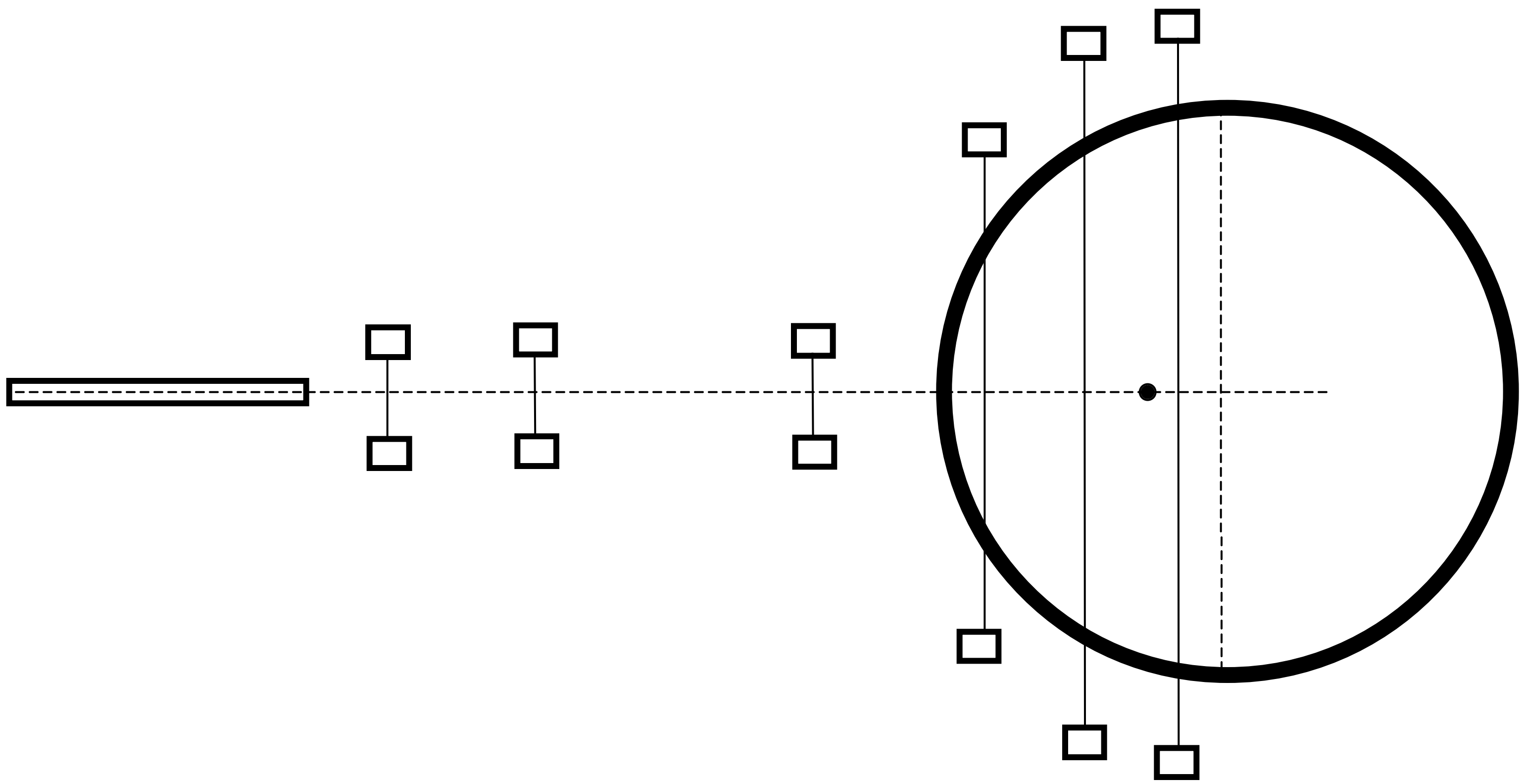
In Chamber Target Tracking and Other Target Injection Considerations



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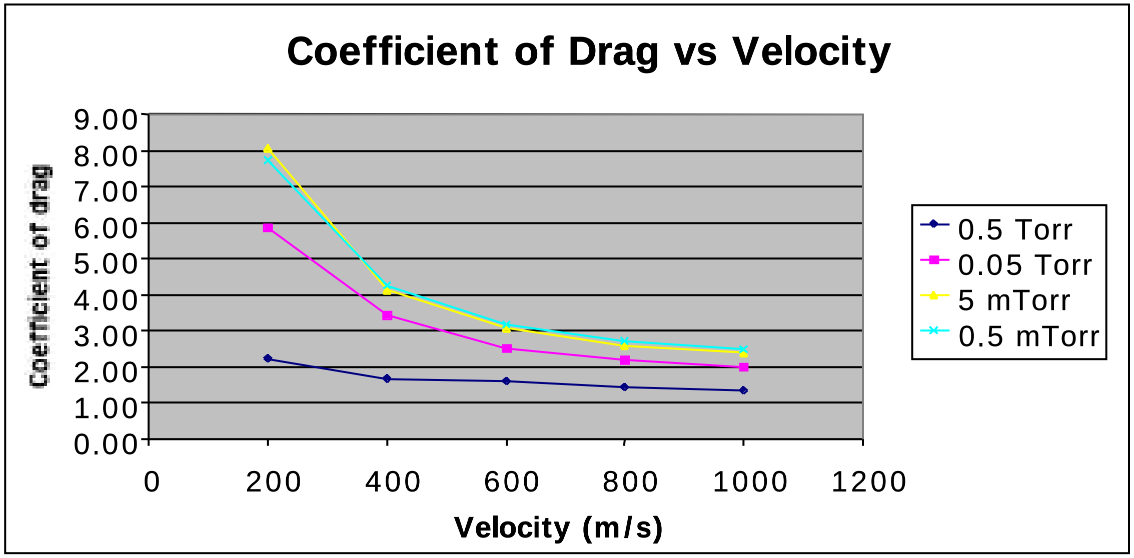
ARIES IFE Electronic Meeting   October 17, 2001

GENERAL ATOMICS

Significant drag occurs even at low chamber gas densities



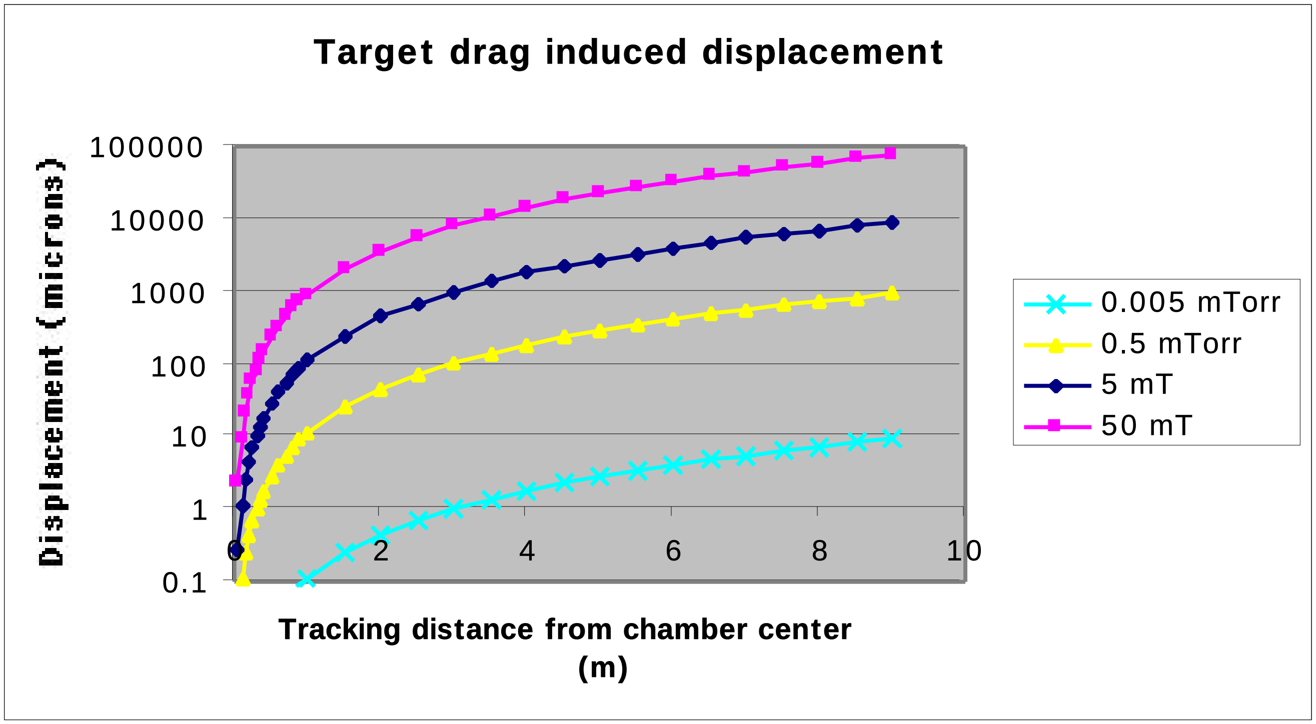
$$C_D = \frac{F_D}{0.5\,\pi\rho r_t^2 v^2}$$

Gas density	Force (mNewton)	Drag Coefficient	Acceleration (m/s²)
0.5 Torr	5.764	1.67	1441
50 mTorr	1.181	3.42	295
5 mTorr	0.1423	4.12	36
0.5 mTorr	0.01467	4.25	3.7

In 50 to 500 mTorr range we don't get linear benefit from pressure reduction
At lower pressures the drag is generally linear with density

GENERAL ATOMICS

Drag induced target displacement is quite large at expected operating pressures



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

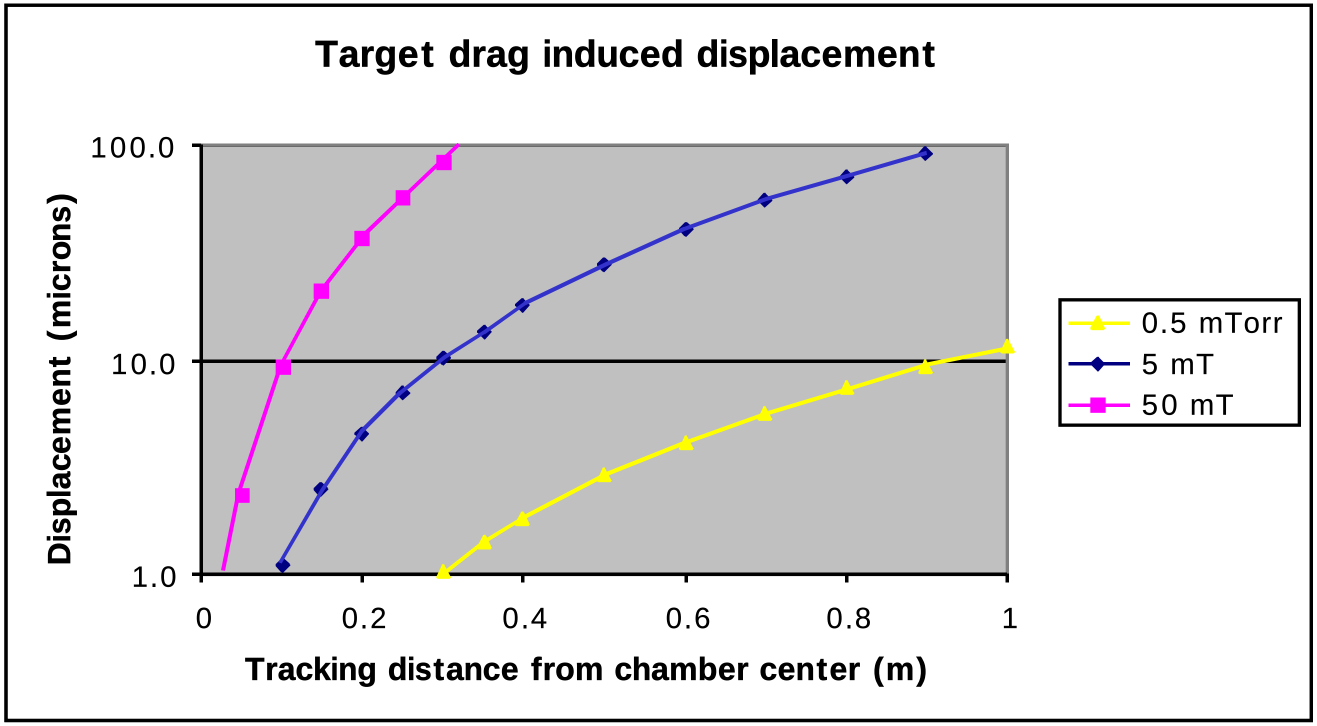
Displacement direction

Flight Path

External target tracking requires
1. Operate at $<5\times10^{-6}$ Torr or
2. Know pressure to $\pm5\times10^{-6}$ Torr

GENERAL ATOMICS

In-chamber tracking is required for higher pressure ops



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

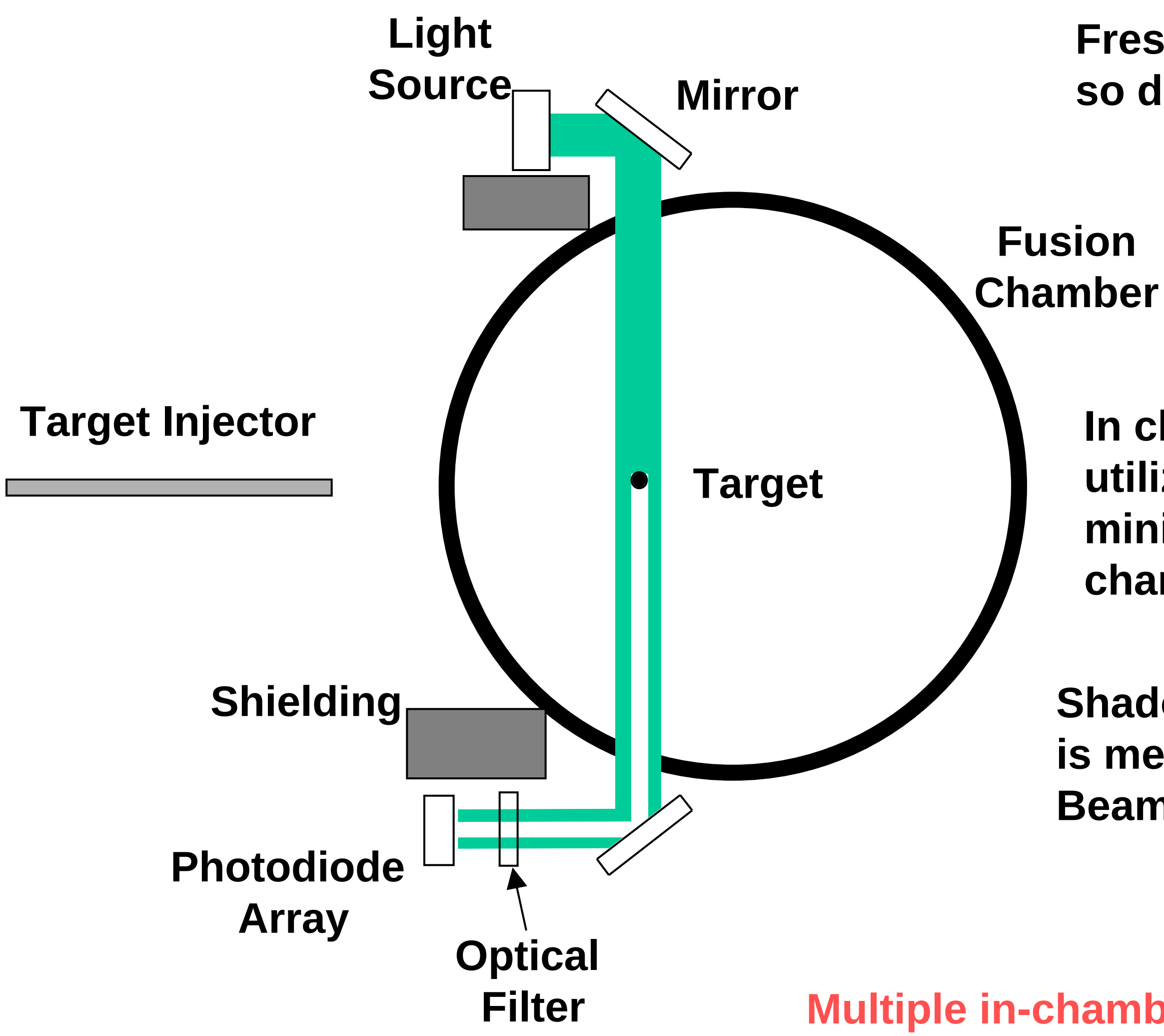
GENERAL ATOMICS

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

Direct view of backlit target is the baseline tracking method



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

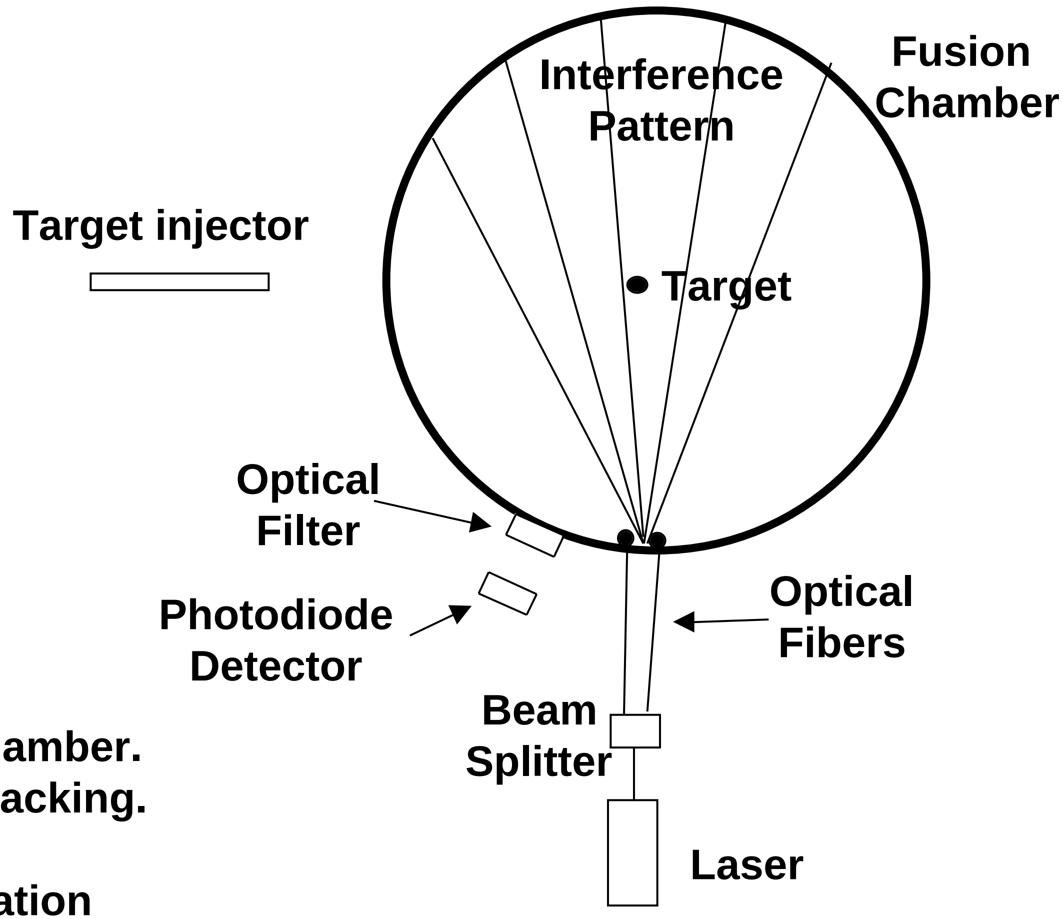
$$F = \frac{a^2}{\lambda R} \sim \frac{(2\,mm)^2}{0.4\ \mu m(10m)} = 1$$

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.

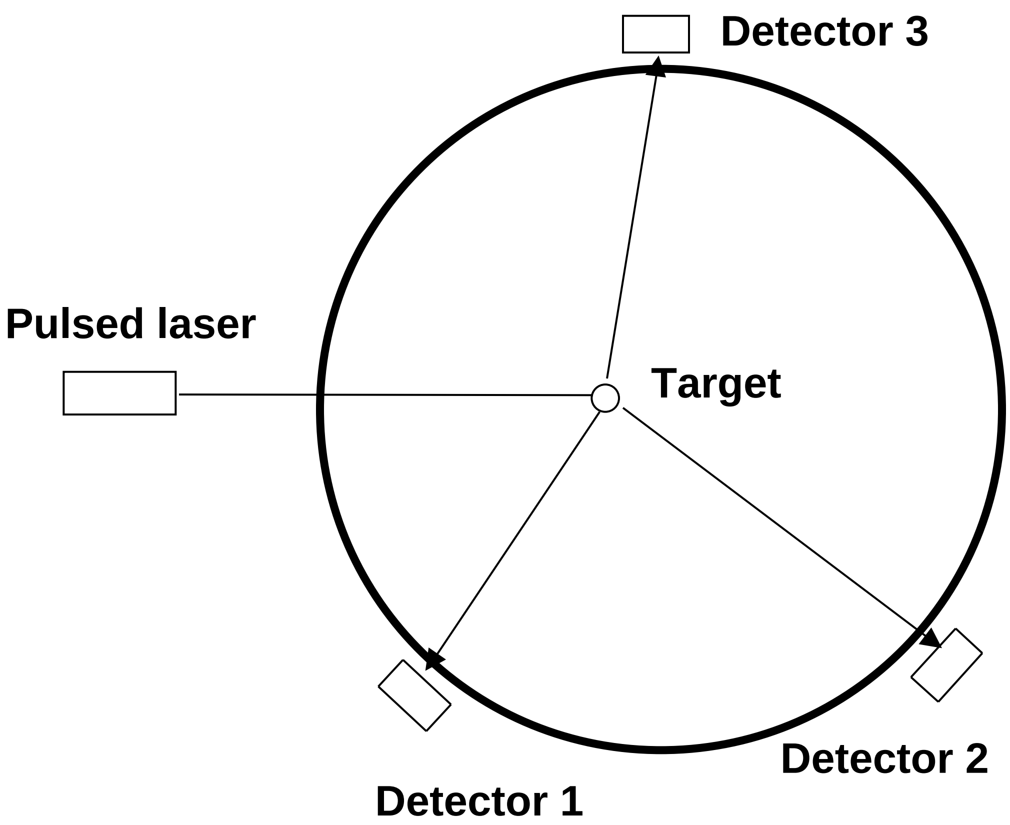
An interferometric tracking method is being studied



Detectors count fringes
as the target passes in the chamber.
Complementary to external tracking.
Dr. Ilya Agurok
SBIR Physical Optics Corporation

GENERAL ATOMICS

Another tracking concept uses pulse timing measurements



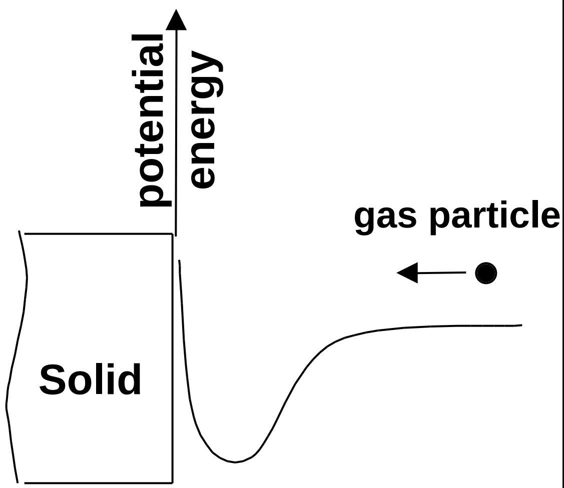
The target position can be calculated from the laser pulse arrival time at multiple detectors. However, current state of the art single pulse measurement accuracy is ~1 cm. Frequency modulation techniques may potentially improve this accuracy.

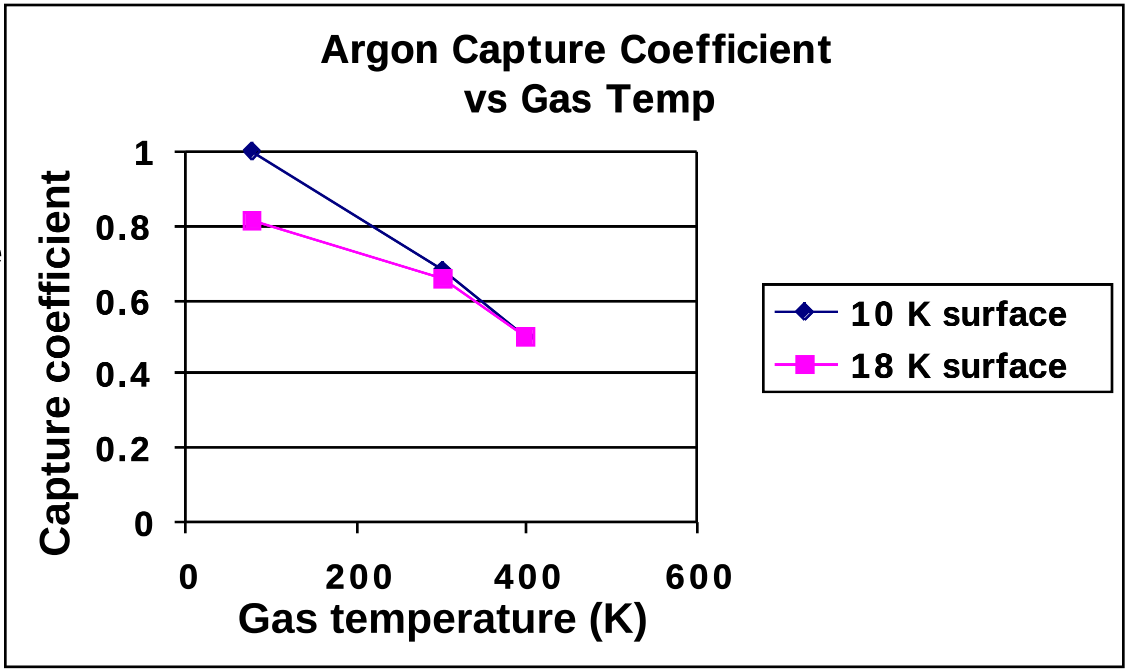
Sensor lighting is spread over much larger area than in back lit case

Ref:Amann, Bosch, Lescure, Myllyla, Rioux, Laser ranging: a critical review of usual techniques for distance measurement, Optical Engineering, Vol.40, No.1 (Jan. 2001) 10-19.

GENERAL ATOMICS

High energy gas molecules do not stick to cold surfaces



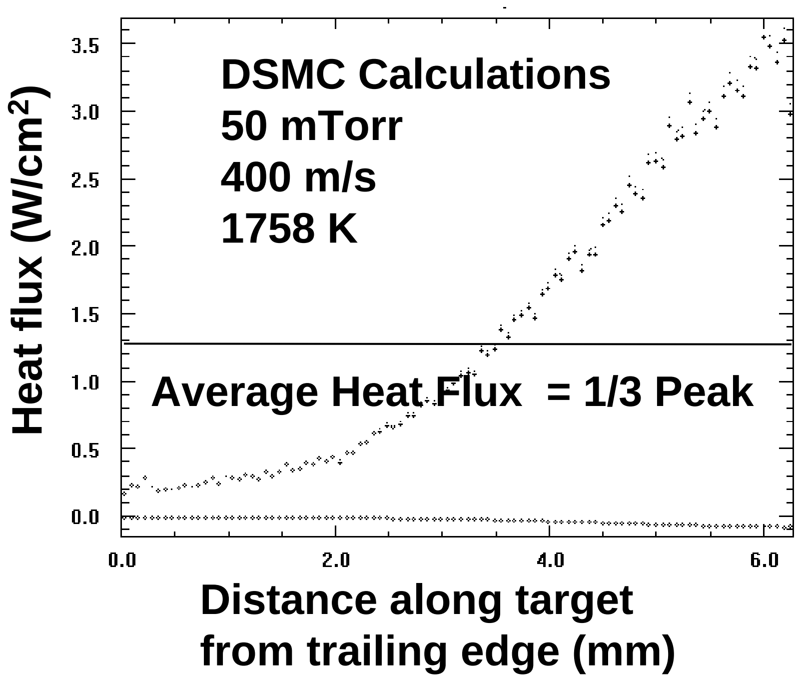


- **Above a critical energy, the gas particle energy lost in collision with a cold surface is not enough to allow capture.**
- **Most high temperature gas molecules are above this temperature.**
- **In a higher density gas(Knudsen number <~1), condensation may still occur after multiple collisions with the cold surface.**

GENERAL ATOMICS

Ref: Melvin M. Eisenstadt, Condensation of Gases during Cryopumping - The Effect of Surface Temperature on the Critical Energy for Trapping, Journal of Vacuum Science and Technology, **7**, No.4, (1970) 479-484.

Peak convection heat flux limits injection temperature



- Leading edge heats more than rest of target
- Thermal expansion does not change radial mass density (so should not affect gain?)
- Temperature rise does not reach center of fuel
- Local temperature rise must be limited to avoid melting or excessive stress

Summary and Conclusions

- 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)
- Base line 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
- Laser pulse time of flight distance measurement techniques appear more difficult
- High temperature gas molecules are not expected to stick to target surface
- Convection heat flux is about 3 times higher than average on target leading surface