High-pressure, Laser-based Floating-Zone Crystal Growth

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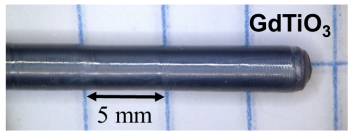
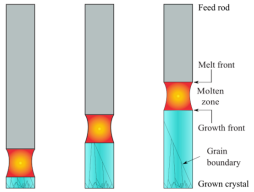
The floating-zone crystal growth technique can produce pristine, bulk single crystals, which are vital for realizing the goals of quantum materials

- **Disorder + impurities** can destabilize delicate quantum states and obscure exotic phase behaviors
- **Large crystals have practical, experimental advantages:**
  1. Resolution of inherent anisotropies
  2. Applicability of further techniques (*e.g.* neutrons)
- **Main limitations: *volatile, metastable*, or extremely *high-T_M* compounds**

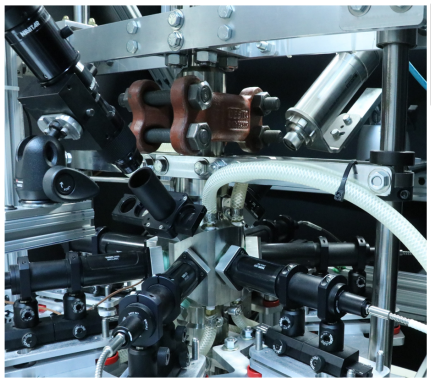
The high-pressure laser furnace [1]

- **Floating zone growth provides large, high quality single crystals**

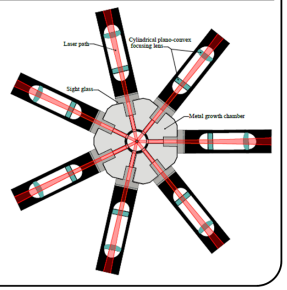




- **Laser heating address the limitations of floating-zone**
  - Allows structural chamber for *high pressure growth*
  - Sharp heating gradients improve *growth stability*
  - High power density for *high-T_M* oxides/intermetallics
- **High-pressure growth expands accessible phase space**
  - Growth of compounds with volatile components
  - Stabilize metastable compounds (i.e. unusual valences)
  - Prevent decomposition to allow (congruent) melting



Heating power:
1. 7 x 100 W, (800 nm)
2. 7 x 200 W, (1070 nm)



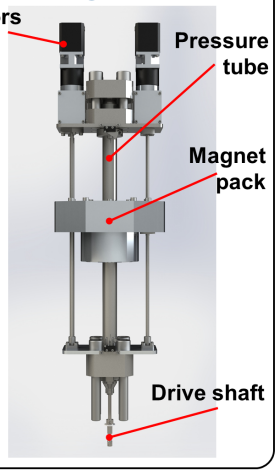
Magnetically coupled translators for smooth sample movement at high-pressure

Challenge:

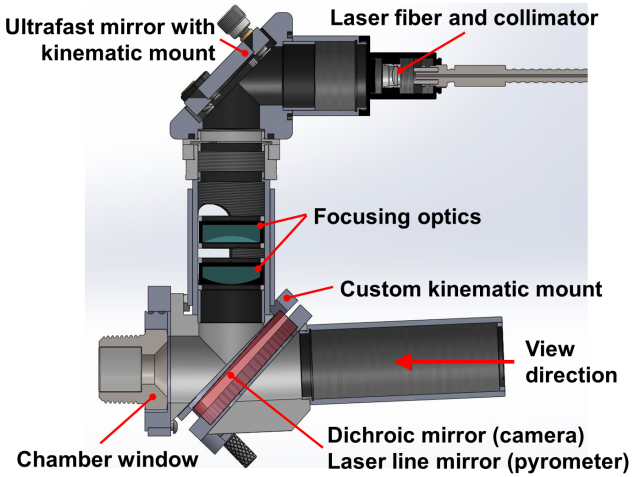
- Stable growth requires smooth *translation* and *rotation*
- A *dynamic seal* is prohibitively difficult at sufficiently high-pressure.

Solution:

- Magnetic coupling eliminates need for dynamic seal
- Drive shaft enclosed in high-pressure environment



In-plane imaging for *active* growth control



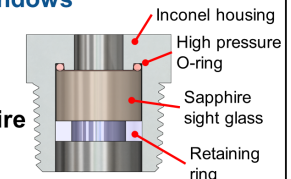
Structural growth chamber and windows

Custom Inconel pressure chamber

- **Max pressure = 15,000 psi (100 MPa)**
- Compatible with **O_2 up to 5000 psi**
- Seals to drives using re-usable metal seal ring (Destec)

Custom optical windows

- **Inconel housing**
- **O-ring seal**
- **Ar-coated sapphire sight glass**



Gas control and purification system

- In-line getter = high-purity inert environment
- High-pressure MFC = dynamic pressure to 10,000 psi

Bronkhorst high-P MFC
- Max inlet P = 10, 000 psi
- Flow = .028 – 1.4 L_n/min

Summary

- Floating-zone crystal growth produces samples well suited to the study of **quantum materials**
- The **high-pressure laser furnace** expands these capabilities and is a versatile platform for quantum materials synthesis
- Pressures up to **10,000 psi** can be realized for **reducing volatility**, **preventing decomposition** and **stabilizing metastable compounds**.

References

1. Schmehr, Julian L., et al. *Review of Scientific Instruments* 90.4 (2019)

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