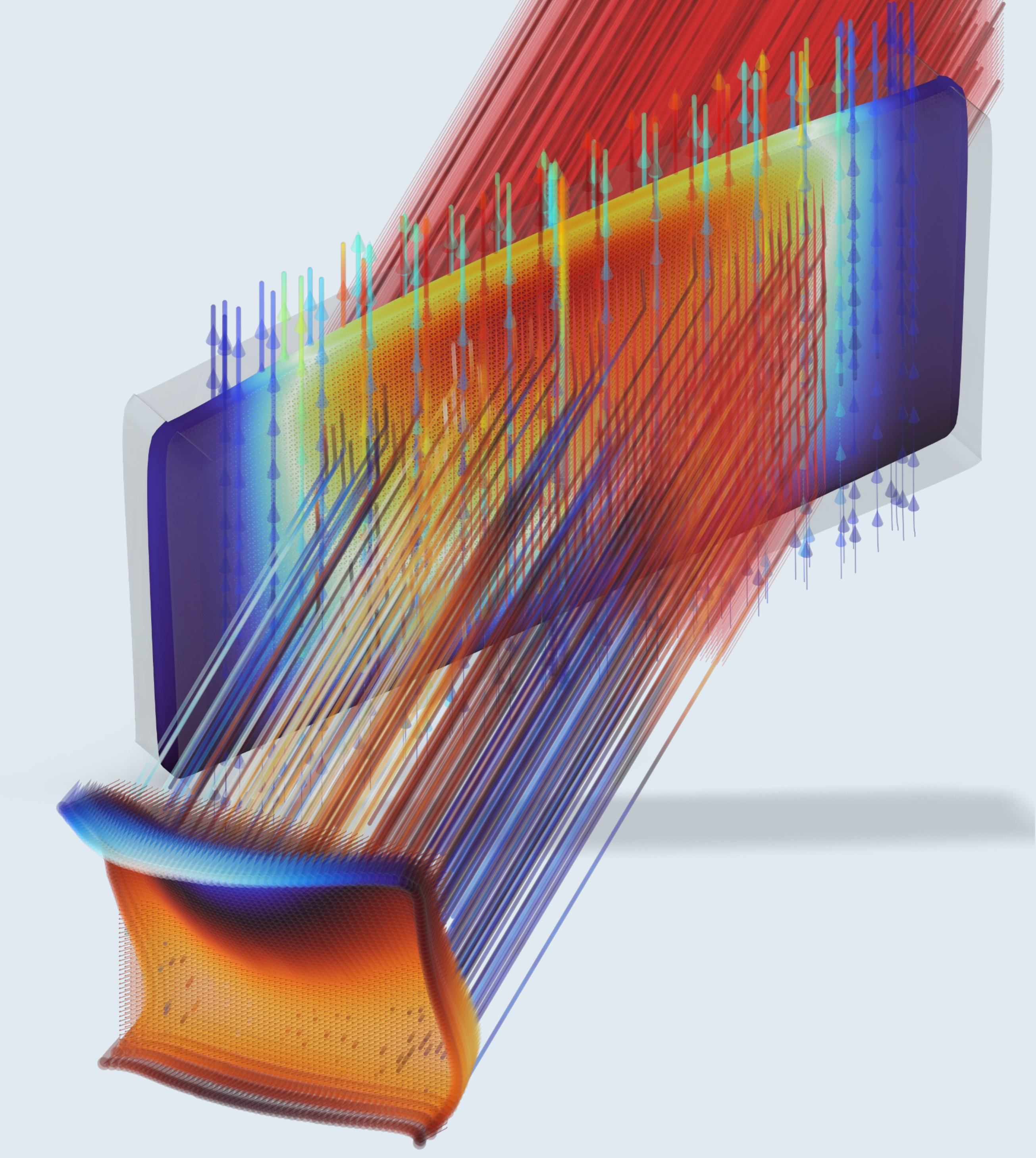

Wavefront Analysis of an Actively-Cooled Fusion Laser Amplifier

Parametric assessment of the sources of optical phase distortions in the output beam of a next-generation fusion-class laser amplifier.

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Introduction

The pioneering achievement of Inertial Fusion Energy Breakeven ($E_{out} > E_{in}$) has paved the way for Fusion R&D that advances commercial viability. To harness energy for a power plant, higher repetition rate laser drivers are required. Therefore, a new generation of large-aperture lasers must be designed, notably with better thermal performance.

An analysis is performed to pinpoint the sources of residual heat in these amplifiers. The resulting optical distortions effectively spread out the laser light at focus, altering the intensity distribution seen by the fuel pellet. The efficacy of controlling distortions with new higher efficiency pumps and altered cooling schema is explored.

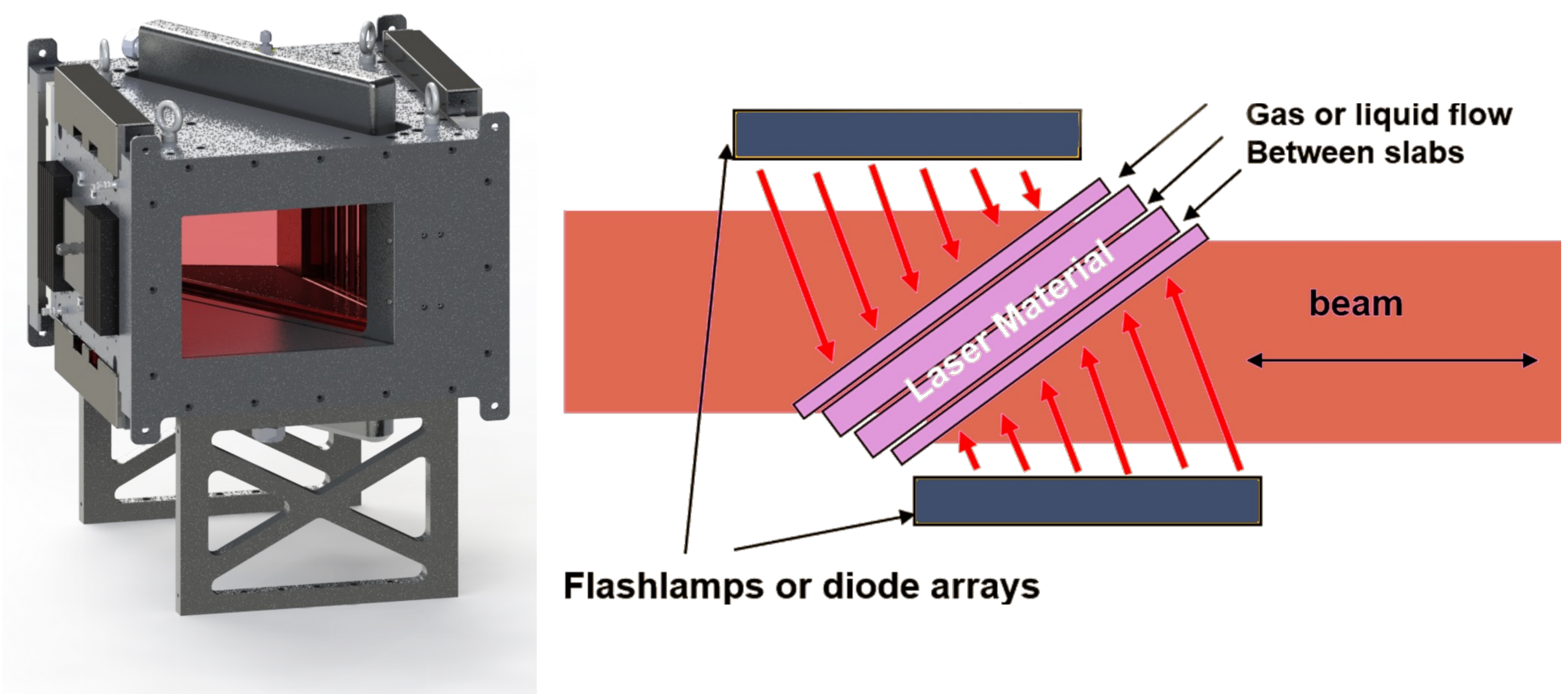

FIGURE 1. Left: Typical IFE Laser Amplifier. Right: Horizontal Cross-Section of simplified amplifier used in the simulation

Methodology

A Laser Amplifier is modeled including all optics and coolant channels. External heat load models drive the Conjugate Heat Transfer and thermo-mechanical solutions. Initial models are stationary to reduce simulation time.

The local index of refraction is modified by both the local temperature and stress. The full 3x3 tensor is calculated for different polarizations (ij):

$$n_{ij} = n_0 + \frac{\partial n}{\partial T} * \Delta T(\vec{r}) + \sum \left(\frac{\partial n_{ij}}{\partial \sigma_{kl}}\right)_{ijkl} * \sigma_{kl}(\vec{r})$$ [1]

Results

The results in Figure 2 shows the Wavefront as a Spot Diagram of the output beam of an actively cooled amplifier.

Phase map shows:

- A strong vertical bottom-to-top upwards phase gradient. This follows the thermal gradient caused by the coolant flow.
- A complex thermal lens with astigmatism ($f_x > f_y$) due to the heat load distribution and non-polar geometry.

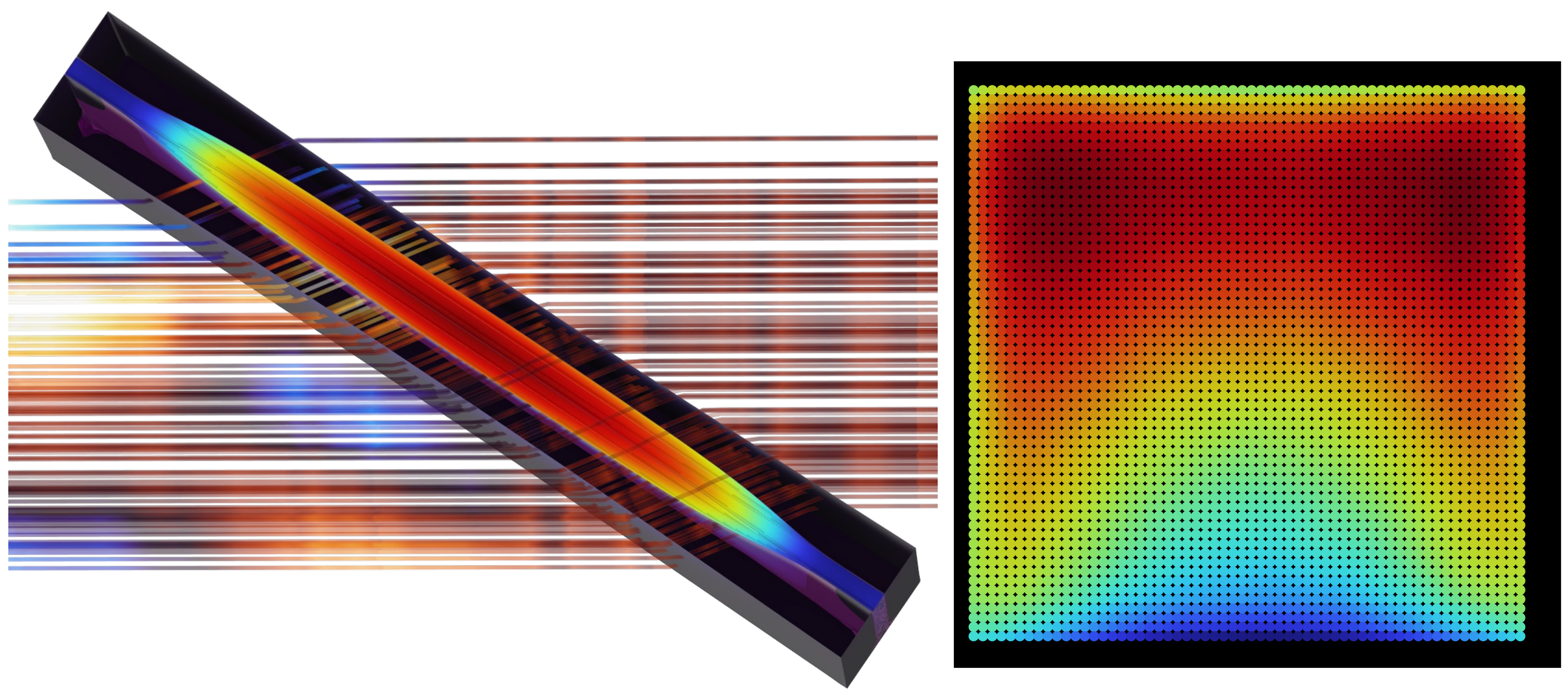

FIGURE 2. Left: Ray Passage through an expanded thermally stressed amplifier. Right: Resulting Output Beam Phase Map.

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1. J. M. Eggleston, T. J. Kane, K. Kuhn, J. Unterharer, & R. L. Byer (1984). The Slab Geometry Laser-Part I: Theory. IEEE JOURNAL OF QUANTUM ELECTRONICS, QE-20(3).

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