High Repetition-Rate Challenges Panel
Wed Morning Summary Session

Neil Alexander	– General Atomics	Jean-Paul Perin	– CEA
Mihail Cernaianu	– ELI-NP	Joachim Schulz	– XFEL
Julien Fuchs	– Ecole Polytechnique	Douglass Schumacher	– Ohio State (Chair)
Keiji Nagai	– TITECH	Martin Tolley	– STFC/Scitech
Alexander Pelka	– HZDR		

EUCALL Satellite Workshop

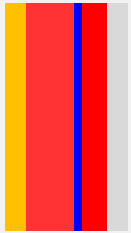
29-31 August 2016

Helmholtz-Zentrum Dresden-Rossendorf

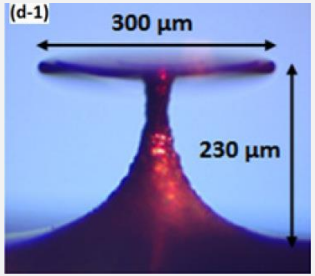
Goal of this panel

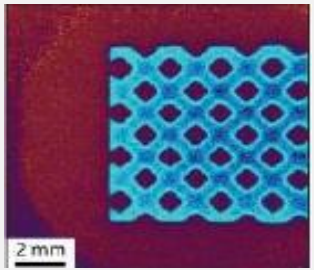
Focus on challenges that are common to a broad range of experiments, target types.

Foils, layered

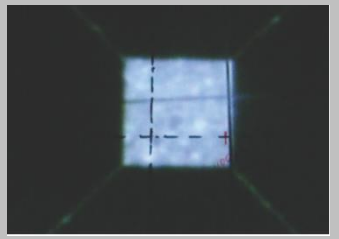


Structured (nano, micro, macro)

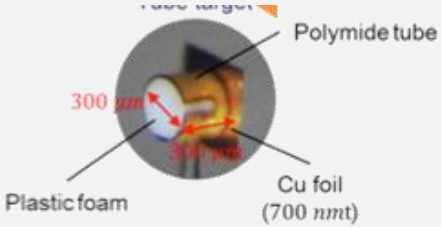




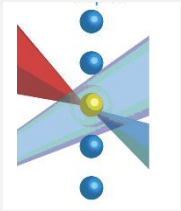
Freestanding, mass limited, …



Subcritical (foams, tailored plasma)

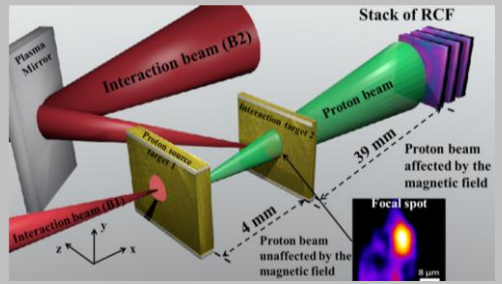


Liquid jets, drops, films



Gas jets, cells, capillaries

Multiple targets and beams



Challenges

- **Production**
- **Characterization**
- **Installation and Alignment**
- **Collateral effects**
  - Damage of nearby targets from shock (“nearby” depends on pulse, target types)
  - Debris - vaporization and shrapnel coating of nearby targets and optics
  - Debris - vaporization affecting laser propagation
  - Plasma damage of target holder frame
  - Target back reflections and scatter
  - EMP
  - Nuclear activation

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Organization of discussion

1) Challenges

Discussed the general kinds of challenges facing high repetition-rate targetry.
Note: Different experiments may define "high" differently.

2) What are we missing?

Comments or questions from the audience?
Are there challenges that may not be broadly recognized or that are not being currently addressed.
Something specific to your facility that might become common?

3) Can we prioritize?

Discussion about relative seriousness of challenges.
Current or anticipated progress towards solutions will be a factor as will actual desired repetition rate.

4) **A targetry network.**

Determine interest in a targetry network or collaborative framework. Increasing access?

Many facilities (more beams than listed)

European XFEL

HED Instrument

- DiPOLE

2-20 ns, 100 J, λ=500 nm, 1-10 Hz

- 100 TW-class CPA Ti:Sapphire

30-50 fs, 3-5 J, λ=500 nm, 10 Hz

ESRF

ID 24

4-10 ns
100-200 J
λ=1064 nm
1 shot/min

CileX Apollon

- 15 fs
- 150 J, 10 PW
- 1 shot/minute

eli beamlines

2 X 1 PW	**10 PW**
15 fs / 30 fs	150 fs – 1.5 ns
15 J / 30 J	150 J – 1.5 kJ
λ= nm	λ= nm
10 Hz	1 shot/min

eli Nuclear Physics

2 x 1 PW	**2 x 10 PW**
25 fs	15-30 fs
30 J	200 J
λ=800 nm	λ=800 nm
1 Hz	1 shot/min

eli attosecond

>2 PW
<20 fs
40 J
↙ = 800 nm
5 Hz

Results of the discussion

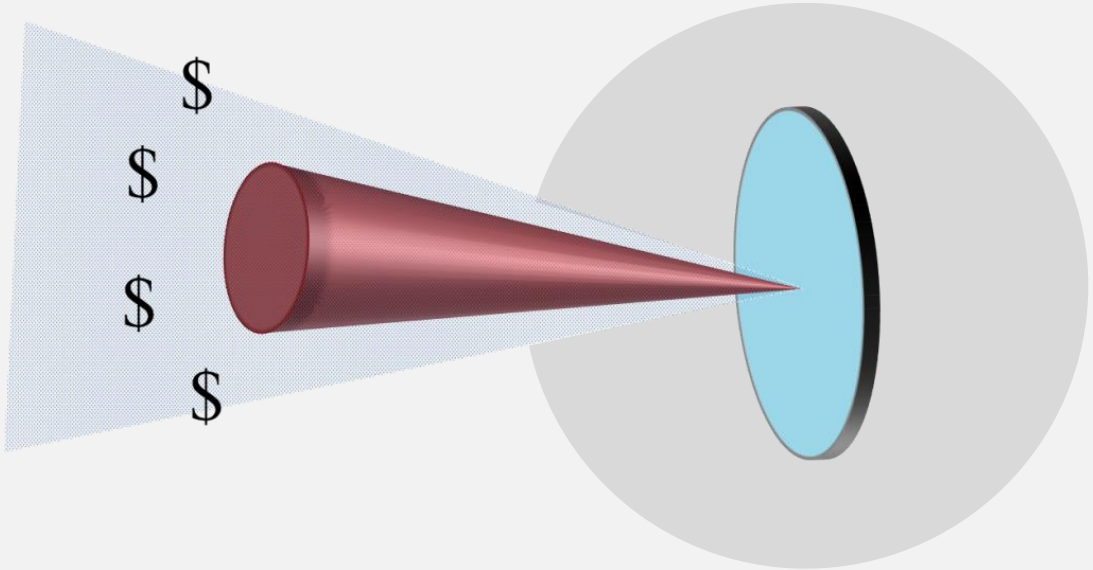
- Although the challenges are severe, there was no sense that they are insurmountable
- Many partial solutions are already well established or are being developed by individual research groups, facilities, target fabrication companies.
- **This progress is not uniformly known by all participants, however.**

- **There is no one solution to the collateral effects problems,**
- The nature of the problems changes too much depending on laser and target (short pulse vs. long pulse, reduced mass isolated target vs. large structured target, etc.)…
- … and experimental configuration (access required for many diagnostics or beams).
- **A took kit of solutions is required that can be deployed as needed with corresponding compromises on repetition rate.**

Results of the discussion

- **We have not by any means completed the process of understanding what the problems are.**
- Examples: Debris, shock damage to nearby targets
- The mix of vaporization and shrapnel changes with pulse parameters.
- 500 TW can be achieved with a mix of parameters that can change the debris or shock.
- **All of the collateral effects must be directly measured over a broad phase space.**
- **This effort has been underway for some time now, but access to a range of laser facilities is required plus grants of facility time even if a Nature paper will not be forthcoming.**

Case study: laser axis debris mitigation



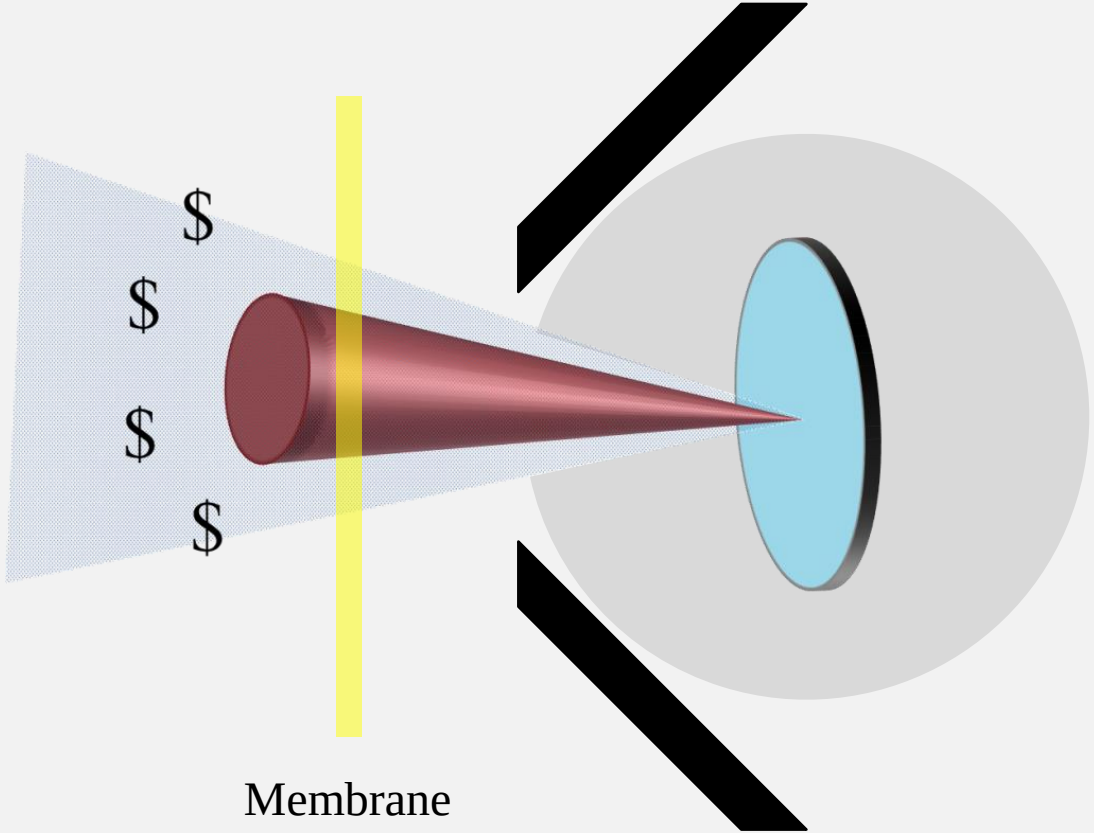
Case study: laser axis debris mitigation

Membrane cost and time to replace requires its survival for as long as possible.

ELI-NP: 550 mm
Apollon: 400 mm

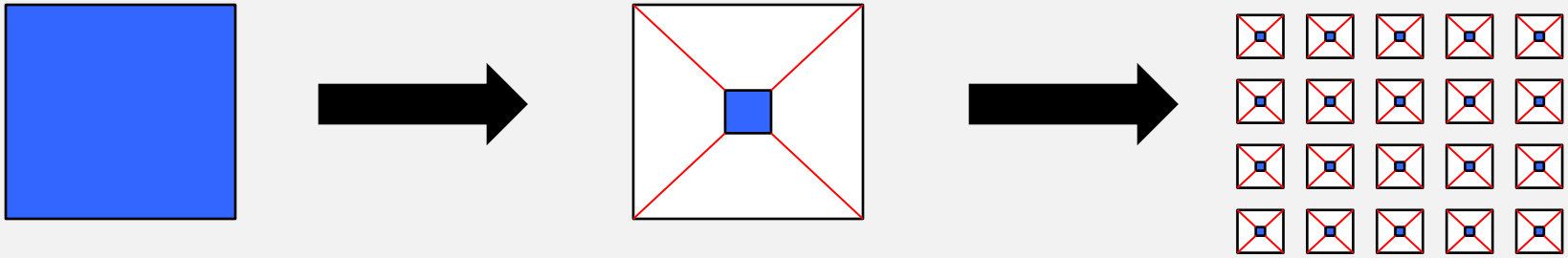
Does not protect against shrapnel.

Must reduce the problem to a level the membrane can handle: tool kit



Case study: laser axis debris mitigation

The best way to mitigate debris is not to make it: reduced mass



Excess material

Technology established, but still expensive

Raster systems – significant development in this currently

Development: cost reduction, research into target oscillation, fragility of very thin targets, …

Some experiments cannot reduce size as much as others (eg. avoiding shock reflections)

Corollary: target design must be better integrated into expert consultation, review process

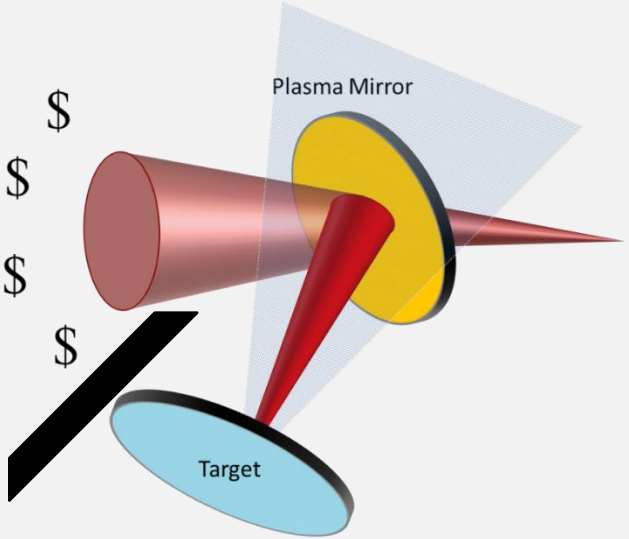
Corollary: Integration in the process

- The proposal review process / facility implementation process might need to include specifying the fraction of the maximum available rep-rate that can be permitted depending on how well **mitigation strategies** are implemented.
- Target experts at fabrication facilities are often consulted during the proposal review process **after** the proposal has been submitted.
- Interaction with experts and iterated proposal development **before** proposal submission will often be needed to use full repetition rate.
- The scale of the number of facilities and (hoped for) number of users means this will place a large burden on target fabrication facilities and companies in both cost and time.
- This should be anticipated and addressed now.

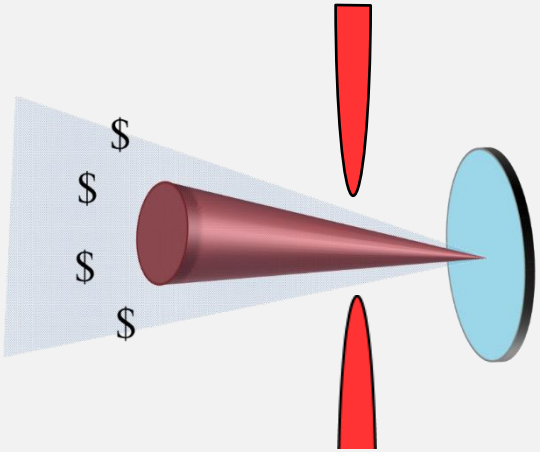
Now, suppose we have reduced the mass as much as possible.
What mitigation strategies are available to maximize survival of the membrane?

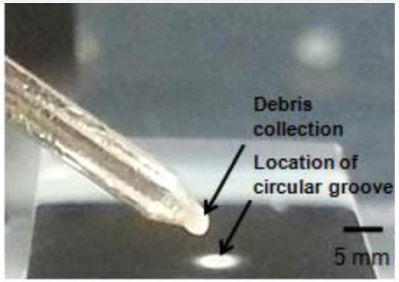
Case study: laser axis debris mitigation

Assembling a tool kit: new ideas

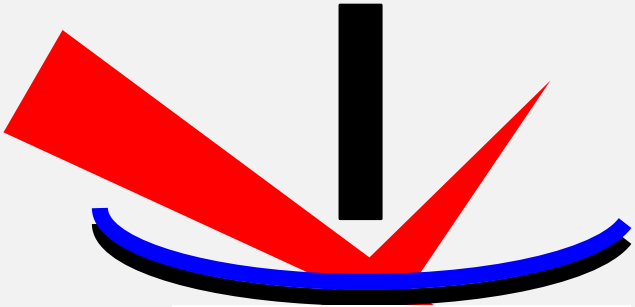


Dynamically formed plasma mirrors





E-field guiding



Reformable mirrors based on Hg or Ga

Park and Farson, Jour. Appl. Phys. (2015)

Rich discussion: more ideas and lessons

- Foregoing discussion just a sample of full panel discussion: debris and shrapnel are not the same. Research to discover mix for various target types and adjustment to mitigation strategies.
- On-line (on-shot) target diagnostics will be important
  - Tracking of target position (μm resolution) via laser tracking or other approach
  - Microscopic imaging of target surface to detect debris, cracking
- Automation will be increasingly needed in many phases including on-line characterization. (Work on automation is well along by target fab companies.)
- For joint x-ray/laser experiments: will “laser” solutions continue to work? EMP?
- Expect to be surprised: back-reflections.
- Existing solutions at low rep-rate are stressed at high rep-rate: EMP mitigation by shutting down all motors, certain diagnostics, etc. Complacency regarding current solutions must be avoided.