Demonstrating a Target Supply for Inertial Fusion Energy

Presented by Ron Petzoldt for Dan Goodin at the ANS 16th Topical Meeting on the Technology of Fusion Energy

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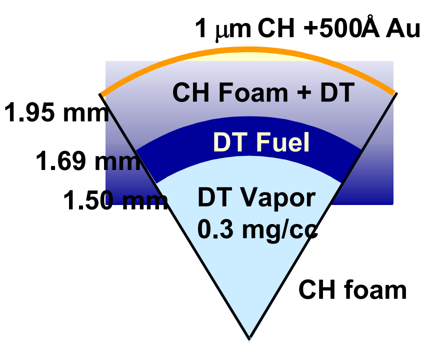
The target supply is an essential component of IFE

- *Target supply* means fabrication <u>plus</u> delivery to chamber & tracking
- Three main IFE concepts
  - Strong synergism in IFE target technology development
  - Some key differences that lead to specific technologies

Laser Fusion

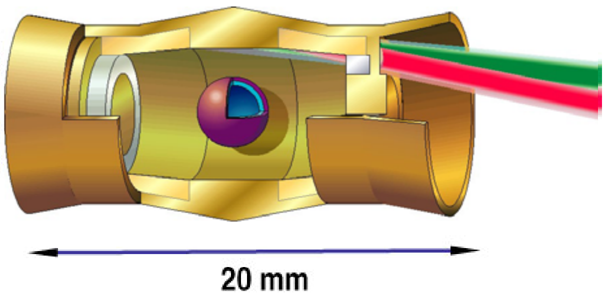
- Direct drive
- Foam capsule
- Dry wall chamber



NRL High Gain Target
(John Sethian)

Heavy Ion Fusion

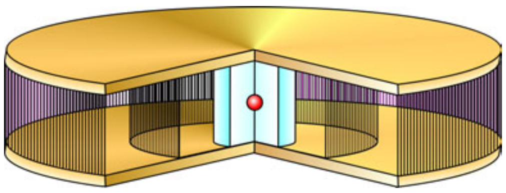
- Indirect drive
- Special materials
- Advanced manufacturing methods



LLNL Distributed Radiator
(Debbie Callahan, Wayne Meier)

Z-Pinch IFE (ZFE)

- Indirect drive
- Emerging requirement's & concepts



SNL Dynamic Hohlraum
(Craig Olson, Gary Rochau)

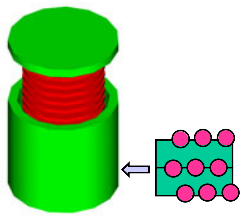
Highlight recent achievements in target technology…….

GENERAL ATOMICS

Target scenarios have many common elements

Fabricate Capsules → **DT Fuel Fill** → **DT Fuel Layer** → **Load capsule**

Microencapsulation, stamping and/or sputter coating (Be)

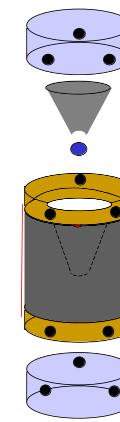


Pressure cell

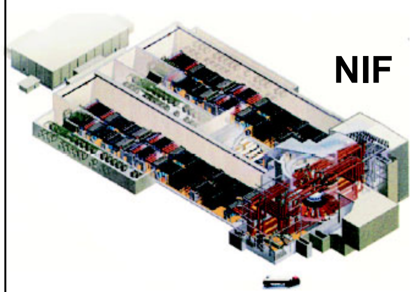
Cryogenic fluidized bed (CH)

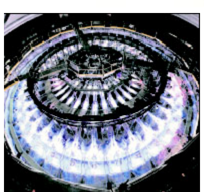
Fabricate hohlraum or sabot → **Load capsule**

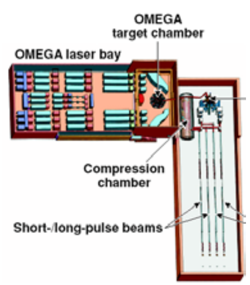
Advanced manufacturing methods



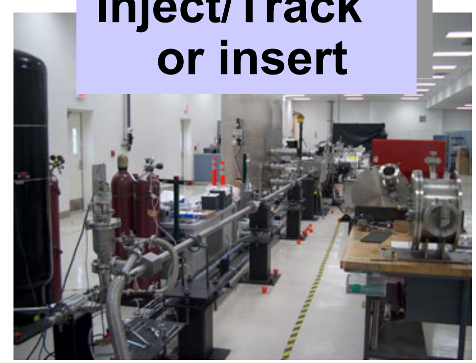
Existing and major new ICF facilities







Inject/Track or insert



Injector demo experiment at GA

Synergism with ICF programs and decades of R&D

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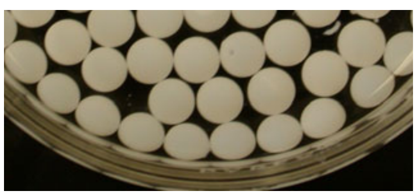
Top level target technology requirements & status

- **Basic requirements**
  - **supply about 500,000 targets per day for a 1000 MW(e) laser fusion or HIF power plant (~88,000 for ZFE at 0.1 Hz, 10 chambers)**
  - **do it cheaply, each laser fusion/HIF target has an energy value of about $3.00 ($22.50 for ZFE)**

Laser Fusion

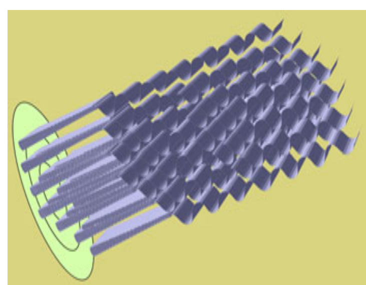
- **Most effort (HAPL)**
- **Fab well underway**
- **Injection is issue**



4 mm 200 μm foam, CH overcoat (Photo: Schroen, Streit)

Heavy Ion Fusion

- **LCVD experiments**
- **Injection is "easier"**
- **Fab & cost is issue**

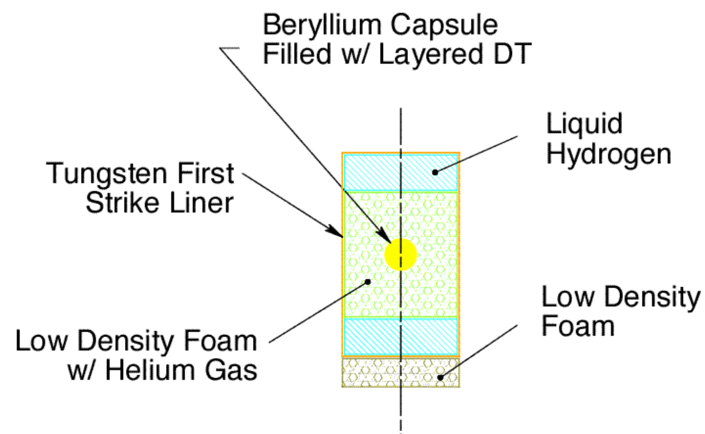


Variable Spacing & Fiber Diameter→Variable Density Metal Foams

J. Maxwell

Z-Pinch IFE (ZFE)

- **Concepts developed**
- **Cost reduction by advanced methods**



C. Gibson, R. Gallix

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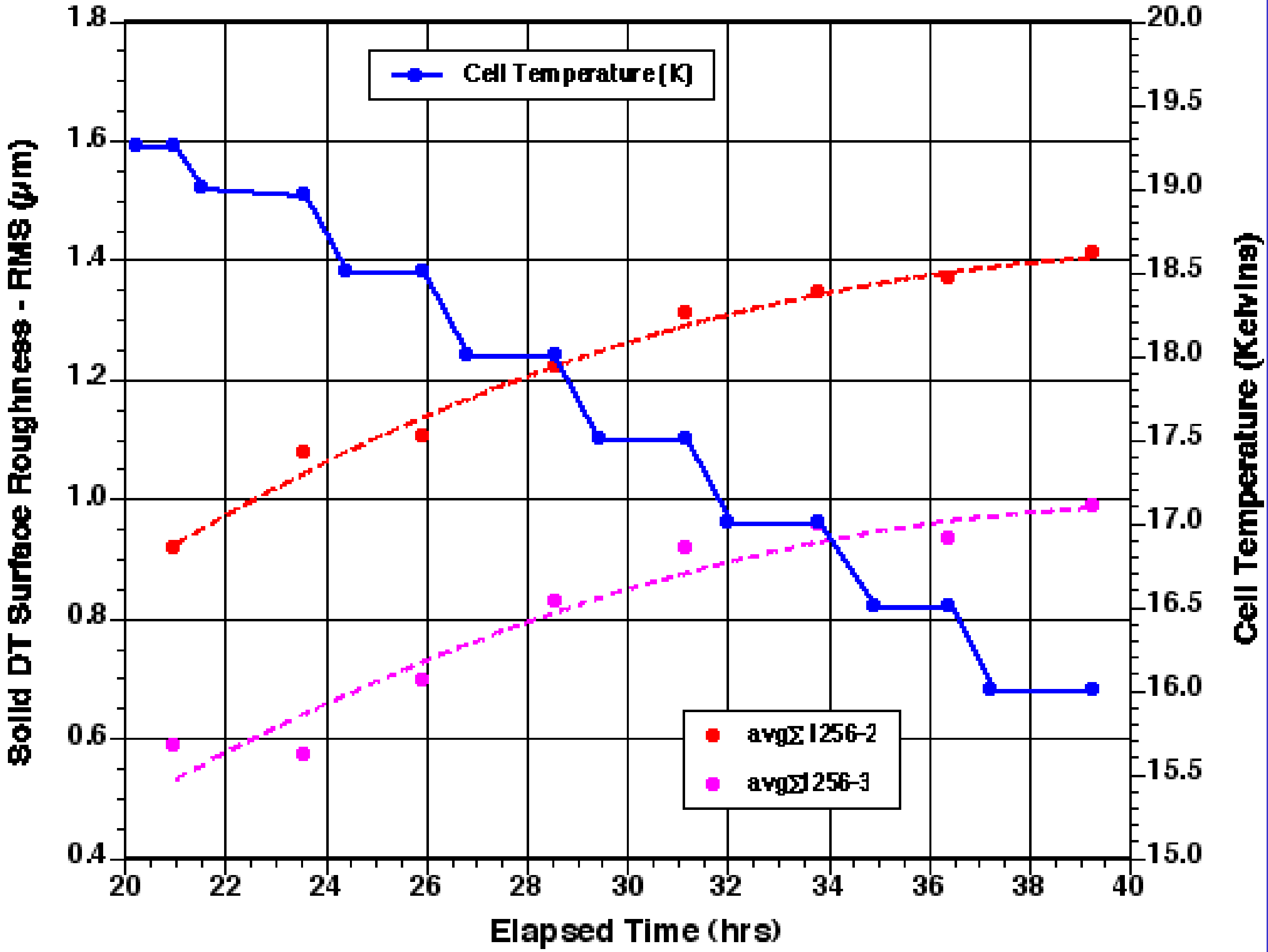
Recent advances in IFE target technology

• **Direct drive target survival during injection**



J. K. Hoffer, D. A. Geller, P. S. Ebey, J. D. Sheliak

- **Foam underlay allows DT to be cooled to ~16K & remain "smooth"**
- **Colder DT is stronger & has more margin for heatup during injection**

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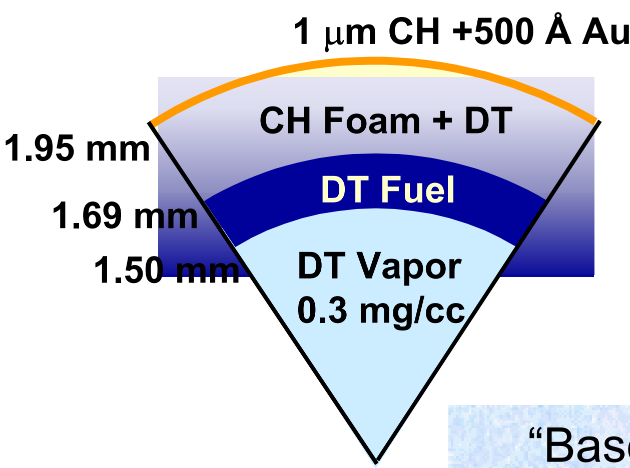
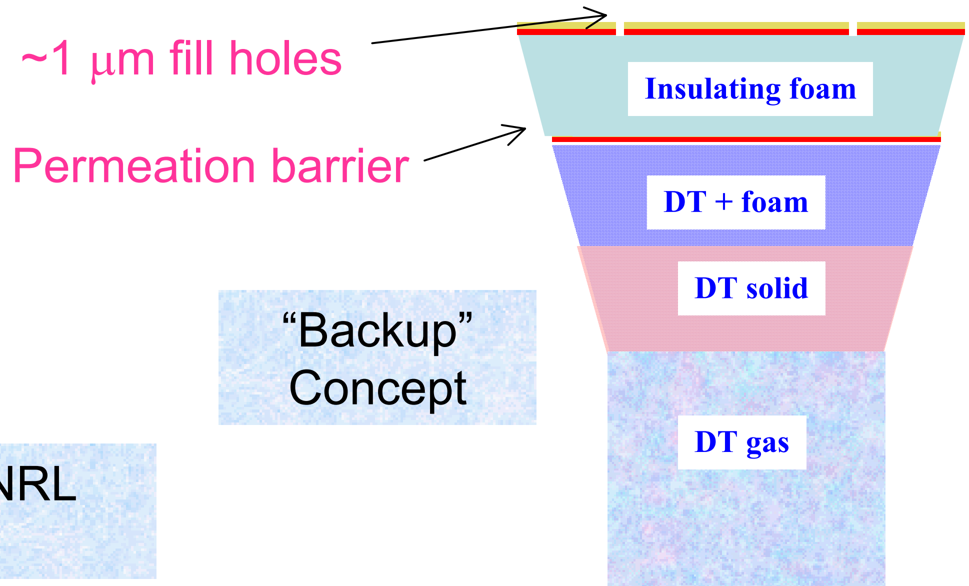
New foam-insulated target concept opens chamber “design window”

- **The baseline target is preferred for its simplicity**
- **A “thermally insulated” target design could increase the thermal robustness**

1. **Baseline target (18K): <0.68 W/cm² (970°C and no gas)**
2. **Foam-insulated: <3.7 W/cm² (970°C and 12.5 mtorr @ 4000K)**
3. **Foam-insulated (16K): <9.3 W/cm² (970°C and 40 mtorr @ 4000K)**



“Baseline” NRL Target



“Backup” Concept

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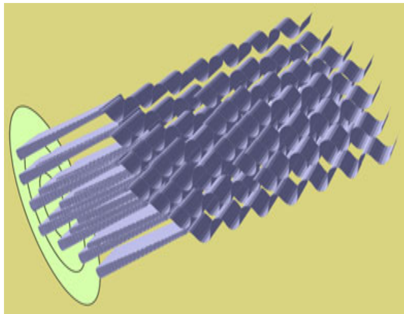
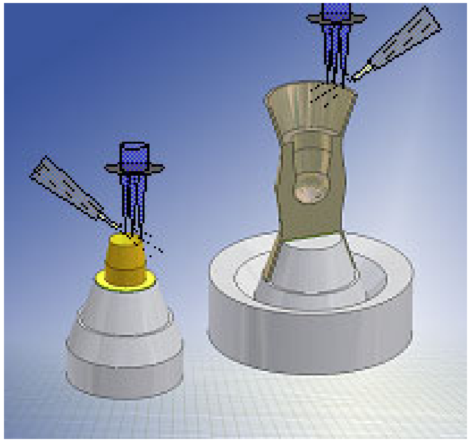
Laser-assisted chemical vapor deposition system has demonstrated fiber-growth in arrays*

- **Low-density, high-Z only materials needed; handling concern**
- **New concept - design for manufacture:**
  - Builds from "inside out"
  - Avoids precision machining steps
  - Avoids handling low-density foam



"Micro-engineered" materials by LCVD



3D-LCVD hohlraum fabrication

Using LCVD, cost per injected target is estimated at ~40.8¢ each for 500,000 per day

*Accepted for publication in *Advanced Functional Materials*

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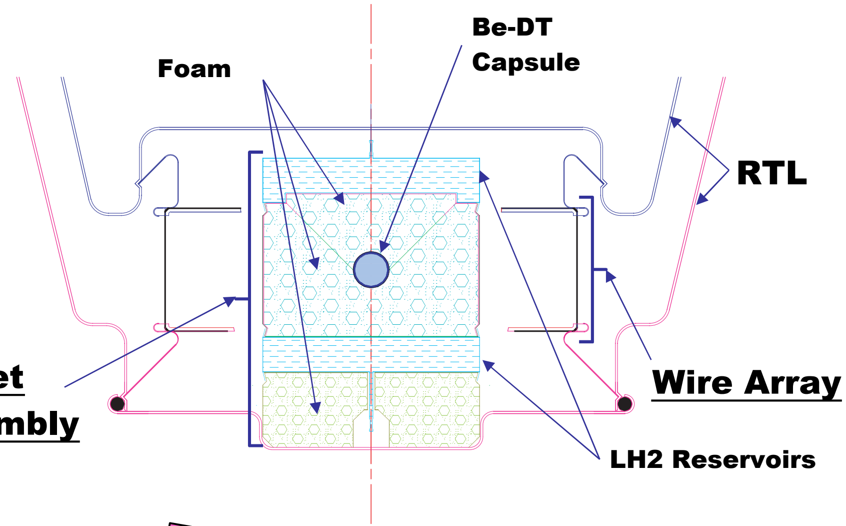
ZFE target conceptual design will allow cost comparison for all three concepts

- **Z-pinch "target load" has liquid hydrogen cooling buffers**
- **Allows temperature control during loading process**



IFE Target Cost Comparison

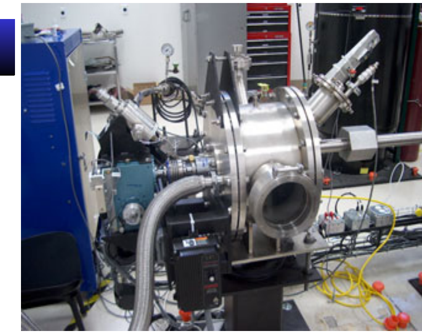
IFE Concept	Target Design	Target Yield (MJ)	Est'd Cost/target for 1000 MW(e)	% of E-value
Laser Fusion	Direct drive foam capsule	~400	$0.17	5.5
HIF	Indirect drive distributed radiator	~400	$0.41	13.6
ZFE	Dynamic hohlraum "target load"	~3000	~$3 *(unpublished)*	~13

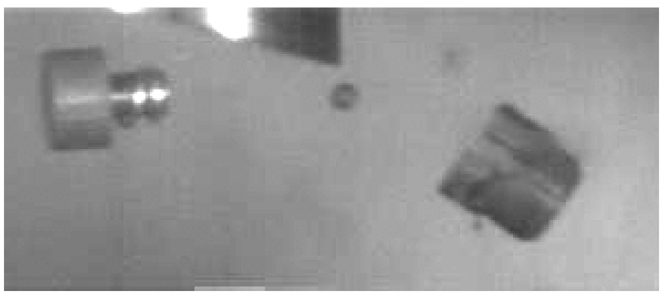
Assumptions:
- development programs done
- nth-of-a-kind plant
- does not include RTL

Full-length target injection & tracking experiment

- We have demonstrated:
  - Rep-rated operation (6 Hz)
  - Two-piece protective sabot separation
  - Injection velocity of 400 m/s
  - In-flight tracking at first detector station
  - Placement accuracy ± 22 mm

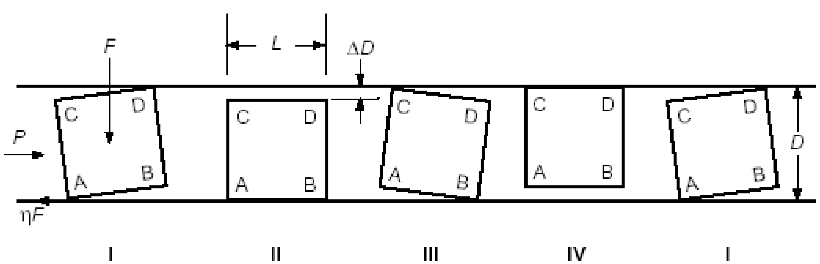
Revolver





In-flight tracking at 400 m/s

- Currently working on accuracy improvement
  - Vibration model predicts error from loose fitment in the barrel
  - Developing interference fit sabot



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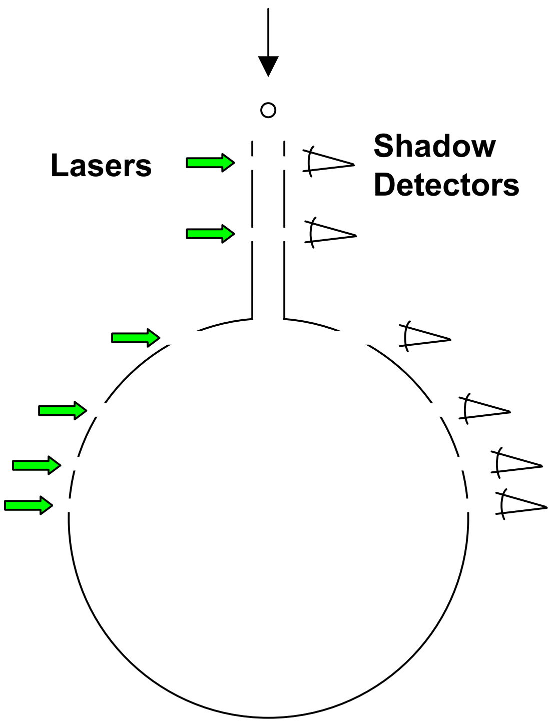
New dry wall chamber modeling shows a need for in-chamber tracking…. advanced concepts

Shot alignment to ± 20 μm
Last measurement at several cm from TCC



Poisson Spot at Centroid Detector

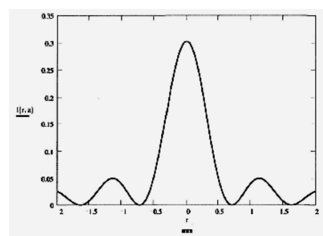
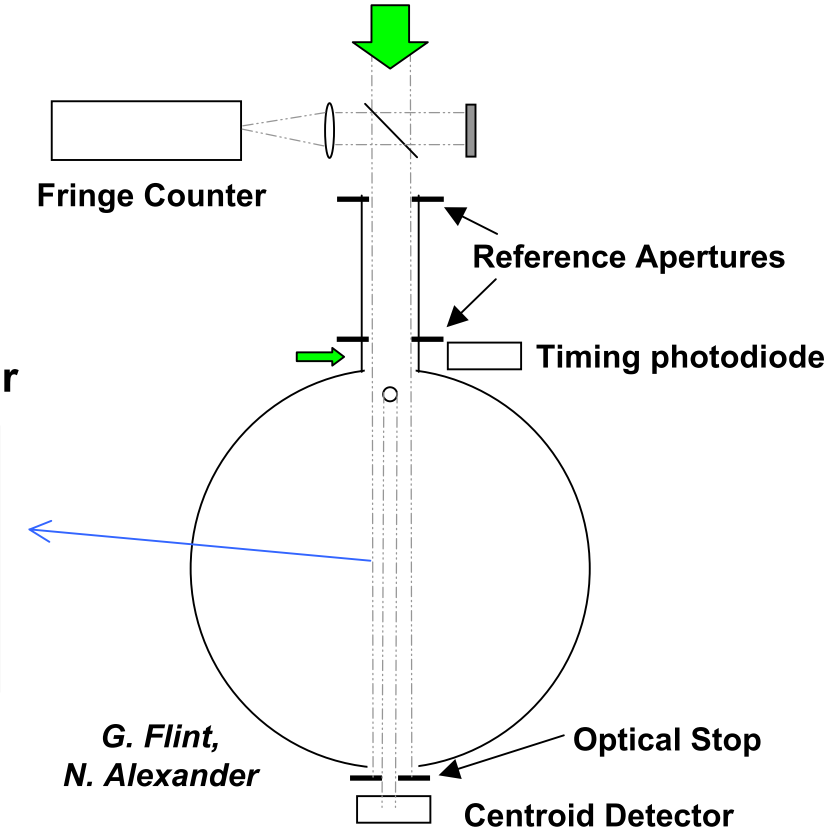


Figure 2. Poisson spot intensity distribution for capsule at chamber center



G. Flint, N. Alexander

<u>Discrete Snapshots</u>

- Extend current system to multiple views across chamber

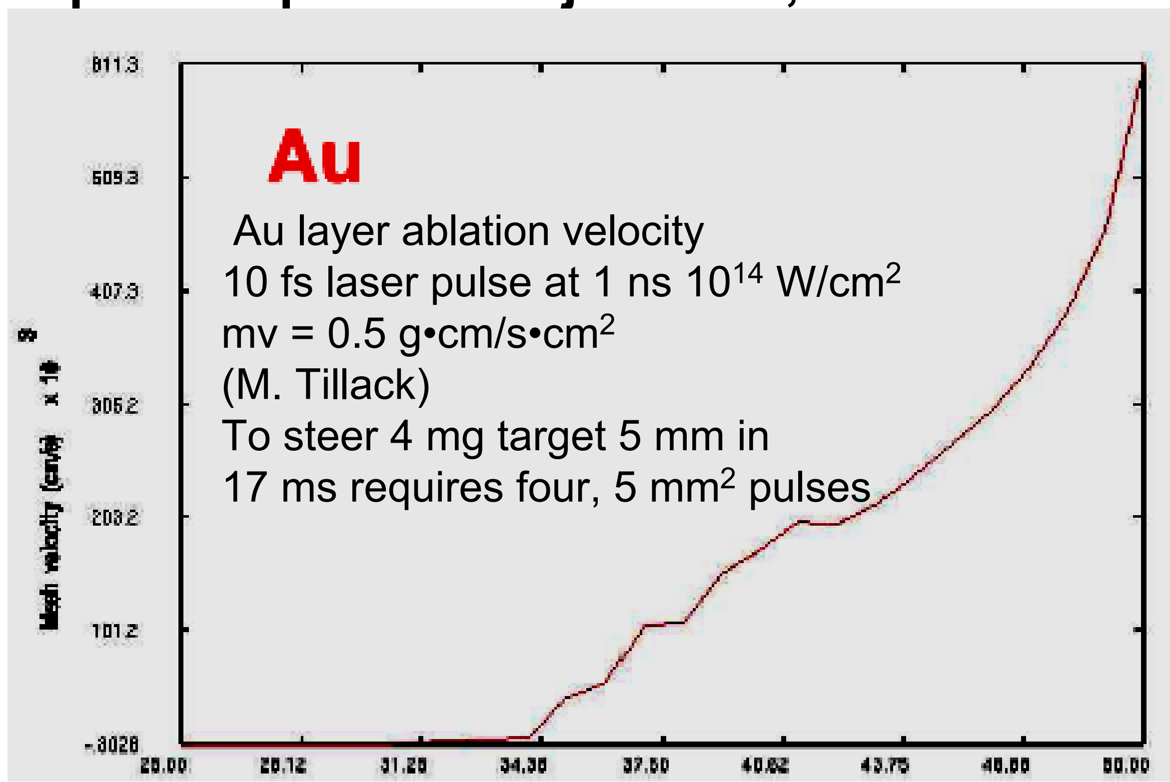
<u>Beam Rider</u>

- Axial position by fringe counting and timing reference
- Transverse position by centroid detection of Poisson Spot in shadow of capsule

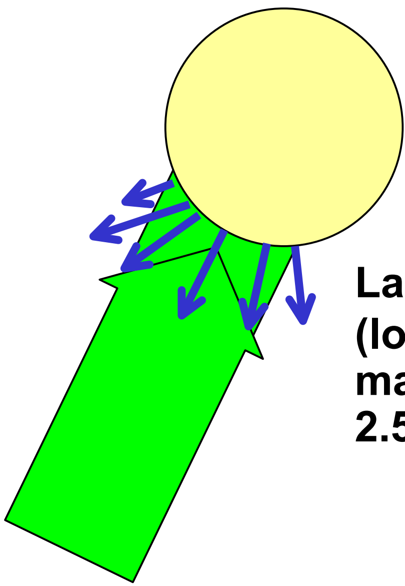
Physical Optics Corp. also evaluating interferometric method

Evaluating target steering to simplify laser fusion system

- Avoids alignment and steering of ~60 driver beams and optics
- Would vastly reduce mass that must be moved
- “Ultimate” system would be passive position adjustment, without active tracking



Potential Target Steering Concept



Laser ablation (low mode, low material removal 2.5 nm/pulse)

Driver beams only adjusted for “long-term” drift

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We have identified target supply scenarios for all three IFE concepts

- Laser fusion advances in recent years:
  - DVB foam capsules have been produced
  - Foam underlay allows “smoother” DT layer
  - Foam-insulated direct drive target for thermal robustness
  - Separable sabot tested for protection of direct drive target
  - Tracking systems online
  - Beginning to evaluate in-chamber tracking and target steering

- HIF and ZFE advances include:
  - Development of process scenarios that appear feasible
  - Development of LCVD method for hohlraum and component fabrication
  - Initial cost estimates reasonable percentage of E value

We are demonstrating a target supply for inertial fusion energy.

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