

Modeling Of The Floating Zone In Laser-Heated Pedestal Growth Of Sapphire Used In Fiber Optics

Ahmad Gad¹, Gisele Maxwell¹, Mikhail Ovchinnikov¹

¹Alcon Labs, Lake Forest, CA, USA

Abstract

Laser-Heated Pedestal Growth (LHPG) is a crystal growth technique that employs a focused laser beam to melt a source material, creating a molten zone that is precisely controlled to produce high-quality single crystals. This method is particularly advantageous for growing crystals with high melting points and for materials that require a clean, contamination-free environment. LHPG allows for the growth of crystals with tailored properties by adjusting the growth parameters, making it suitable for applications in electronics, photonics, and materials science. The process also enables the production of fibers and rods with uniform composition and superior structural integrity.

In this work, we present a Finite Element (FE) model to analyze the steady state of the sapphire molten zone generated by the Laser-Heated Pedestal Growth (LHPG) technique. We employ an incompressible fluid flow coupled with a heat transfer model to simulate the floating (molten) zone, while a heat transfer model is applied to the seed and solidified sections. The model incorporates phase change and mass transfer across the melting and solidification interfaces, buoyancy effects within the molten zone, and the Marangoni effect on the free surface. The solid sections are treated as rigid bodies moving at a uniform velocity. The boundaries of the molten zone (melting line, solidification line, and free surface) are tracked using an arbitrary Eulerian-Lagrangian approach. Heat input to the molten zone is provided by a far-field Gaussian temperature profile optimized to match our operating conditions. The numerical results closely align with experimental data, demonstrating excellent agreement in the shape and size of the molten zone.

The LHPG apparatus used in this work features a CO₂ laser as the heat source, an optical setup with a reflexicon for generating an annular beam, and a system of mirrors to focus the beam onto the feed rod. The diameter of the growing crystal is controlled by adjusting the feed rod and seed speeds during growth.

Reference

1. Dossa, Scott S., and Jeffrey J. Derby. "Modeling optical floating zone crystal growth in a high-pressure, single-lamp furnace." *Journal of Crystal Growth* 591 (2022): 126723.
2. Lan, Chung-Wen, and Sindo Kou. "Heat transfer, fluid flow and interface shapes in floating-zone crystal growth." *Journal of crystal growth* 108.1-2 (1991): 351-366.
3. Fejer, Martin Michael. "Single crystal fibers: Growth dynamics and nonlinear optical interactions." Stanford University, 1986.

Figures used in the abstract

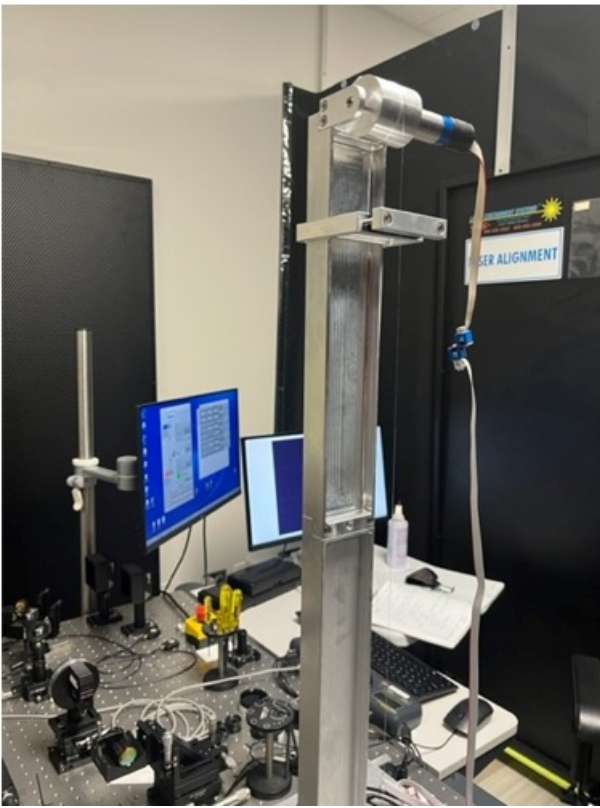


Figure 1 : Sapphire Growth Apparatus

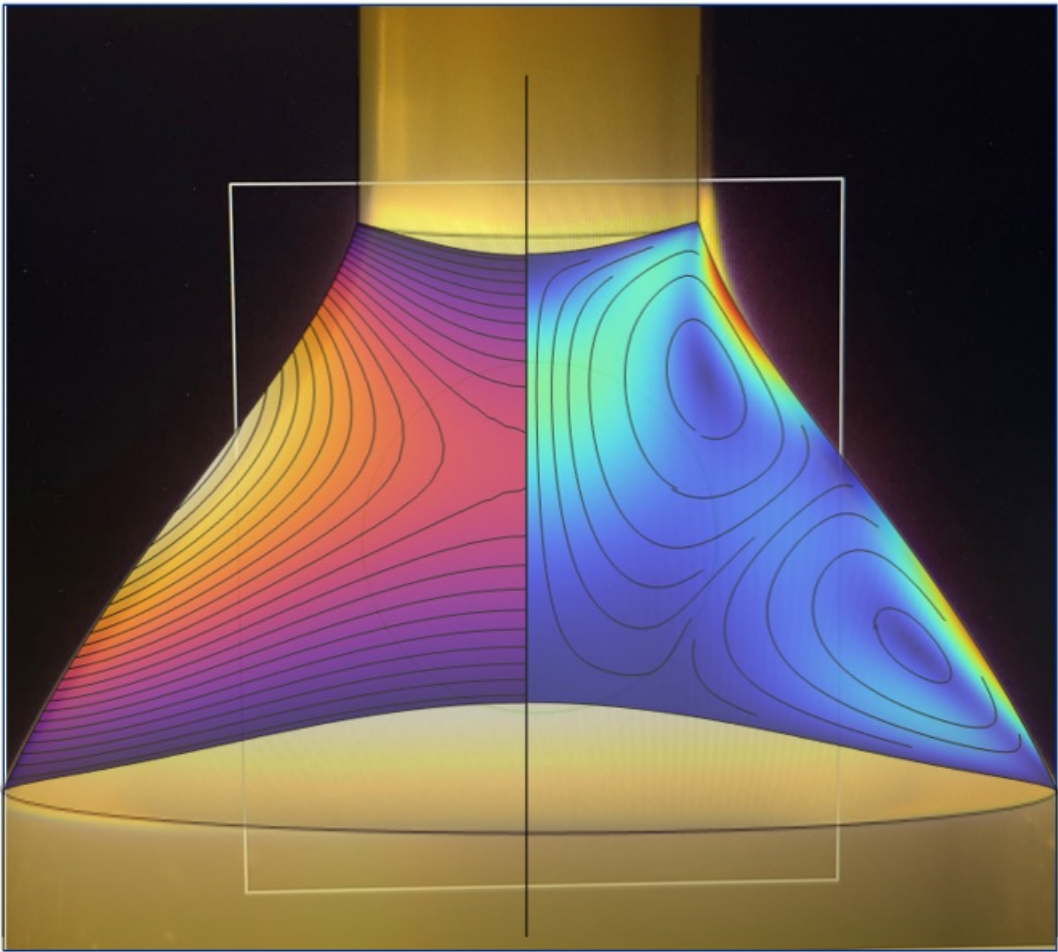


Figure 2 : Shape of the Molten Zone

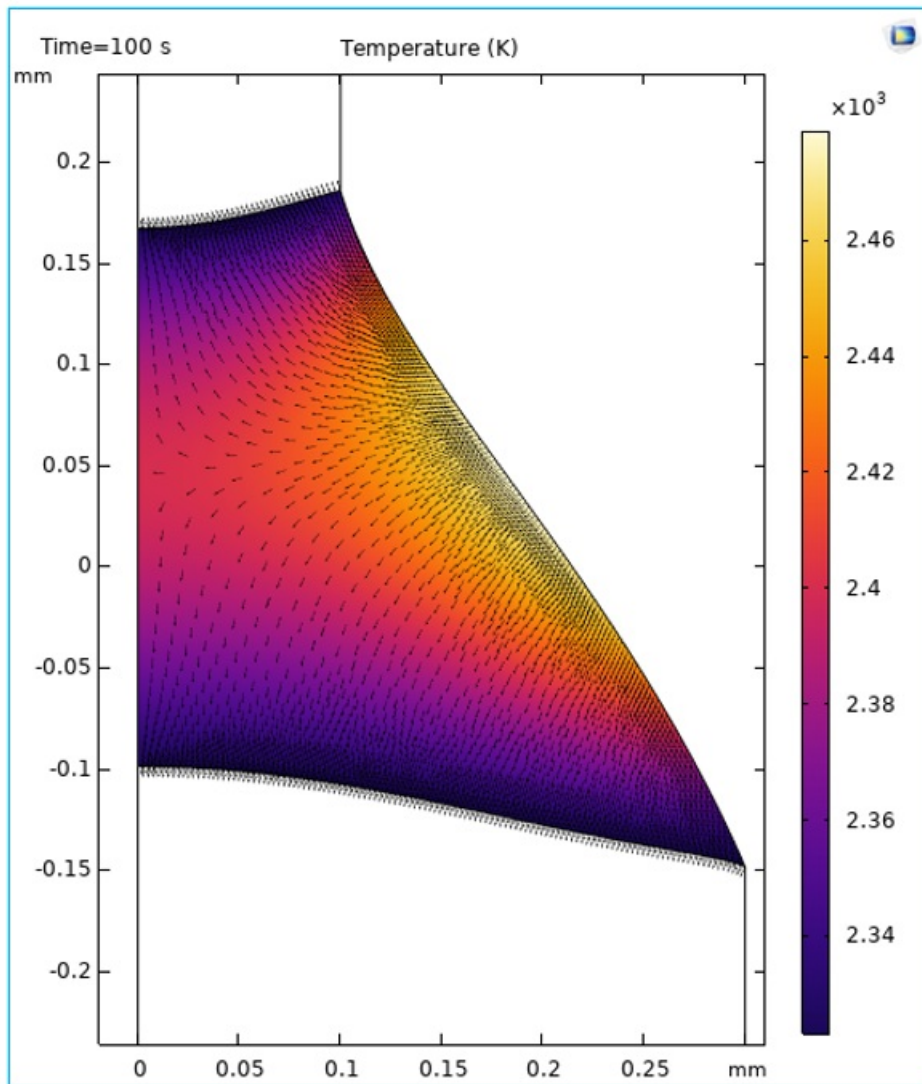


Figure 3 : Steady State Temperature Distribution

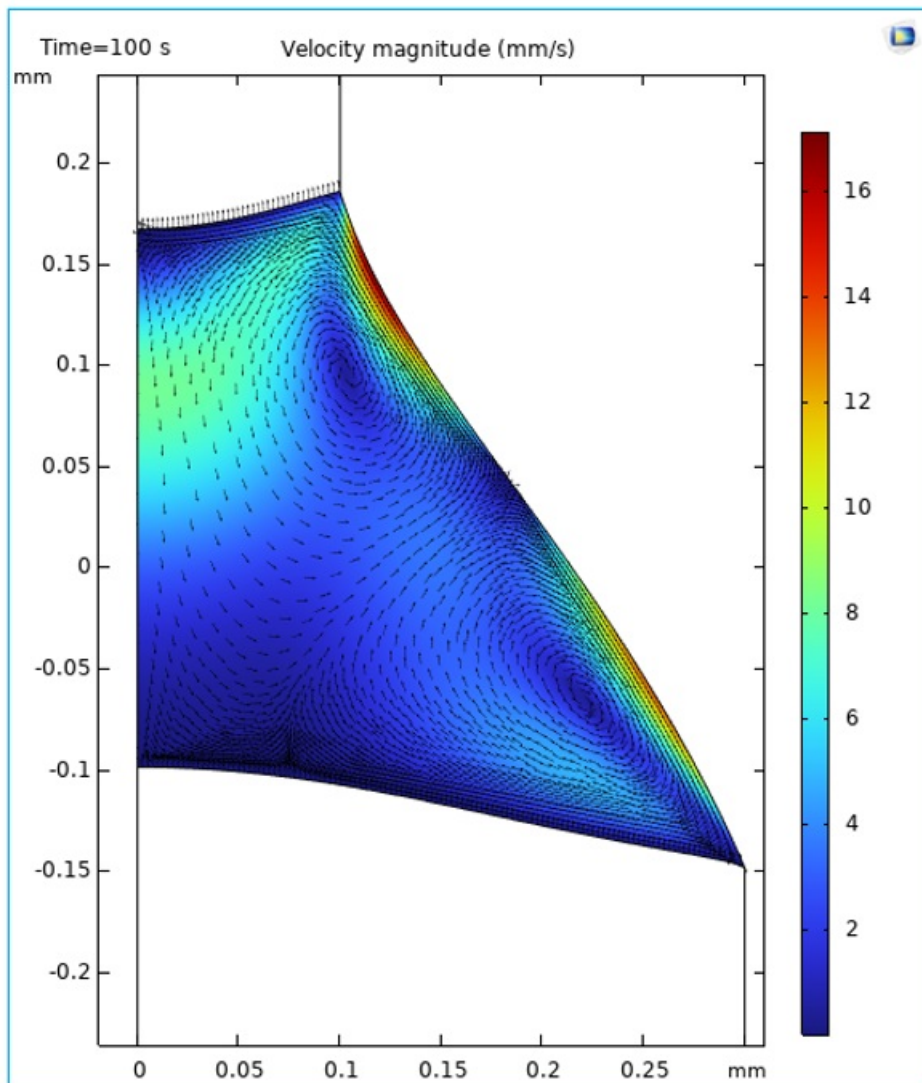


Figure 4 : Steady State Velocity Magnitude Distribution