Modeling of Target Radiation Heating

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ARIES Project Meeting

December 5-7, 2000

University of California, San Diego
OUTLINE

- Overview
- Modeling Approach
- Initial Results for Au/GDP/Si Target
- Future Plans
Radiation Target Heating - An Overview

- Target composition: Au / GDP / solid DT / vapor DT

- Minimize target heating inside chamber before beam irradiation: \( T_{\text{fuel}} < \text{DT triple point (21 K)} \)

- Sombrero study showed:
  
  Radiation heating from chamber wall
  \( >> \) Convective heat transfer from chamber gas

- Target is illuminated by heat radiation uniformly.

- Radiation heat load is assumed to be from black radiation power produced by chamber wall at temperature \( T_w \):

  \[
e_b = \sigma T_w^4
  \]

  where \( \sigma \) is Stefan-Boltzmann constant.
Objective is to analyze radiation heating of inertial fusion target during injection and before beam (laser or HI) irradiation. Specifically calculate:

1. Power reflectivity on target
2. Local power deposition on various layers.

Assume incident black body radiation spectrum:

\[ i_{\lambda b}(\lambda, T) = 2C_1/\lambda^5 \left( e^{C_2/\lambda T} - 1 \right) \]

Include both S- and P-polarization components. Assuming random polarization mix, we have for reflectivity:

\[ R = 0.5 \left( R_S + R_P \right) \]

Calculate reflectivity averaged over incident angles by

\[ \langle R \rangle_\theta = 2 \int_0^{\pi/2} R(\theta) \sin \theta \cos \theta d\theta \]

Integrate over radiation spectrum to obtain total reflectivity:

\[ \mathcal{R}(T) = \pi \int_0^\infty d\lambda \langle R \rangle_\theta i_{\lambda b}(\lambda, T) / \sigma T_W^4 \]
Target Reflectivity for S- and P-Polarization of Incident Radiation

- The target shell is composed of Au/GDP/Si(DT). At a wall temperature of 625°C, blackbody radiation intensity is peaked at $\lambda = 3.23 \, \mu m$.

- To calculate reflectivity for p-polarization, we substitute $n_j \cos \theta_j$ in Fresnel formulae for S-polarization by $\cos \theta_j / n_j$, and define total reflectivity as $R = (R_s + R_p) / 2$. 

![Graph showing reflectivity and total reflectivity vs. gold film thickness.](image)
Target is Highly Reflective in the Infrared Spectrum
With Gold Film Thickness > 0.04\textmu m

- Reflectivity (S+P polarization) exhibits minimum as $\theta_{\text{inc}} \rightarrow 90^\circ$ for polymer thickness of 1 \textmu m.

- Angle-averaged reflectivity variation with gold thickness is similar for $\lambda = 1, 3.2$ \textmu m; rises and levels off at $<R> = 0.976$ as $d \rightarrow 0.1$ \textmu m.
Target Reflectivity is High in Infrared Spectrum, and Insensitive to Polymer Layer Thickness in 1-10 µm Range

- Reflectivity (S+P polarization) exhibits a minimum close to tangential incidence. Periodic interference effects are seen for 10 µm GDP thickness incident angle is varied.

- Angle-averaged reflectivity ~ 0.97 for GDP thickness = 1 - 10 µm.
Target Heating is Strong in Visible Spectrum

- Radiation absorption is strong over all angles of incidence.  
  \[ R < 0.6 \quad \text{for} \quad \theta_{\text{inc}} < 80^\circ. \]

- Angle-averaged reflectivity drops drastically as \( \lambda = 1 \text{mm} \rightarrow 0.5 \text{ mm}. \)

Since \( \lambda_{\text{max}} \sim T_{\text{wall}}, \) this implies low first wall temperature is desirable.
FUTURE PLANS

• Calculation of total reflectivity integrated over radiation spectrum and fractional power deposition in various layers

• Comparison of Silicon substrate with DT

• Extrapolation to low temperature
  - n and κ values at room temperature have been used

• Correct accounting of geometry and surface roughness

• Sensitivity studies w.r.t. wall temperature and fuel temperature