Laser, X-Ray, and Ion Heating of Reflective & Transmissive Final Optics

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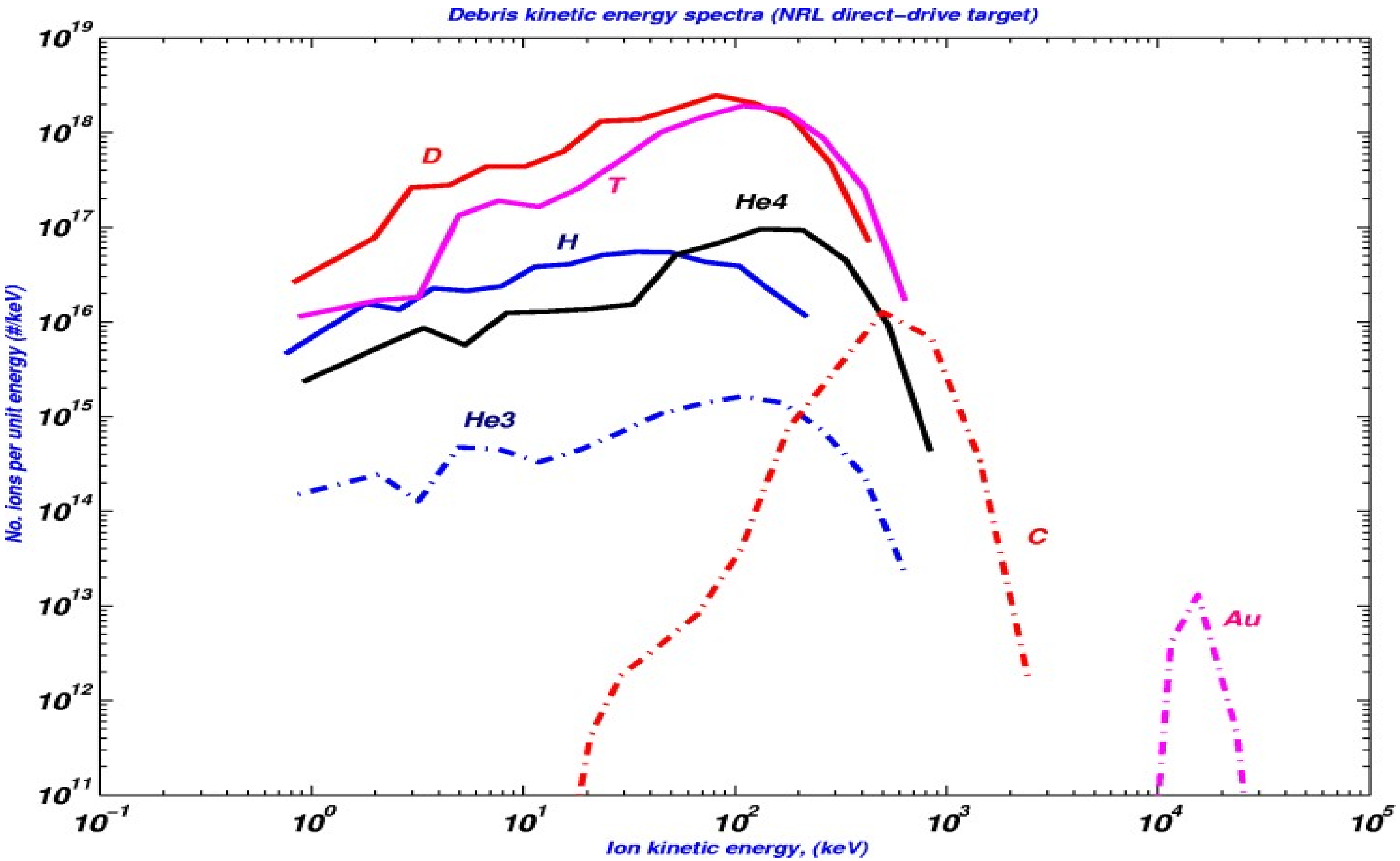
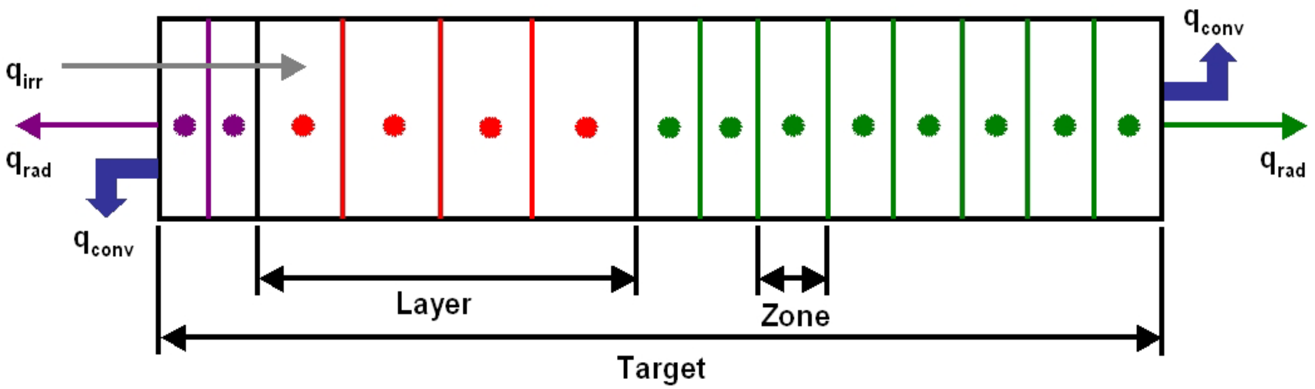
Laser profile and target spectra are the first ingredients in determining final optic temperature and stress conditions

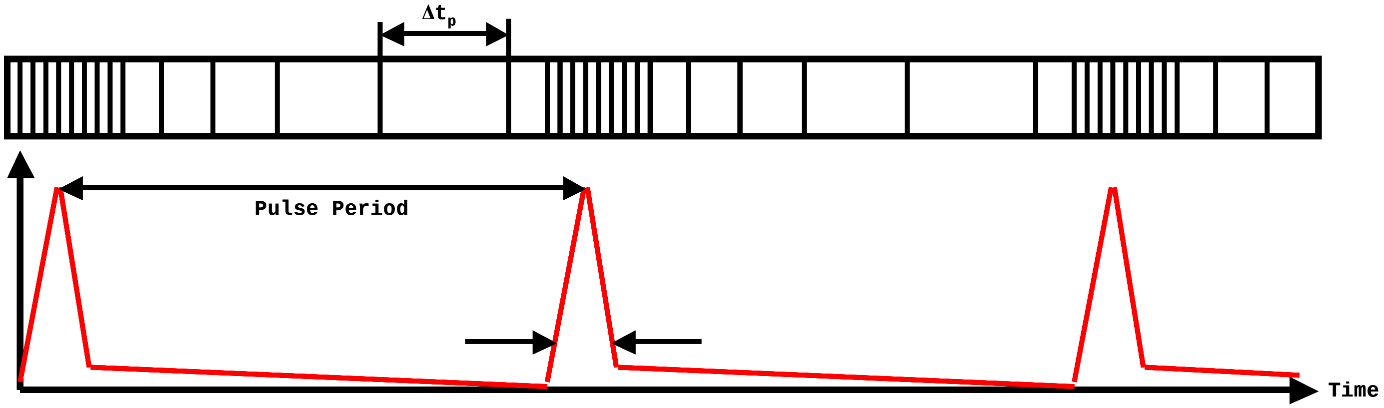


- **With consideration of system geometry, the raw target output spectra for x-rays and burn & debris ions can be translated into inputs for RadHeat**

RadHeat is a transient heat transfer code that can handle multilayer targets in pulsed radiation environments…

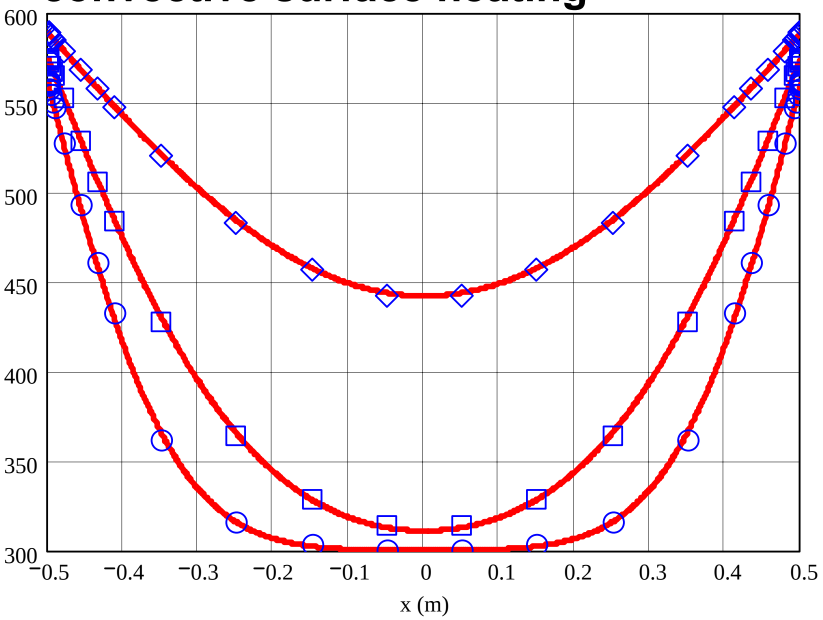


- **Robust implicit time-stepping, temperature dependent material properties, flexible meshing and a host of other features make RadHeat an ideal tool for studying transient thermal processes in IFE chamber component studies**



… that has been benchmarked with good success

- **Response of flat plate to symmetric convective surface heating**



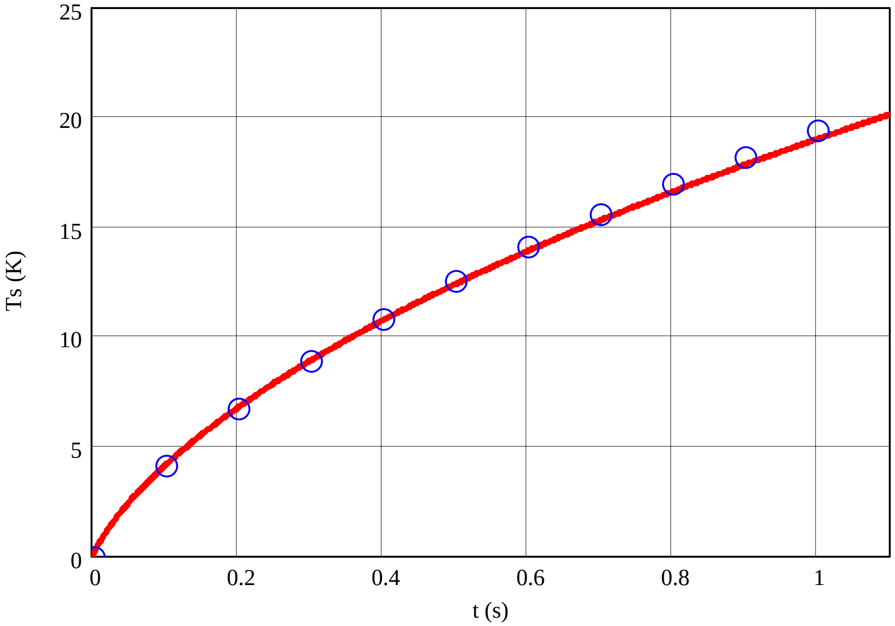
$$T = \left(T_i - T_f\right)\cdot\left[\sum_{n=1}^{\infty}\left[C_n e^{-\left(\zeta_n\right)^2\cdot\frac{\alpha\cdot t}{L^2}}\cdot\cos\left(\frac{x}{L}\cdot\zeta_n\right)\right]\right] + T_f$$

$$C_n = \frac{4\cdot\sin\left(\zeta_n\right)}{2\cdot\zeta_n + \sin\left(2\cdot\zeta_n\right)}$$

$$T_s = \frac{q}{k\cdot\gamma}\cdot\left(\frac{2\cdot\zeta}{\sqrt{\pi}} - 1 + e^{\zeta^2}\cdot\mathrm{erfc}(\zeta)\right)$$

$$\zeta = \gamma\cdot\sqrt{\alpha\cdot t} \qquad \alpha = \frac{k}{\rho\cdot c}$$

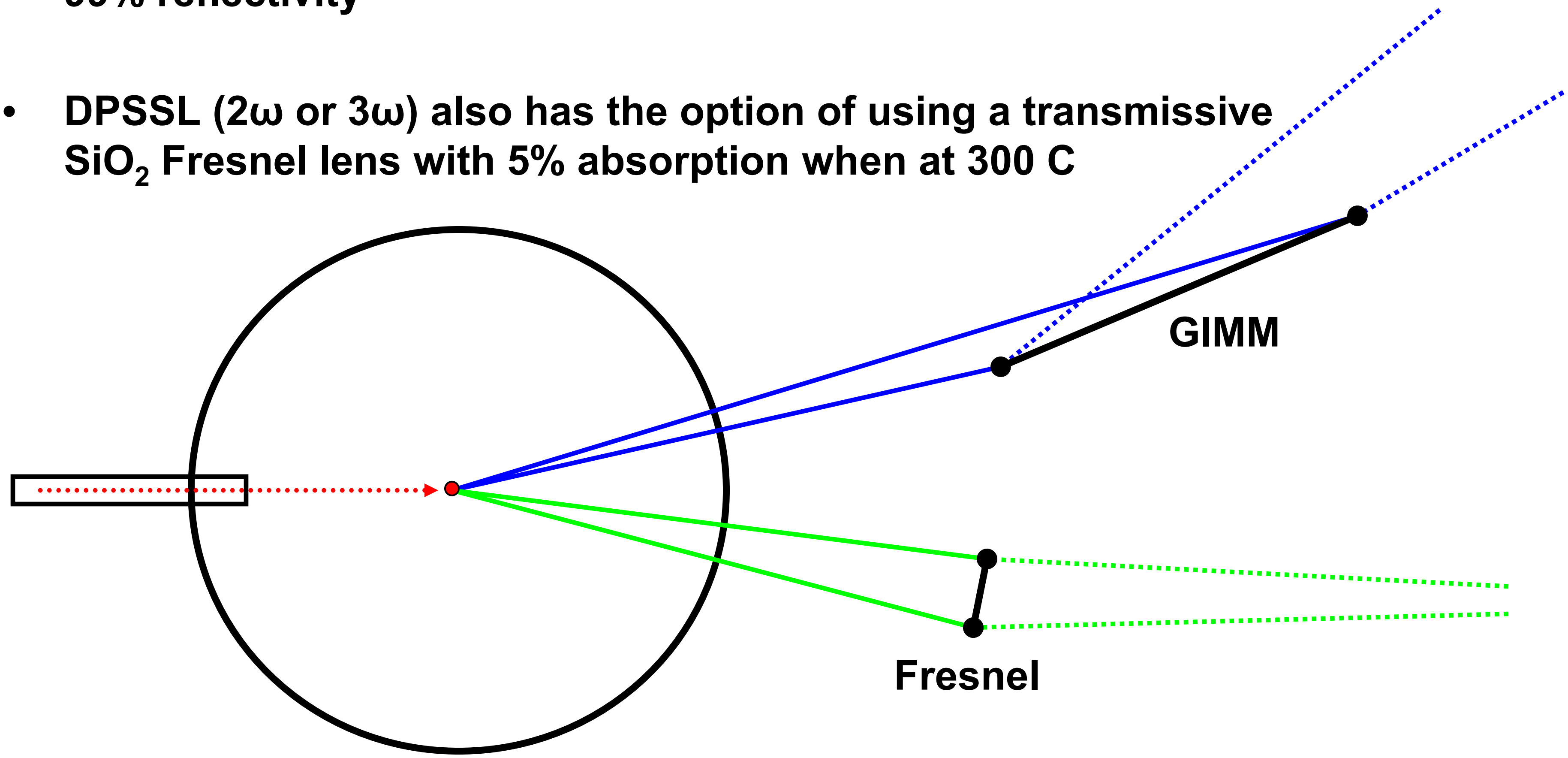
- **Response of semi-infinite wall to heating from penetrating photon irradiation**



Both reflective and transmissive candidates are being considered for IFE final optics

- **The base-case KrF (4ω) final optic is a grazing incidence metal mirror (GIMM) made from aluminum and oriented 85° to achieve 99% reflectivity**

- **DPSSL (2ω or 3ω) also has the option of using a transmissive SiO_2 Fresnel lens with 5% absorption when at 300 C**



Fluence limitations on both approaches must be put in the proper context

	GIMM @ 85°	Fresnel
Normal to beam laser fluence goal	5.0e+00 J/cm^2	2.0e+00 J/cm^2
Corresponding optic normal fluence	4.4e-01 J/cm^2	2.0e+00 J/cm^2
Normal to beam fluence absorbed	4.4e-03 J/cm^2	1.0e-01 J/cm^2
Specific heating to optic	2.9e+01 J/g	8.7e-01 J/g

We simulated several optic configurations using RadHeat

- **A reflective Al GIMM at 26 m from chamber center subjected to a KrF laser pulse and output from a 350 MJ target at 85°**

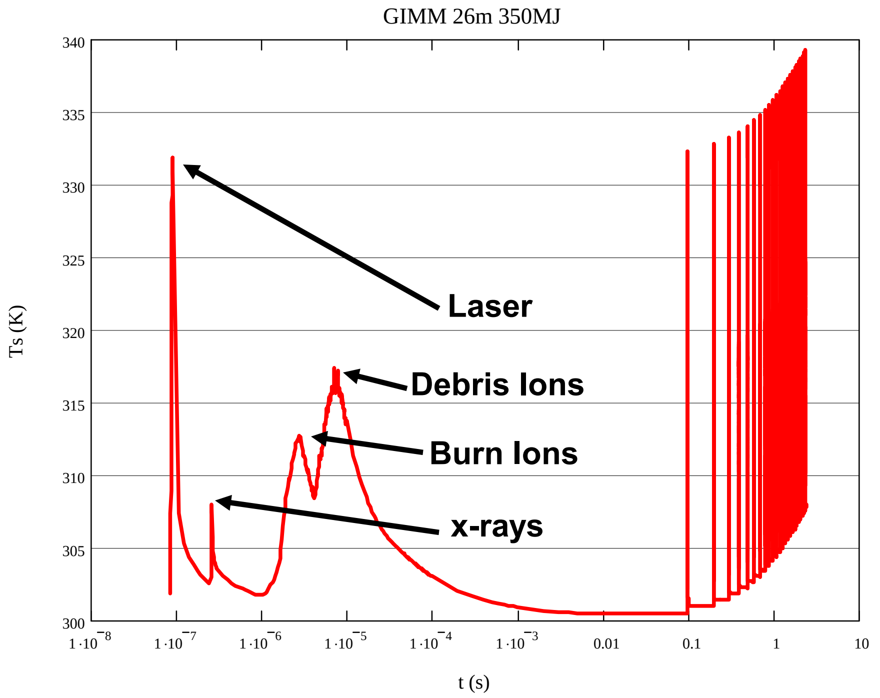
- **A transmissive SiO_2 Fresnel lens also at 26 m subjected to a DPSSL laser pulse and the same target output used for the GIMM**

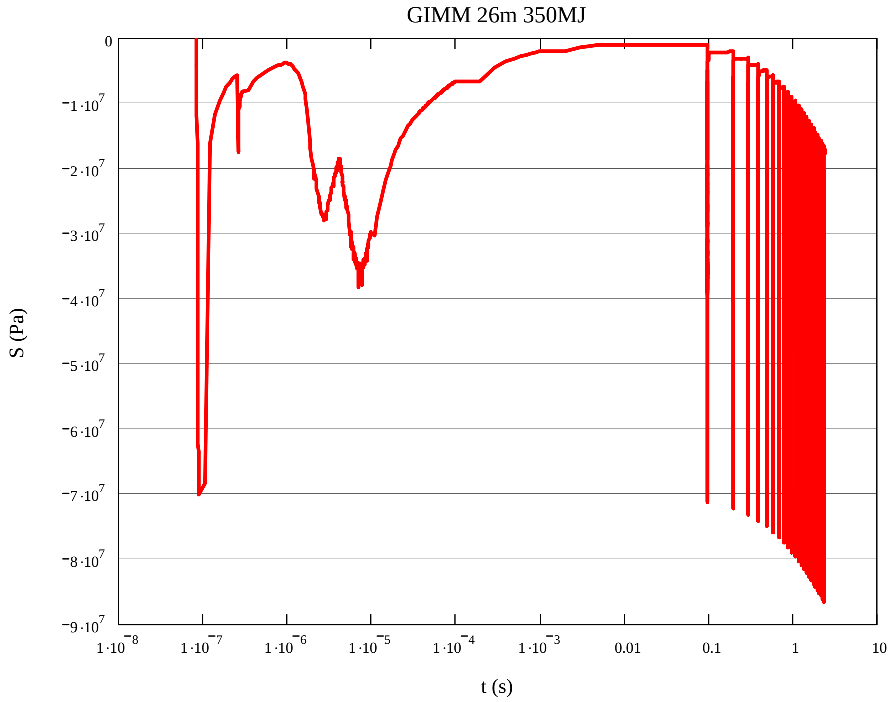
- **A Fresnel lens identical to the situation above but without ion irradiation**

The final case indicates what would happen if a successful ion deflection scheme were employed

The GIMM run shows that while the temperature response may seem reasonable, stresses will could be significant

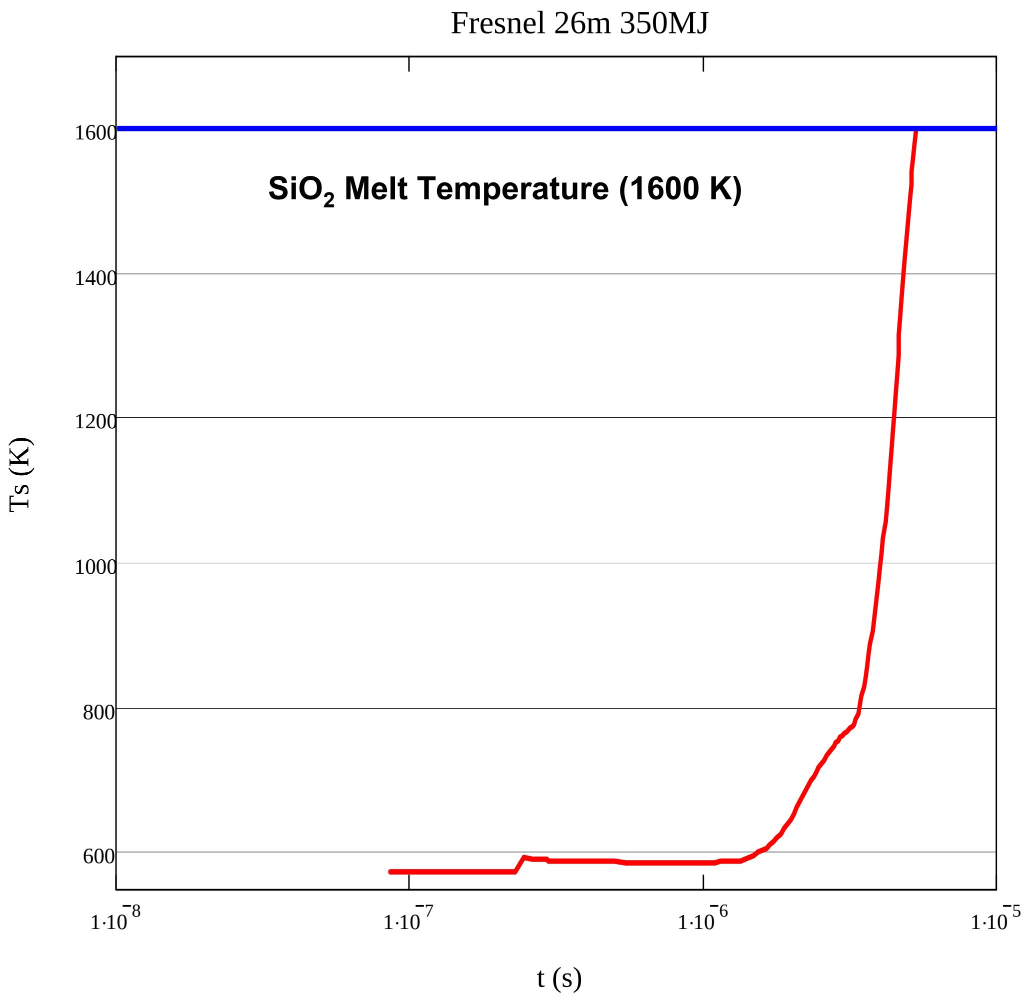
- **The laser pulse will generate the greatest temperature spike with a magnitude of ~ 30 degrees**





- **Compressive surface stresses could cause the optic to yield in compression and pose a fatigue or cracking threat**

The Fresnel run indicates ion irradiation will cause the silica to melt



- Laser has virtually no heating effect on transmissive optic due to the volumetric nature of energy deposition

- Reduced thermal conductivity bottles ion energy in thin deposition layer leading to surface melting

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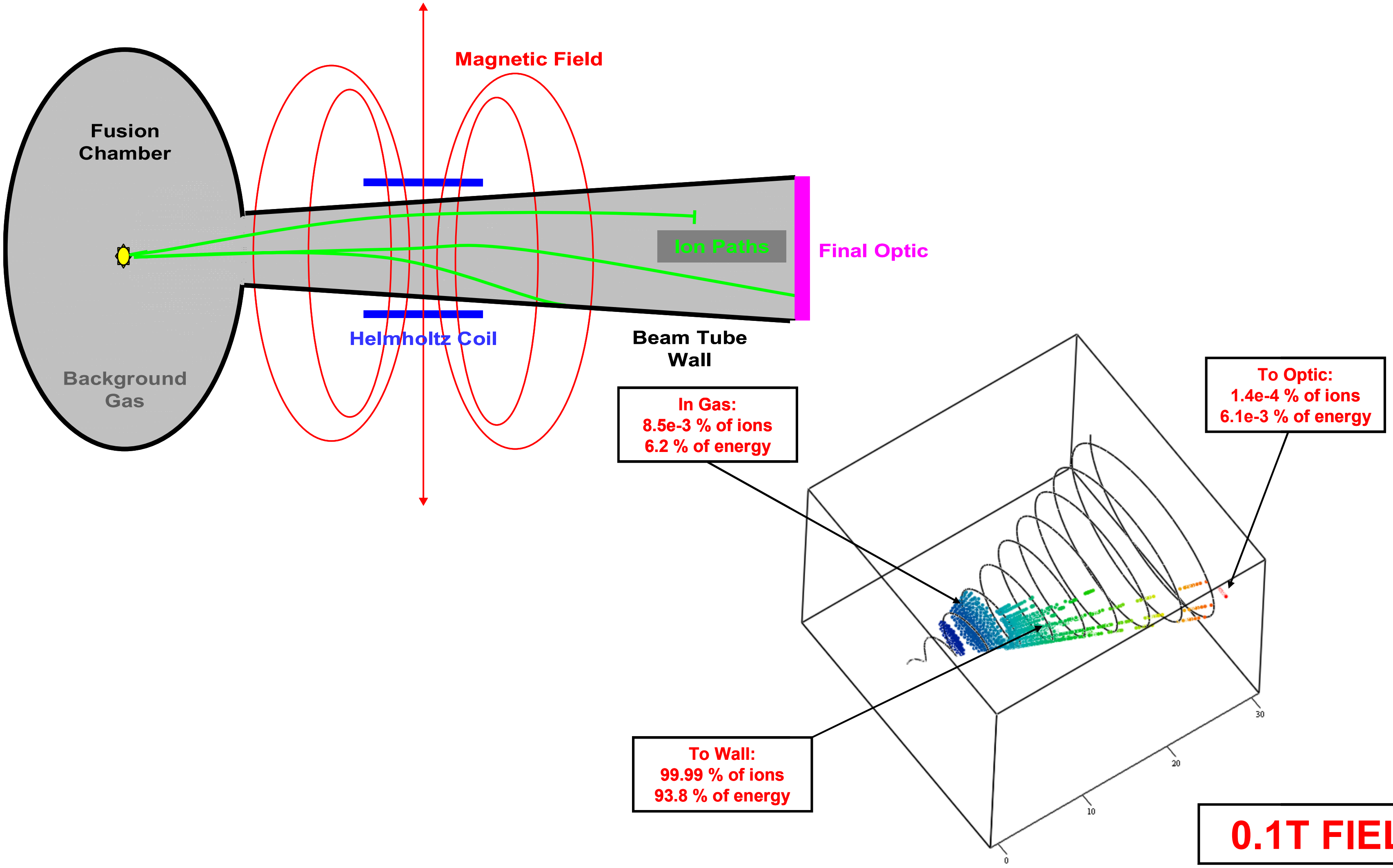
Ion deflection will therefore be needed for Fresnel optics



In Gas:
8.5e-3 % of ions
6.2 % of energy

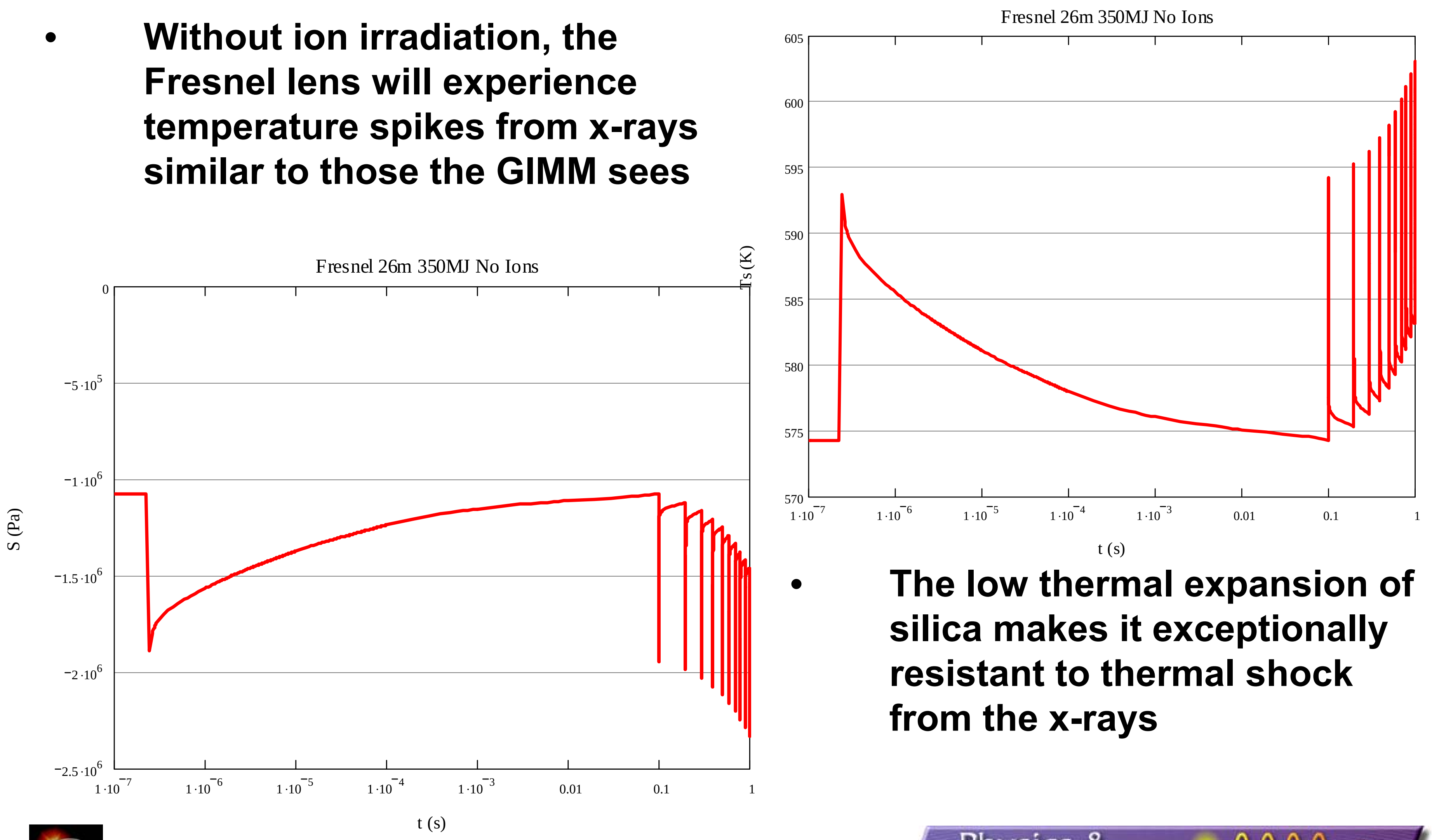
To Optic:
1.4e-4 % of ions
6.1e-3 % of energy

To Wall:
99.99 % of ions
93.8 % of energy

0.1T FIELD

With ion deflection, surface temperatures of silica are much more reasonable

- **Without ion irradiation, the Fresnel lens will experience temperature spikes from x-rays similar to those the GIMM sees**



- **The low thermal expansion of silica makes it exceptionally resistant to thermal shock from the x-rays**

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