The Effects of High Pressure on Crystal Growth in an Optical Floating Zone System

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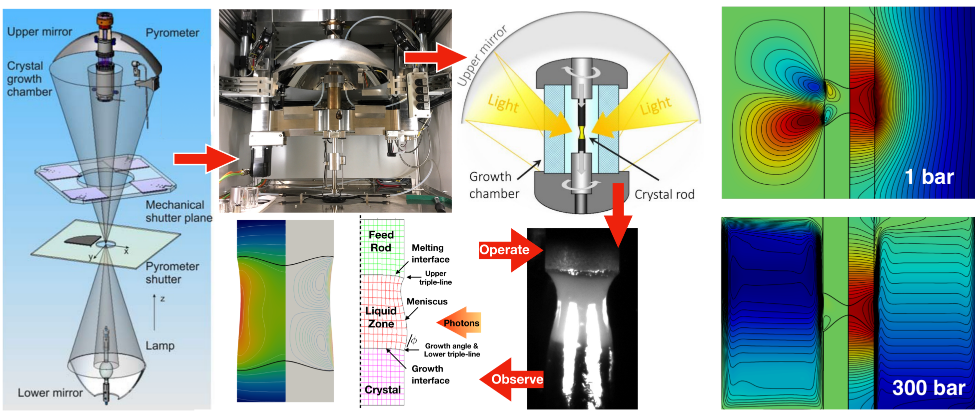
Optical floating zone (OFZ) crystal growth furnaces are powerful tools to grow single-crystal samples of materials that have never before been synthesized, a necessary step in the discovery of new materials with novel properties [1,2]. However, full utilization of these novel crystal growth systems is hindered by operational challenges brought on by nonlinear, strongly coupled phenomena and a lack of understanding of their underlying physical interactions. In a review of the OFZ technique, Dabkowska and Dabkowski [2] explain that growth is frequently difficult and that success often relies on intuition built from prior experience. These problems are further compounded by growth behaviors exhibited in the new generation of OFZ furnaces.

In this research, we focus on single-lamp, two-mirror optical floating zone systems that have been designed to operate under very high pressures, up to 300 bar (such as the HKZ system from Scientific Instruments Dresden, GmbH). We describe new challenges for the theoretical modeling of this growth system, particularly the representation of gas/fluid flows within the enclosure under high pressures [3].

Model results demonstrate the strong influence of high pressure in the gas/fluid volume surrounding the sample. We show how buoyant flows in this region dramatically strengthen with pressure, increasing heat transfer from the zone and further exacerbating vertical asymmetries. We address the impact of pressure on volatilization of components from the melt zone into the surrounding atmosphere. Additionally, we discuss probable instabilities that arise as these gas/fluid flows become turbulent at very high pressures.



(a) (b)

Figure 1: (a) We have developed models that describe high-pressure, optical floating zone (OFZ) crystal growth. (b) Sample results show flow streamlines (left) and isotherms (right) for sapphire crystals grown in the OFZ.

References

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[2] H.A. Dabkowska and A.B. Dabkowski. Optical Floating Zone–Complementary Crystal Growth Technique for New Classes of Oxide Materials. In: Bulk Crystal Growth: Handbook of Crystal Growth Vol. IIA, Basic Techniques, Ed. P. Rudolph. Elsevier 2015.

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