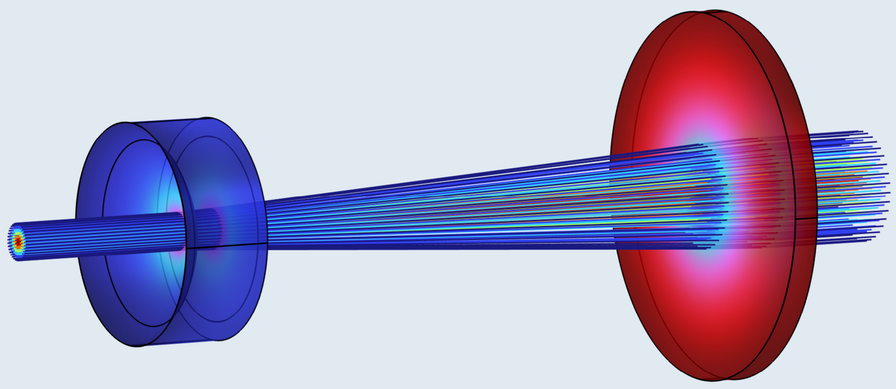

Multiphysics Design and Analysis of a Refractive Beam Expander for High-Power Laser

High-power laser beam propagating through optical elements leads to thermo-mechanical effects.
A COMSOL® mulitphysics modeling is performed to analyze the beam quality.

J. B. Accary

Optronics Division, CILAS, Orléans, France

Introduction & Goals

The goal of this work is to analyze and further optimize a refractive beam expander made of 2 lenses for a multi-kW continuous wave laser.

COMSOL Multiphysics® and the Ray Optics Module are used to conduct a comparative study between a beam expander made of 2 Fused-Silica lenses and another one made of a single CaF2 and a single Fused-Silica lenses.

The performance is measured by the mean of the transmitted wavefront error.

The lenses are assembled in a simple barrel made of Aluminum and an RTV for their bounding.

The analyze is performed for both the transient and steady states.

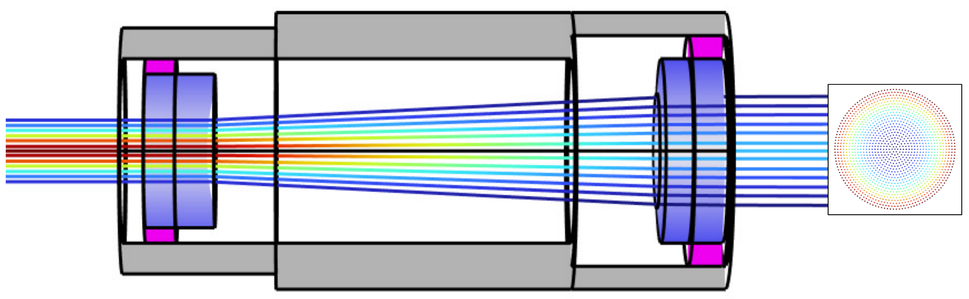

FIGURE 1: Beam expander with a 5kW laser. Ray color relate to the power (gop.Q [W]), purple for RTV and Gray for aluminum barrel. A map of the optical path length difference is shown on the right.

Methodology

>>> Equations for the study

- Laser power 5 kW @1µm with a Gaussian intensity profile.
- Laser beam intensity profile: $I = I_0\, exp\left[-2\left(\frac{r}{w_0}\right)^2\right]$ with $w_0 = 1\text{mm}$
- Heat power absorption: $I = I_0 exp\left(-\frac{2k_0 \kappa L}{n}\right)$ with the refractive index such as $n - i\kappa$
- Heat transfer in solid: $\boldsymbol{q} = -k\nabla T$
- Heat transfer at interface: $q_0 = h(T_{ext} - T)$

>>> Physics

- Thermal expansion, Ray heating, Solid mechanics

>>> Study

- Temporal Ray trace and/or Bidirectional Coupled Ray Tracing

Results

Analysis of thermo-optical effect induced by a high power laser has been conducted with *COMSOL Multiphysics®* and the *Ray Optics Module.*

An improvement is achieved with the lenses of opposite sign of thermal refractive index change. This analysis also provides information about the temporal evolution of the system.

The transmitted wavefront aberration of the beam expander can be further optimized with the *Optimization Module* of COMSOL®.

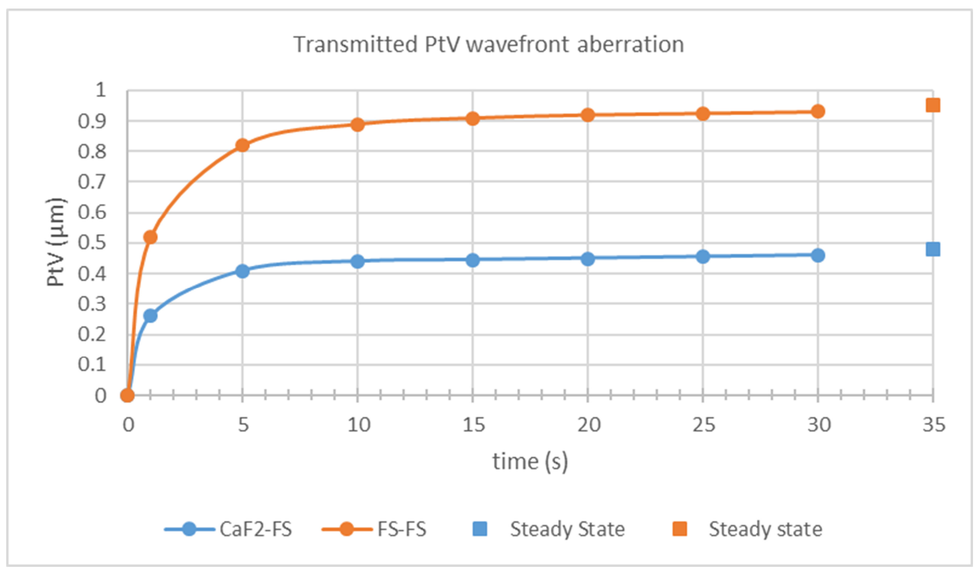

Figure 2: Time evolution of the transmitted wavefront error.

REFERENCES

Thermally Induced Focal Shift in High-Power Laser Focusing Systems. Comsol Application Gallery ID: 19955.

Excerpt from the Proceedings of the COMSOL Conference 2023 Munich