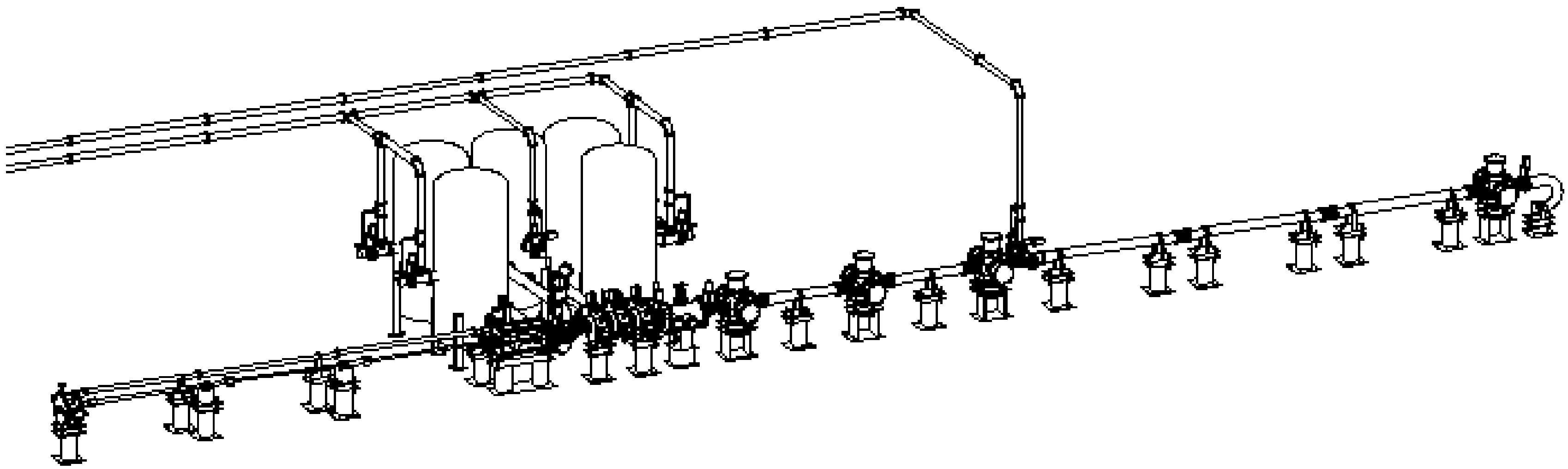
Status of Target Injector, In-Chamber Tracking, and Electromagnetic Injector



Ronald Petzoldt, Dan Goodin, Neil Alexander, Gottfried Besenbruch, Walt Egli, Leslie Evans, John Follin, Dane Fricker, Chuck Gibson, Mike Gouge, Michael Hollins, Kevin Jonestrask, and Dennis Lieurance

HAPL Project Review **Pleasanton, CA November 13, 2001**

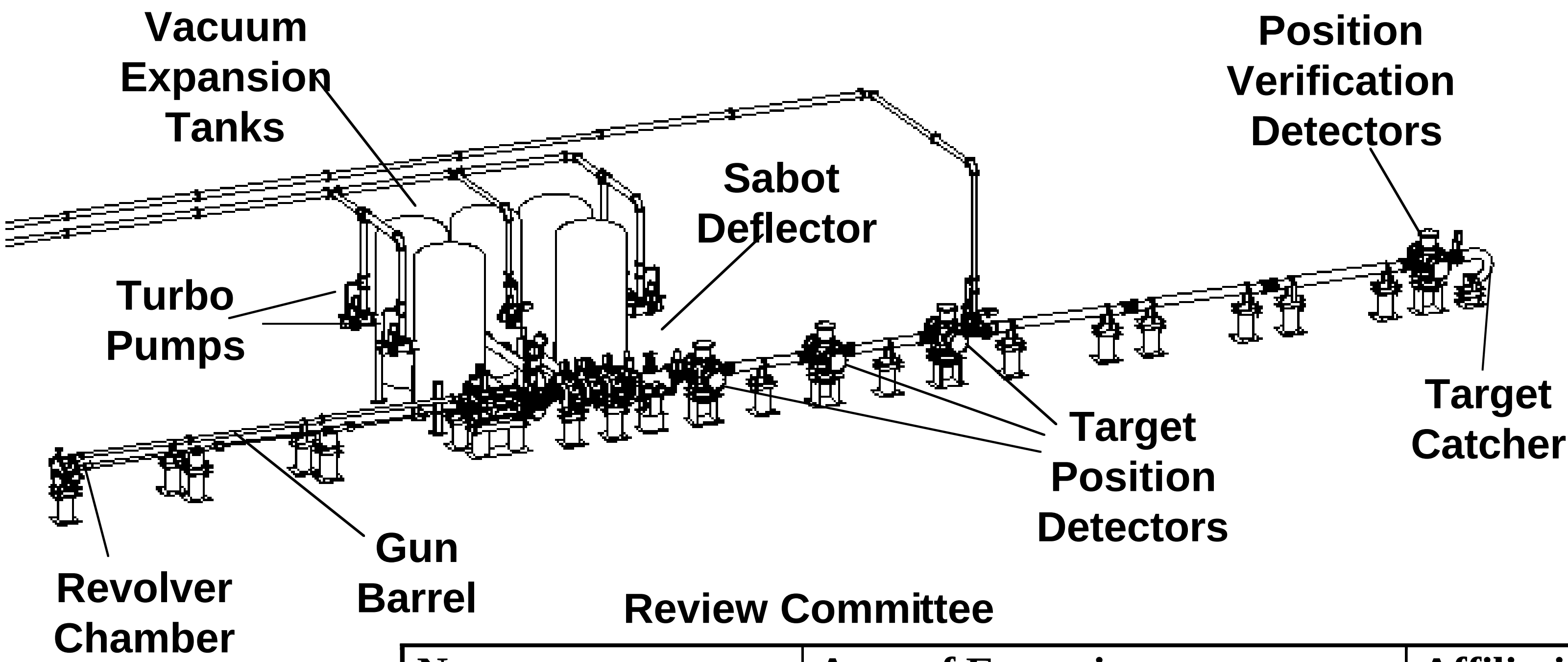
Overview/Summary

Status of injector
- **Design status**
- **Selected examples of mechanical design**
- **Schedule overview**

Analysis of tracking requirements based on chamber pressure
- **Coefficient of drag**
- **Target displacement**
- **In-chamber tracking likely required for chamber pressure > 10^{-4} Torr**
- **Methods of in-chamber tracking**

Electromagnetic injector is being modeled as a backup to the gas gun
- **Advantages for power plant use**

The Experimental Target Injection and Tracking System Final Design Review will be held at GA on 16 November



Review Committee

Name	Area of Expertise	Affiliation
Frederick Dahms	(Chairman)	Independent
Ted Torres	Computer and Control Systems	LANL/GA
Lance Lund	Mechanical Engineering	LLE Rochester
Rudi Klasen	Mechanical Engineering	GA
Pat Connors	Quality Assurance	GA

Final check of drawings and design documents prior to procuring equipment

Detailed design work has been accomplished

Document type		
Drawings		
PFD and P&ID		
Mechanical Assembly		
Weldment		
Control Block Diagram		
Electrical Schematic		
Miscelaneous		
Word Documents		
System Design Descriptions		
QAPD		
Technical Spe cifications		
Equipment/ instrument lists		
Miscelaneous docs		

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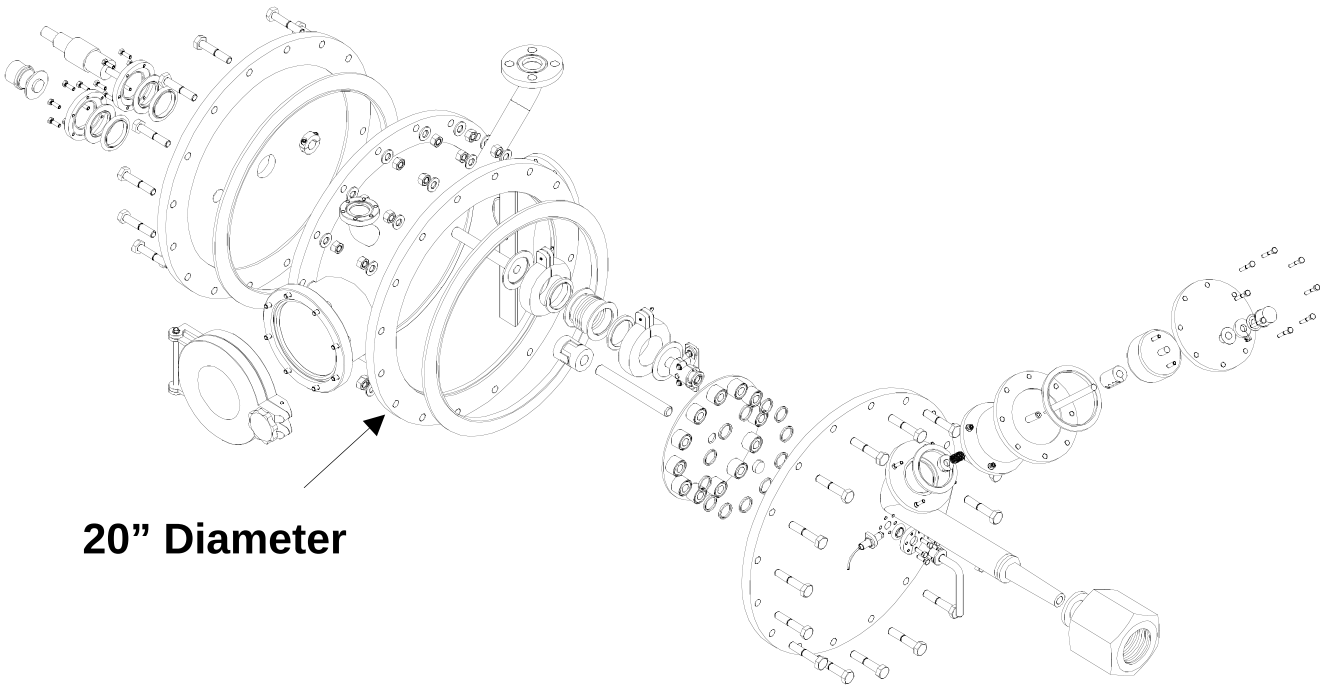
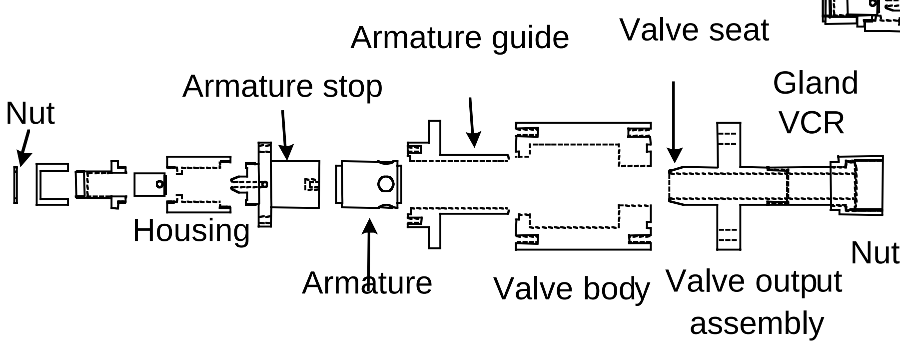
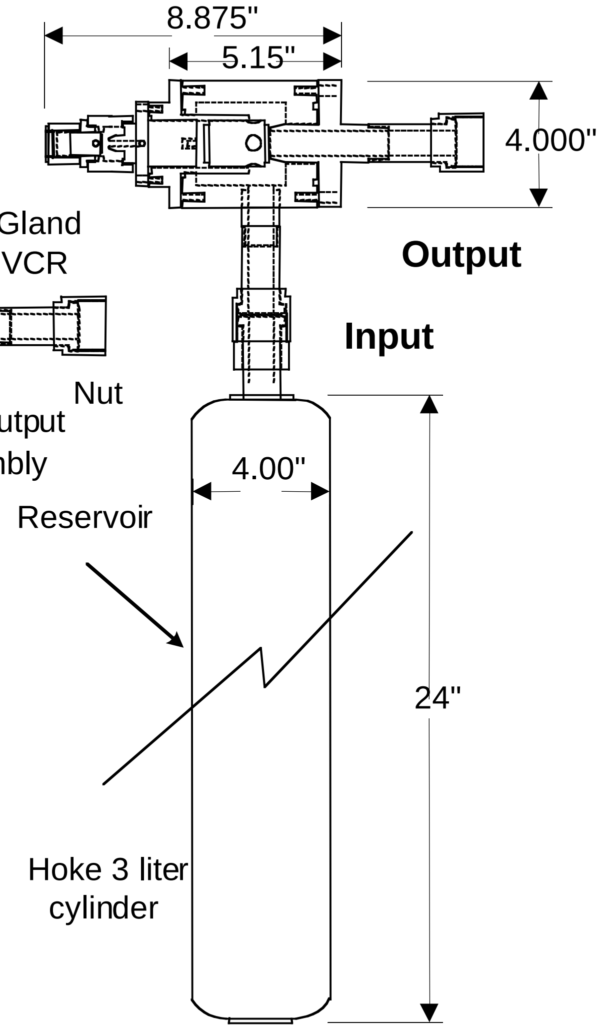
Design Example:
Exploded view of revolver chamber assembly



20” Diameter

Design Example:
Fast acting gas valve





IFE Fast Propellant Valve

C. R. Foust, ORNL

10/31/2001

<2 ms operation

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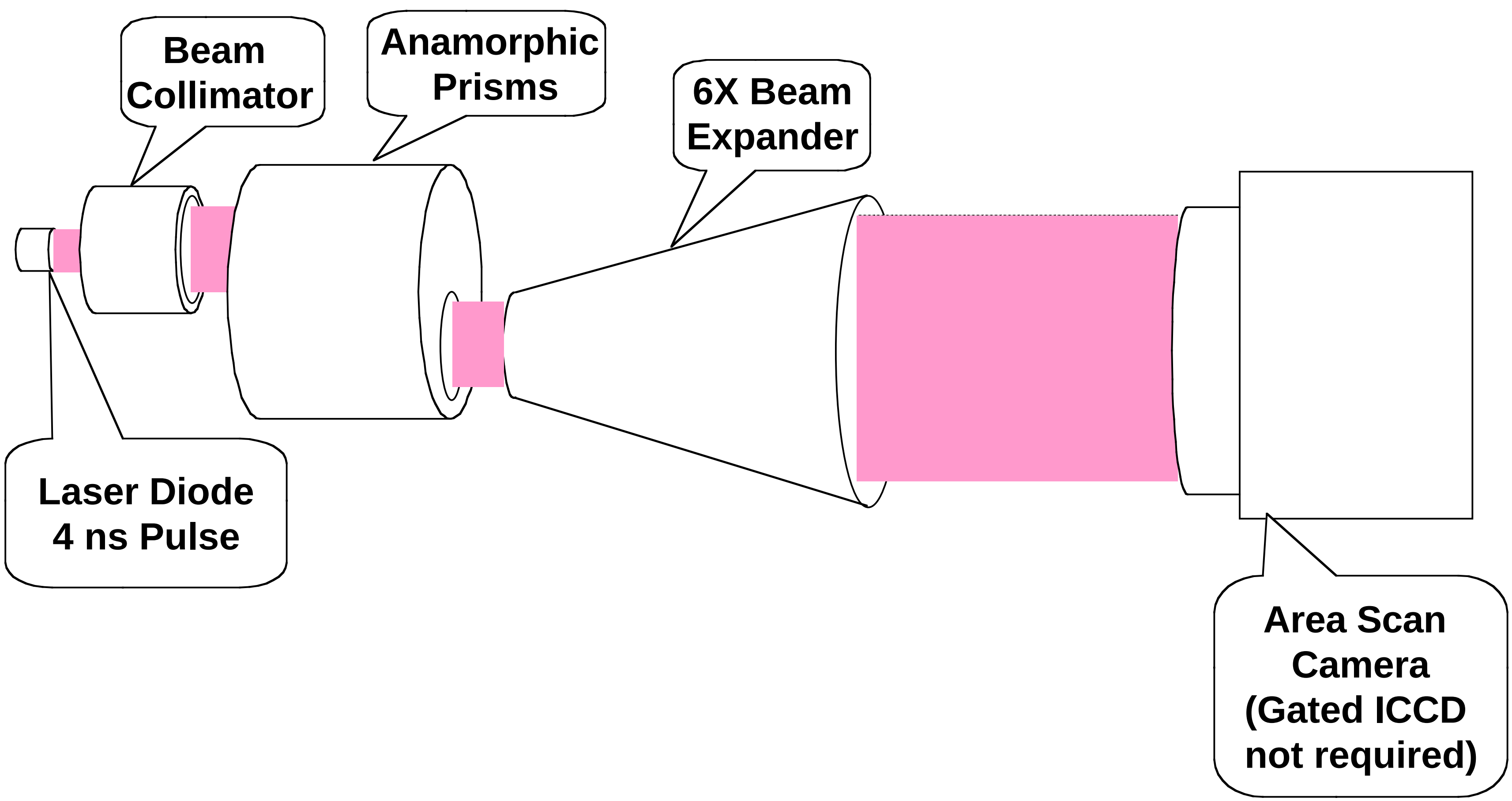
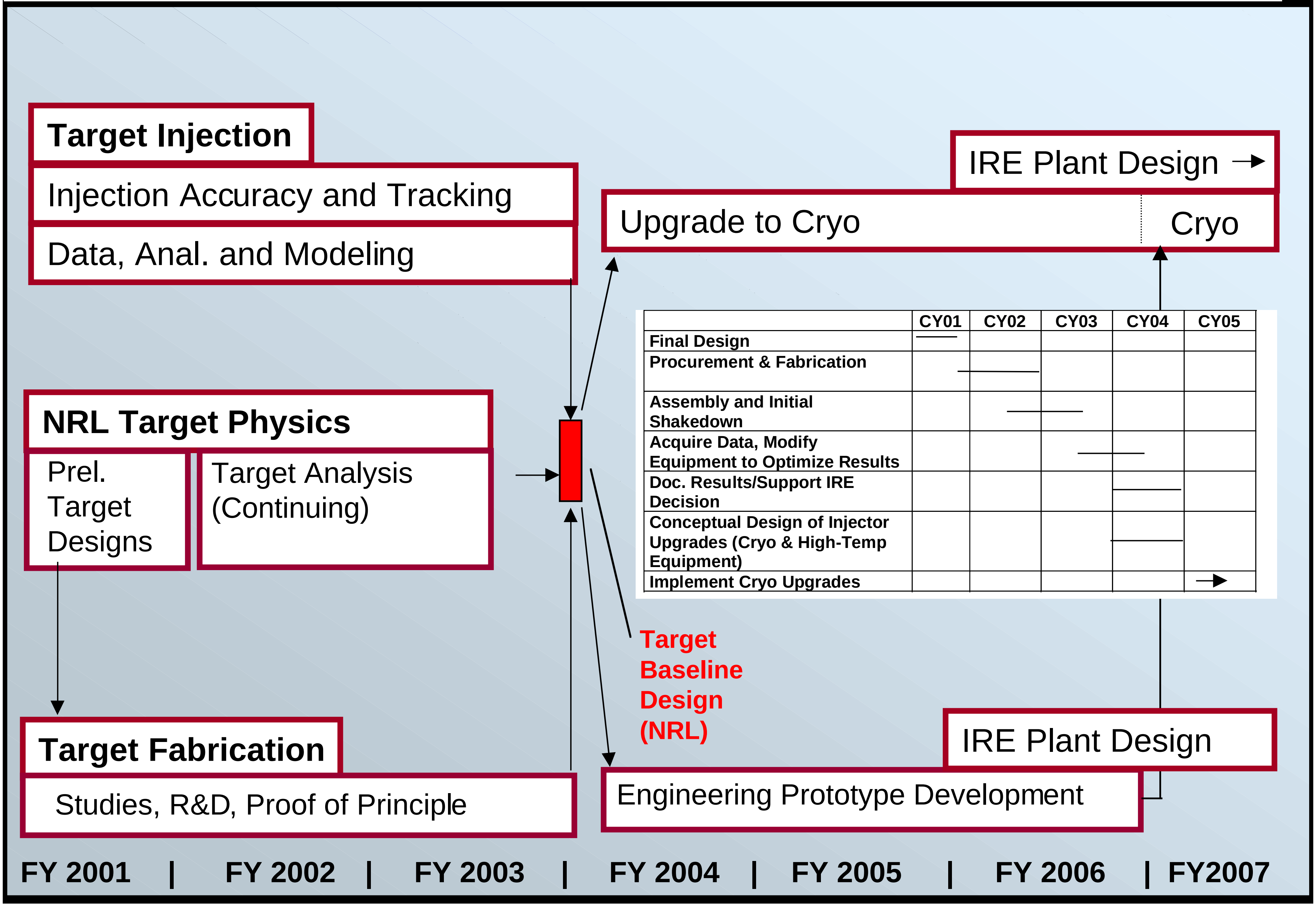
A change from the PDR is use of pulsed laser illumination of position verification cameras



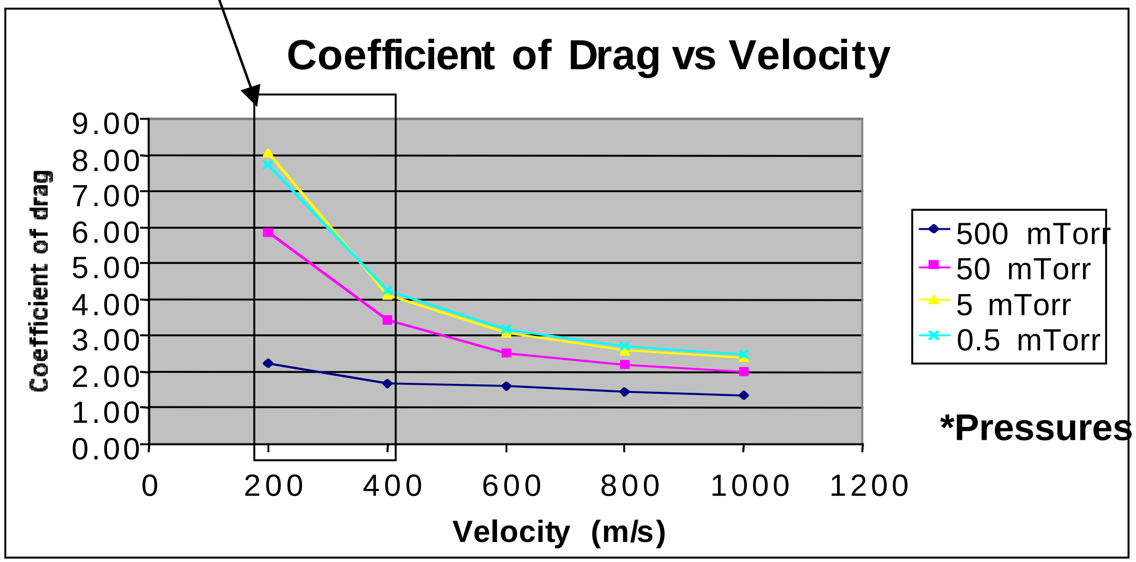
Simplified Target Fab/Injection 5-Year Plan



	CY01	CY02	CY03	CY04	CY05
Final Design					
Procurement & Fabrication					
Assembly and Initial Shakedown					
Acquire Data, Modify Equipment to Optimize Results					
Doc. Results/Support IRE Decision					
Conceptual Design of Injector Upgrades (Cryo & High-Temp Equipment)					
Implement Cryo Upgrades					

Significant drag occurs even at low chamber gas densities

Range of interest



$$F_D = C_D(0.5)\pi\rho r_t^2 v^2$$

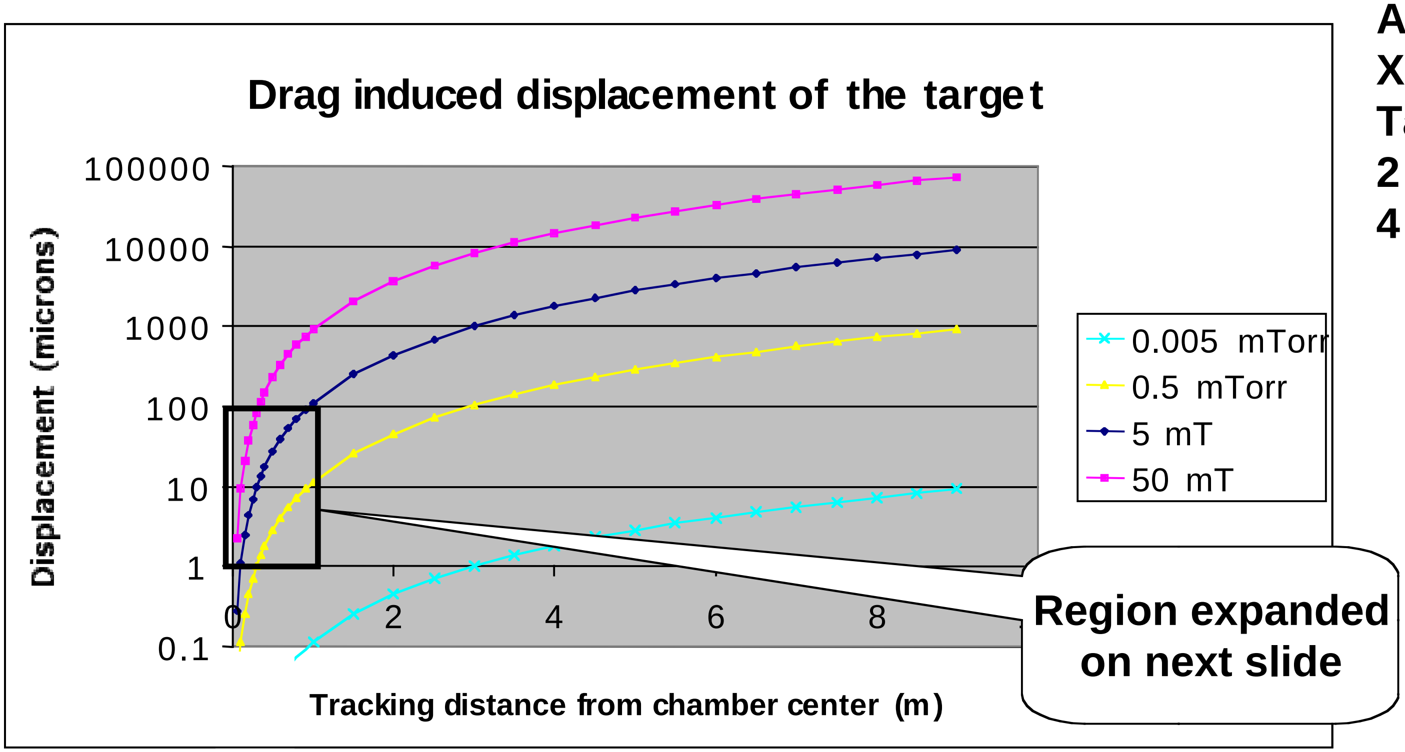
*Pressures at standard temperature

Based on DSMC drag force calculations

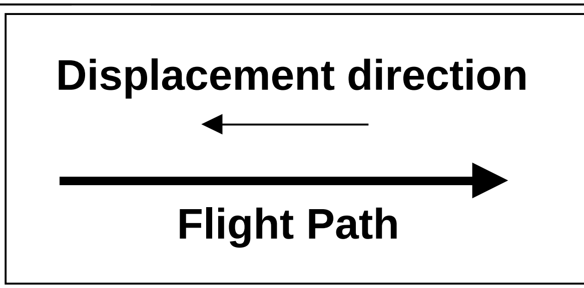
At lower (<~ 5 mTorr) pressures C_D does not change with density. Therefore the drag force increases linearly with density.

For low density (< 50 mTorr), the drag coefficient is cut in half as speed increases from 200 to 400 m/s. Therefore, $F_D \sim C_D v^2$ increases linearly rather than quadratically with speed.

Drag induced target displacement is quite large even at modest operating pressures (i.e. 5 to 50 mTorr)



Assumptions:
Xe gas in chamber
Target speed = 400 m/s
2 mm radius target
4 mg target

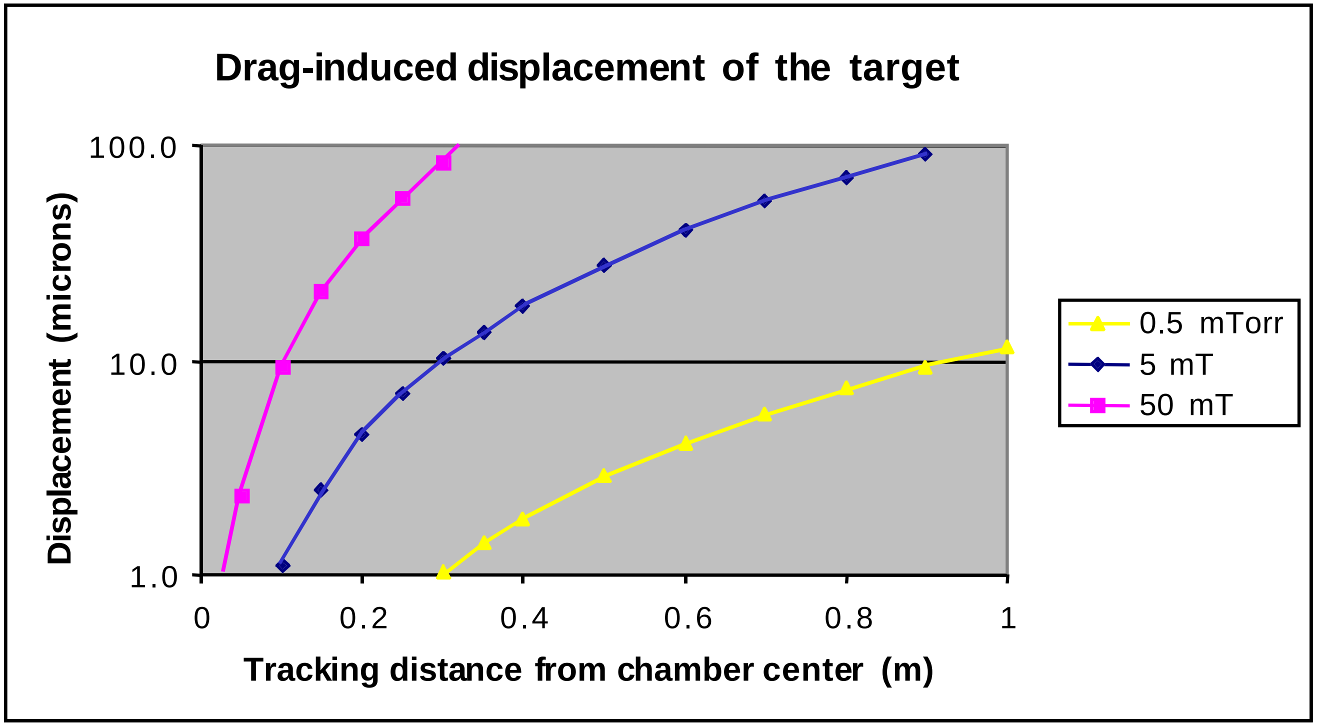


Only external target tracking requires

1. Operate at <5×10^{-6} Torr or

2. Know pressure to ±5×10^{-6} Torr

In-chamber tracking is required for higher pressure ops



Conclusion:
Need to track to within 1 m if pressure is known to 0.5 mTorr

Gas density fluctuations affect required tracking distance

	5 mTorr	10 mTorr	50 mTorr
5% Fluctuations	1.3 m (3.2 ms)	0.95 m (2.4 ms)	0.46 m (1.2 ms)
10% Fluctuations	0.95 m (2.4 ms)	0.66 m (1.65 ms)	0.33 m (0.83 ms)
50% Fluctuations	0.42 m (1.1 ms)	0.30 m (0.75 ms)	0.15 m (0.38 ms)

Assumptions:
Shot to shot chamber gas density is unknown to ± fluctuation value
2 mm radius, 4 mg target moving 400 m/s
Target velocity is well measured
Xe gas drag ±10 micron affect on target position

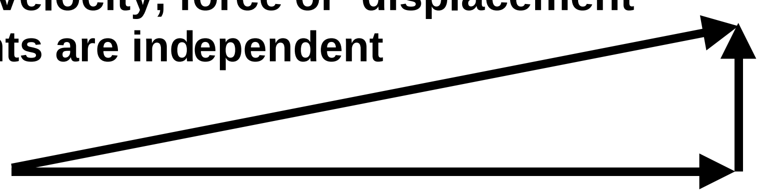
Even 5% fluctuations of 5 mTorr chamber gas requires tracking to within 1.3 m of chamber center

Windspeed fluctuations affect required tracking distance

Normalized wind speed	5 mTorr	10 mTorr	50 mTorr
5% Fluctuations	1.3 m (3.2 ms)	0.95 m (2.4 ms)	0.46 m (1.2 ms)
10% Fluctuations	0.95 m (2.4 ms)	0.66 m (1.65 ms)	0.33 m (0.83 ms)
50% Fluctuations	0.42 m (1.1 ms)	0.30 m (0.75 ms)	0.15 m (0.38 ms)

Same table applies as for gas density variations
Normalized wind speed is chamber gas speed divided by target speed

Resultant velocity, force or displacement components are independent

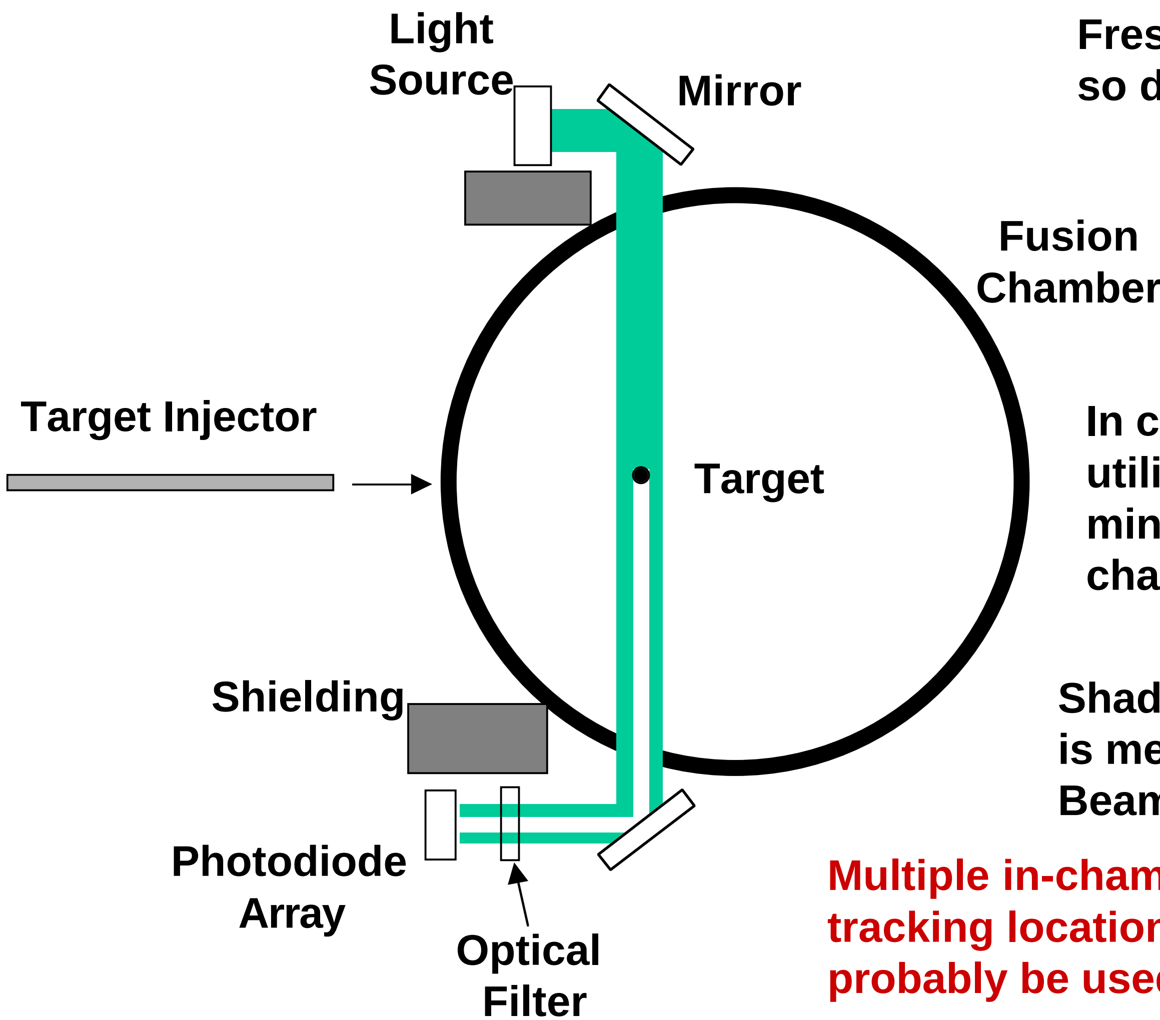


Force or displacement due to wind speed

Force or displacement due to target velocity

Assumptions:
2 mm radius, 4 mg target moving 400 m/s
Shot to shot normalized wind speed is unknown to ± fluctuation value
Target velocity is well measured
Unknown wind affect on drag has ±10 micron affect on target position
Drag force is proportional to target velocity relative to chamber gas
(true for <~50 mTorr gas and velocity < ~400 m/s)

Direct view of backlit target is the "baseline" in-chamber tracking method



Fresnel number is of order unity so diffraction will be significant.

$$F = \frac{a^2}{\lambda R} \sim \frac{(2mm)^2}{0.4\mu m(10m)} = 1$$

In chamber tracking systems utilize band pass optical filters to minimize interference from hot chamber radiation

Shadow cast by target is measured by photodiode array
Beam path is shown rotated 90°

Multiple in-chamber tracking locations would probably be used.

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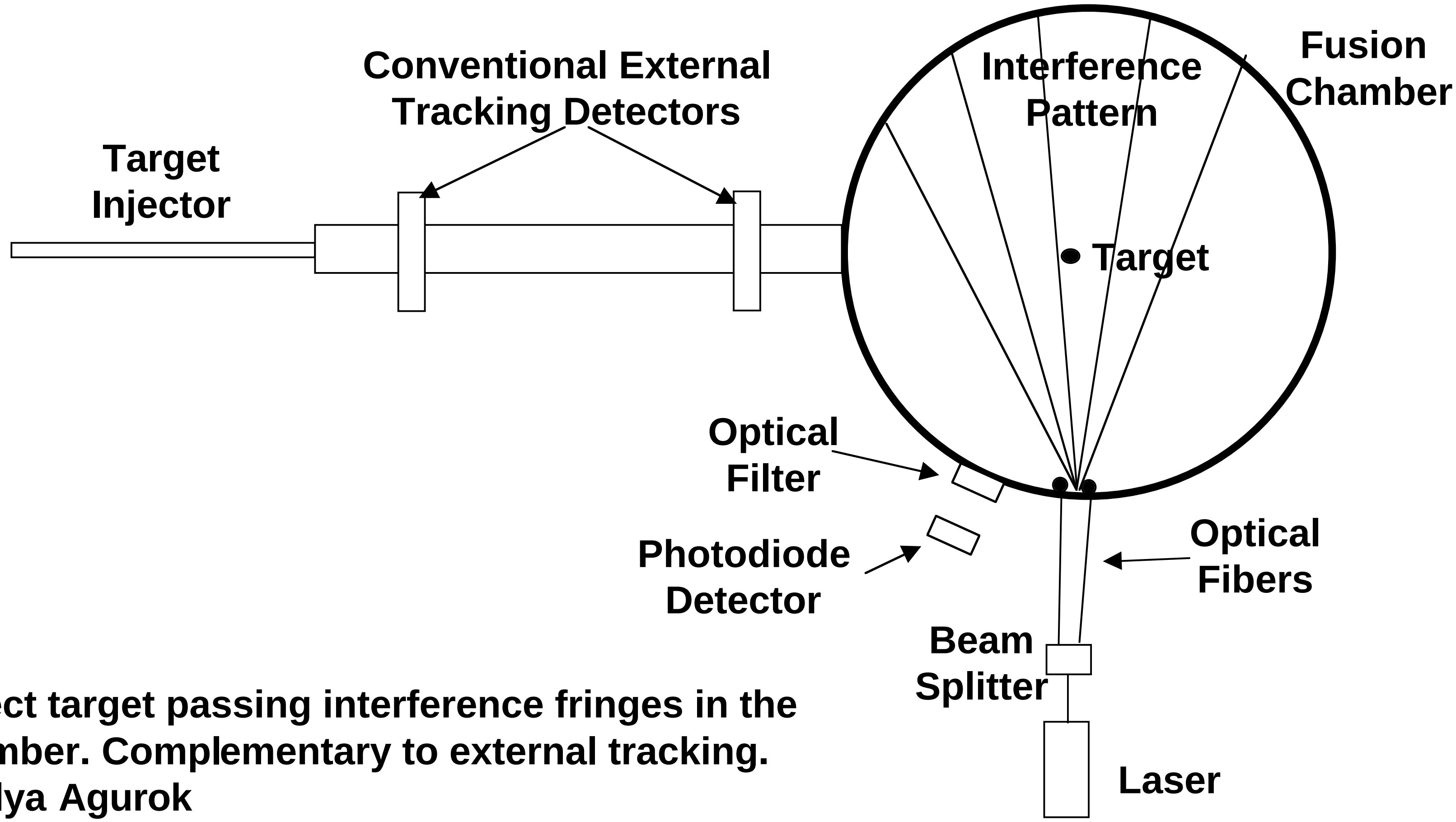
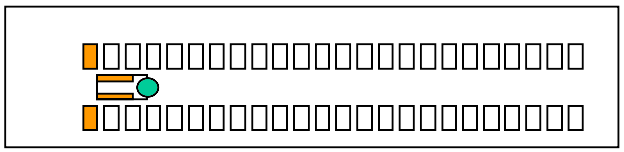
An interferometric tracking method may also be possible

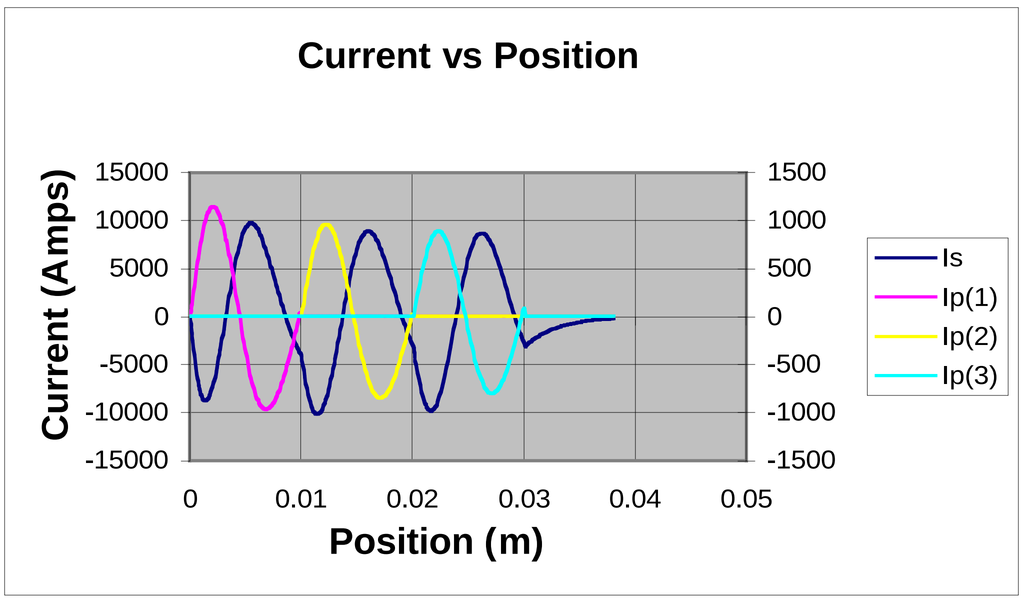


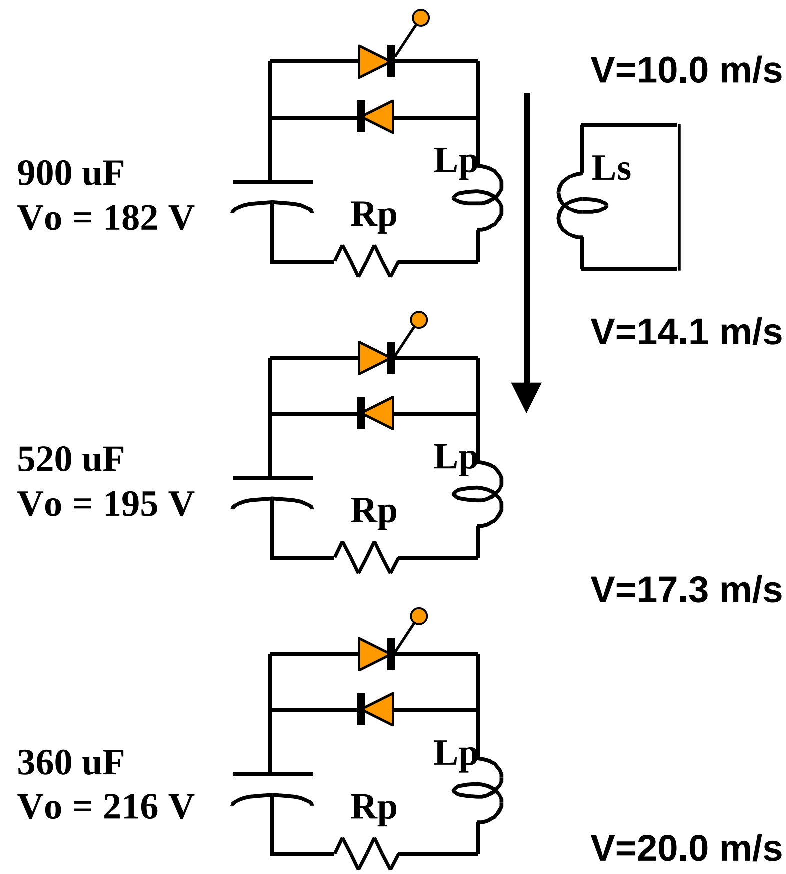
Detect target passing interference fringes in the chamber. Complementary to external tracking.
Dr. Ilya Agurok
SBIR-Physcical Optics Corporation, Torrance, CA

An electromagnetic injector has advantages for production use.

Being studied as a backup to the gas gun
Advantage: Repulsive force allows potential for self centering low wear operation
Strategy: Computer modeling of injector operation to facilitate design.
Building small scale experiment to verify computer model IAW FY 99 plan







Opposite direction primary and secondary currents cause repulsive force

Summary and Conclusions

Injection and tracking experimental design

- Project is proceeding on schedule
- The target injection and tracking system final design review is this Friday

In-chamber tracking

- External tracking of direct drive targets requires pressure known to ~10^{-5} Torr
- 0.5 mTorr Xe pressure uncertainty requires tracking to 1 m from center (Direct Drive)
- A fractional change in normalized wind speed affects target trajectory same as an equivalent change in gas density
- "Baseline" in-chamber tracking is modified external method
    - Mirrors and optical filters will be added
    - Stand-off distance is greater implying more diffraction
- Interferometric target tracking is being investigated

Electromagnetic injector

- A non-contacting electromagnetic injector is being modeled as a backup to the gas gun