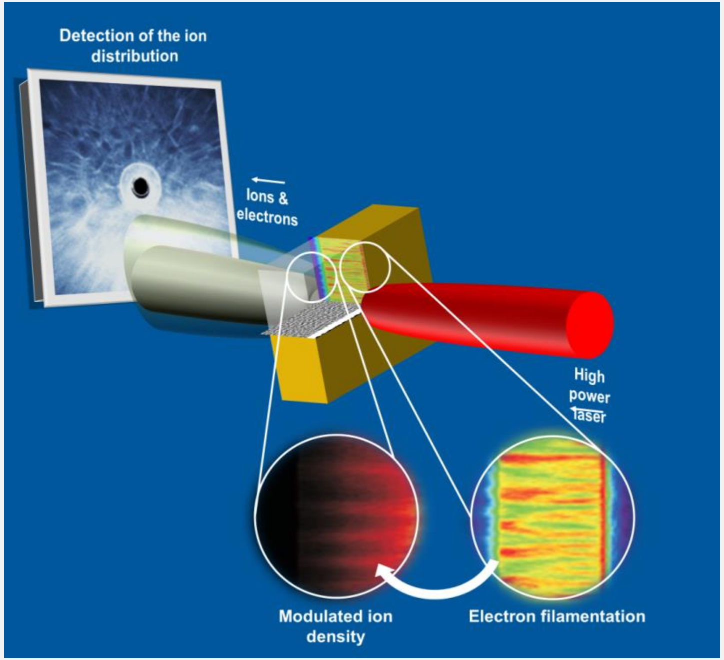
Agenda

- Example experiments – Kluge, Metzkes
- Generic science objectives/target types – numbers needed
- Challenges to production in large number – new requirements, new techniques?
- What new fabrication capability is needed for full operation?
- Do we need (a few) common target handling systems?
- How should targets be provided?

Prototypical experiment:
Electron Transport in Laser-Driven Ion Acceleration

Josefine Metzkes (HZDR)



Metzkes *et al.*, NJP 16, 023008 (2014)

- Goal: proton pulses for medical applications
  - Issue: Plasma-instabilities lead to filamented proton beams

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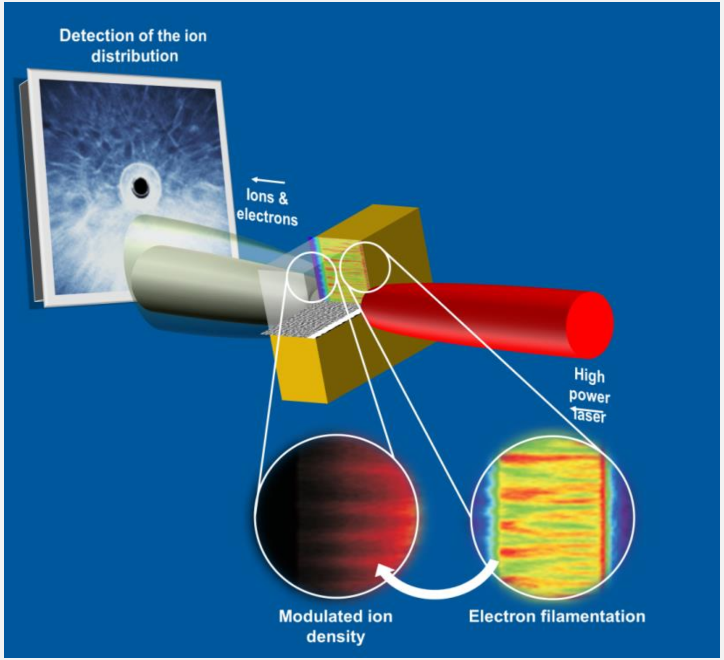

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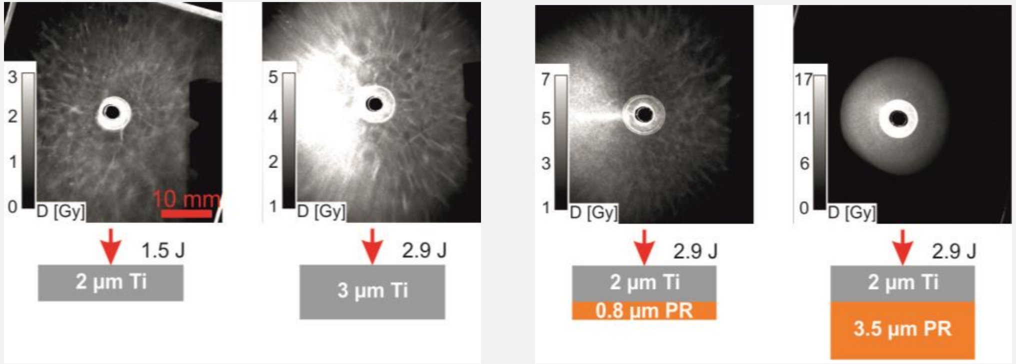
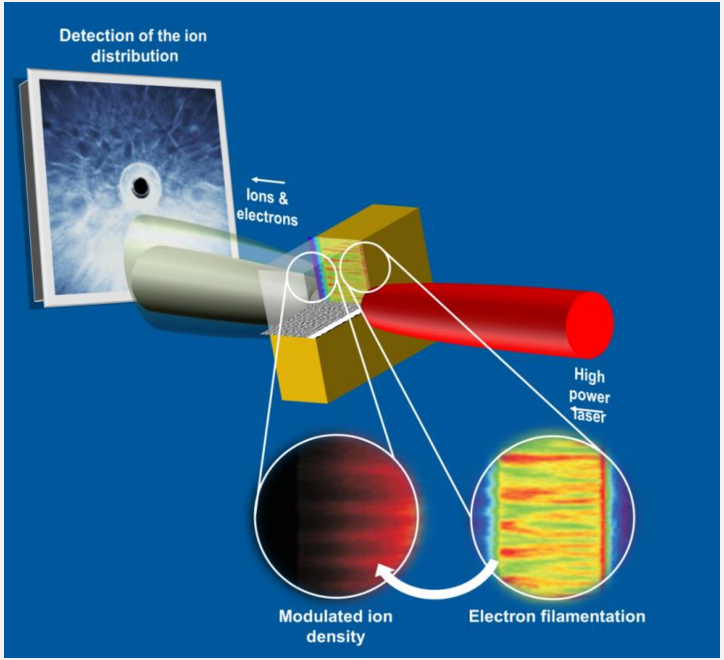


XFEL probes density modulations:

SAXS Small Angle Xray Scattering
- **electron – electron correlations**
- **plasma oscillations, filaments, hole boring**



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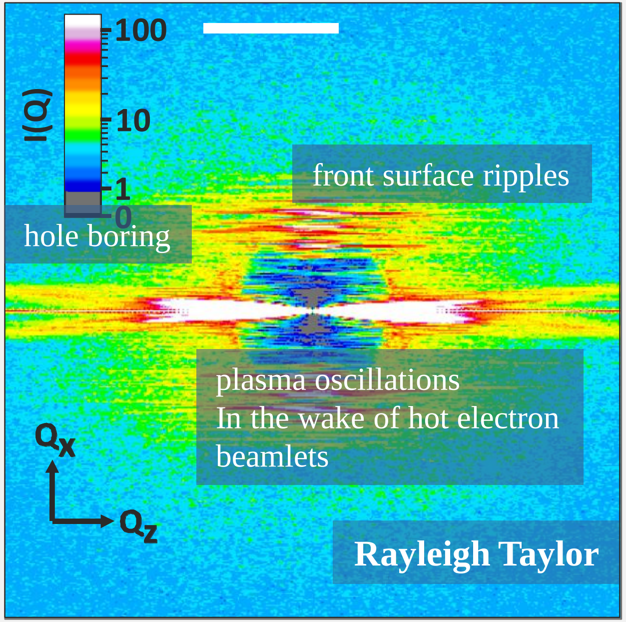
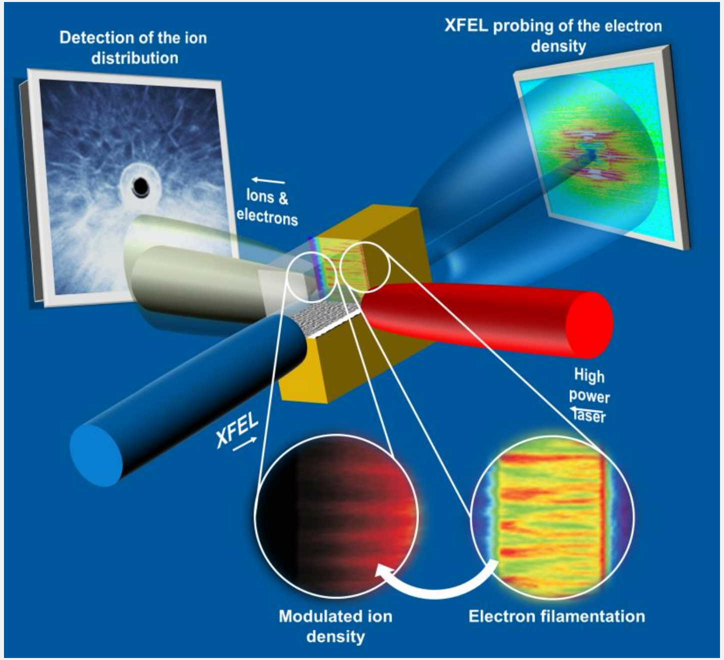


Param.: a_0=10, n=100 n_c, Z/A=1/2, no preplasma
XFEL 8 keV, 10^{10} phot., focused to 5x5 μm

Study using gratings to seed instabilities



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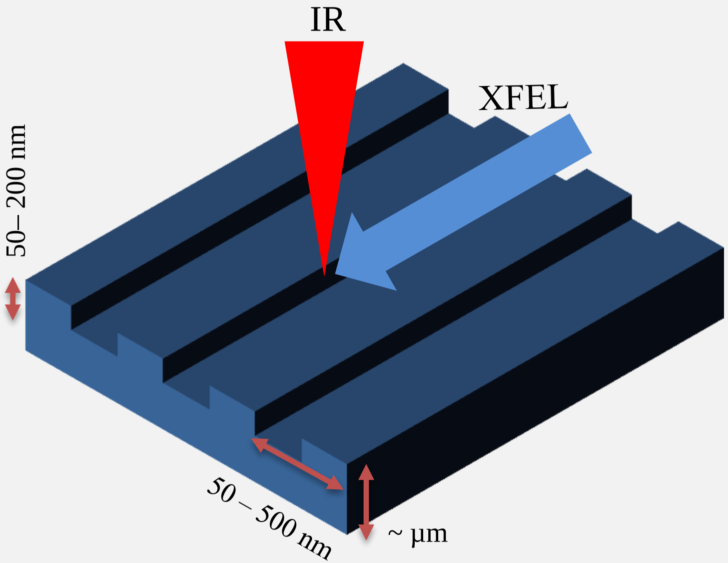
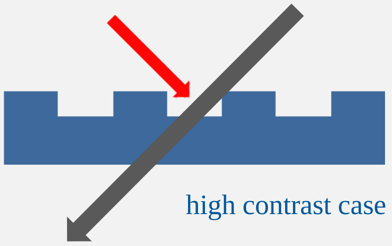
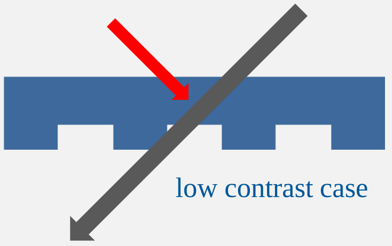


Experimental realization options:

SAXS

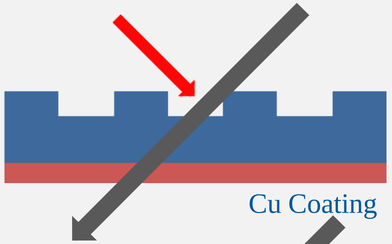
- scattering from cold target
- scattering vanishes in laser interaction
- hole boring

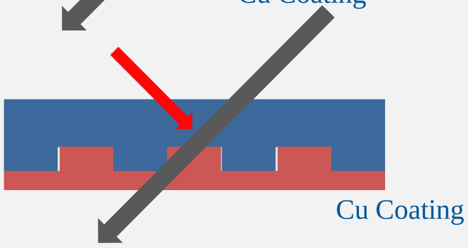




Resonant SAXS

- resonant SAXS → see grating in Cu in resonance
- buried grating structure → vanishes only during main pulse interaction





Summary – IR-XFEL pump probe experiments

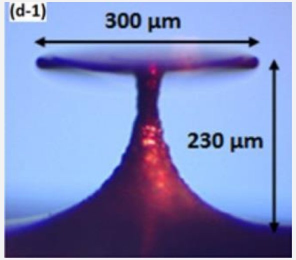
1) Repetition rate
- ~ 100 of targets needed
- scan of target parameters: grating size/depth, coating
- precise alignment needed → repetition rate reduced to ~ 1 shot/min

2) Target needs
- targets need precise geometric properties
- target delivery on the scale of a few months
- issue: protection of targets during shots on neighboring targets → all targets will sit on membranes on the same wafer

3) Target production
- electron beam lithography
- biggest issue: preparation time – qualification of the preparation „recipes“

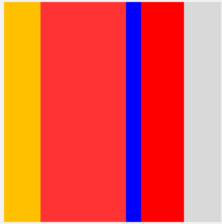
4) Target characterization
- grating sizes, surface roughness, periodicity over the target surface

Examples of science objectives:



Control coupling into plasma:

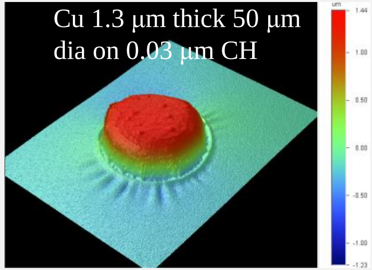
2½- or 3-D surface structure, prepulse control, tight focus



Measure electron spreading in dense plasma:

buried structure for guiding and/or detecting electrons, minimize refluxing

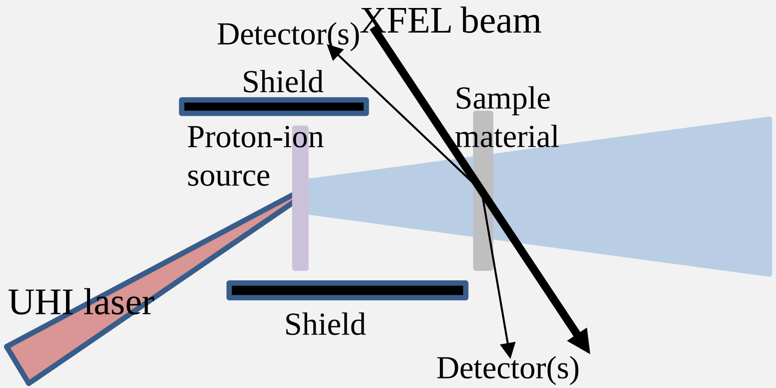
Create hot dense plasma:



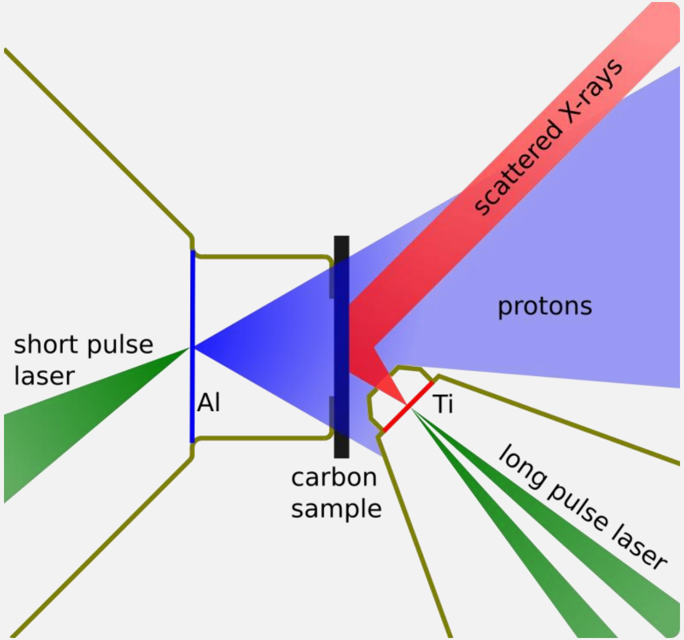
minimal mass and coupling to substrate, maximum stopping of incident energy.

Source & Diagnostic coupling adds superstructure:

Shielding:



Creation of multiple sources:



A. Otten et al. (unpublished, because very difficult)

Scope and goals for this panel

- What experiments/objectives require large numbers of shots – other reasons for high rep rate?
- What challenges do such targets present when produced and shot in large numbers?
- What are current fabrication capabilities and what is needed for full operation?
- Do we need (a few) common target handling systems?
- How should those capabilities be structured?

Experiments requiring large shot numbers:

Statistics

- Small effects in e.g. energy transfer requires large numbers to average over shot-to-shot variation.
- Might look for chaotic processes/instabilities in add anomalously large variance

Parameter scan

- Test experiment: Use larger parameter range to figure out optimal parameters
- Utilize inherent fluctuations from laser/XFEL shot to shot variations or target manufacture.
  - Actual values must be known & connected to each target to allow sorting of shot results.
- "Hidden" variations in laser and target can overwhelm deliberate parameter scan by increase in variance (e.g. target roughness, grain structure at laser focal spot).

Strategy

- Mix well-tested and new experiment types (e.g. low- and high-risk goals) – allows collecting preliminary data for detailed proposal (this is common in all campaigns)
- View of target fab: Targetry has be confirmed to give results even before an experiment at a large facility is scheduled

Challenges fielding large target numbers:

Parameter scans will be required in some campaigns

- Deliberate scan, by mask design → but not true for all targets – can increase effort
- Inherent parameter scan from imperfect processes → need to be characterized

Characterization effort depends on production variation

- Random – e.g deposition typically 5-10% endpoint uncertainty
  - Only decrease if each target characterized (perhaps too time consuming?)
- Systematic – e.g. deterministic variation over wafer
  - Process can be characterized
  - Characterize fewer targets to reduce uncertainty
  - Impossible for short lead times (e.g. LCLS schedule)

Individual parameters connected to each shot result

Target planning is vital

- Start before people get approvals for their experiments – even before writing proposal
- Target fab has to be part of the experiment, making sure that all physics aspects are sufficiently considered in the design → early involvement is crucial!!!

Fabrication techniques for large numbers of targets:

Problems with multiple target designs?

- No clear answer – depends on details of previous similar designs
- Limited possibilities with standard designs – experiments always tread new ground.

Flexibility of Robotic assembly procedures for associated superstructure?

- Reprogramming robotic assemblies gets easier with experience
    - Increasing designs in assembly program library
    - Could be a few weeks effort to accommodate new design.
    - Adding vision feedback to recognize target hence minimize setup details.
    - It is already cost-effective – precision, gentle assembly, no coffee breaks

Early involvement of PIs and target fab minimizes effort & ensures correct target properties are ensured

Handling technique(s) for large target numbers:

One wafer OK for lower energy shots

- For higher energy, fewer targets fit on one wafer current holder scheme would run out of targets in minutes to hour
- 10 Hz operation of experiments not to be expected soon, so not of immediate concern.

Target belt for alternate handling at high energy

→ see poster by N. Alexander/GA

When will real 3D targets be needed? (e.g. including superstructure on mm scale: shields etc.)

Fabrication capability structure:

Need to set up guidelines:

- target costs → How expensive can a target be for a campaign?
- time frame → 6 month such as at LCLS are not enough → particularly at open-access user facilities
- exploratory vs. statistics experiments → Which type of experiment does the facility serve?

Close collaboration between target fab and experimenters necessary for good results

- Start discussion with target fab already in the proposal phase
- Don't charge for collaboration

→ 2 target consultants at XFEL (and/or need money to allow free energy for target fab consultations)

- Consider target fab effort in evaluating proposal
- Consider target fab effort in determining schedule
- issue with consulting: often discrepancy between what can in principle be done vs. what can be done by a certain lab vs. what could be done with additional investment of time/money
- tentative schedule: shot-on-demand in 2018 → exploratory phase

Major Considerations

- contact between PIs and target fab → early (even before proposal) and close
- MEMS technology, robotic assembly seems to be the way to go for target fab
- **Point to develop further: communication!!!**