Laser-Based Floating Zone Furnace by Quantum Design

Quantum Design is proud to offer a laser-based floating zone (L-FZ) furnace. This novel system, based on technology developed by RIKEN CEMS (Center for Emergent Matter Science) in Japan, promises the opportunity to grow materials unable to be grown by more traditional floating zone methods.

This 1.5kW or 2kW high-power furnace allows growth of:

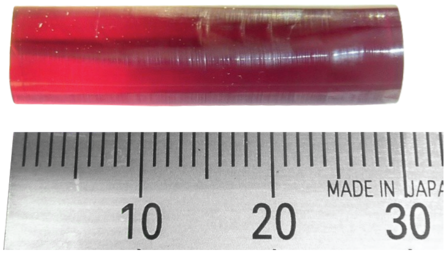
- Materials that melt within a narrow temperature range
- Materials with incongruent melting (ideal solution for TSFZ process)
- Materials with high vapor pressures near the melting temperature
- Metallic compounds with large thermal conductivity coefficients

** Photographs of the single crystals and data provided by Dr. Y. Kaneko of RIKEN CEMS.*

Patented technology:

The laser-based FZ furnace consists of a 5 laser-head design for guaranteed high uniformity of power density in the FZ region. The laser profile has been optimized to reduce thermal stresses during the crystal growth process. In addition, the system includes an integrated temperature sensor for real-time temperature readout and control.

Single crystals of high refractory materials (T_m > 2000 °C) are easily grown:



Ruby (T_m ~2072 °C)

Ruby with such a clean crystal surface cannot be grown in a Ha-FZ furnace.

Y-type Ferrite; $Ba_2Co_2Fe_{12}O_{22}$ (Tm 1440 °C)
(room temperature multi-ferroic materials)

Single crystals of materials with incongruent properties at melting temperature, due to a narrow melting temperature range (10 °C), cannot easily be grown by Ha-FZ method.

SmB_6 (T_m ~2345 °C) (a topological insulator)

Materials with refractory and high conductivity properties cannot be grown in a Ha-FZ furnace.

Traveling Solvent FZ (TSFZ) $SrCu_2(BO_3)_2$ could be grown over 320 hrs (14 days) (growth speed 0.25mm/hr)

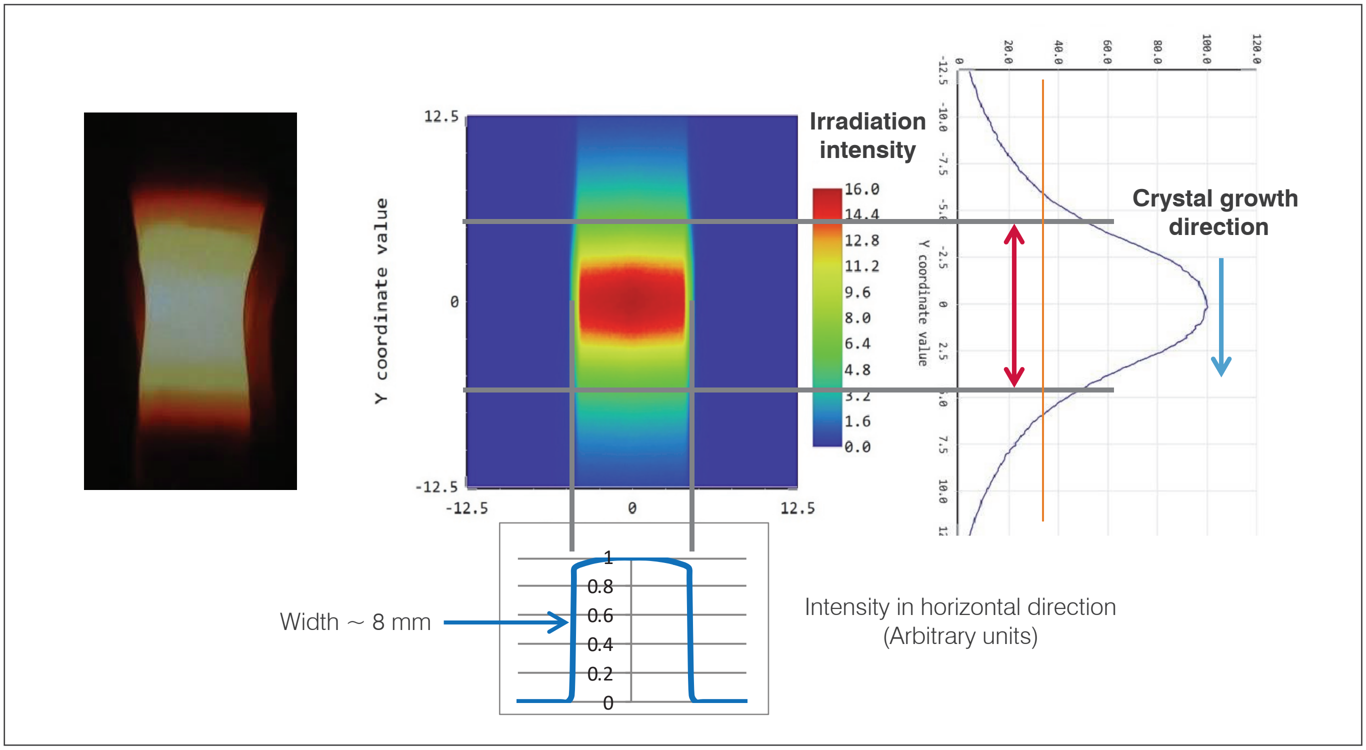
With the Ha-FZ method, 24 hr monitoring of the growth process is necessary. With the L-FZ system, automated feedback control of the FZ environment is possible to precisely monitor and control the FZ temperature, greatly reducing the required labor.

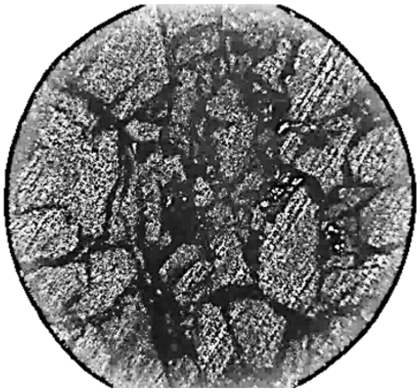
Wide temperature range from low to high melting temperatures available:

- One unit can cover the entire temperature range that traditionally requires both Halogen and Xenon lamps to achieve. **400 to 3000 °C** is achieved in one platform.
- No laser alignment or other adjustments to the optical system are necessary to cover the entire range of laser power.

Laser beam profile:

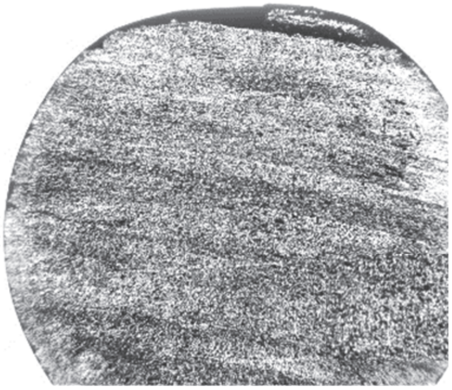
- The irradiation intensity distribution of the heating laser is **circumferentially uniform**. Whereas in the direction of the crystal growth, a **gradual irradiation intensity** distribution is adopted.
- A circumferential homogeneity of **over 95%** of irradiation intensity on the outer surface of the raw material is achieved.
- This optimization of the laser beam profile reduces thermal stresses on crystals as compared against a conventional laser FZ furnace consisting of a traditional top-hat laser power profile.





$TbMnO_3$ grown in a L-FZ furnace with atypical **top-hat** laser power profile – cracks in the material due to thermal stresses.

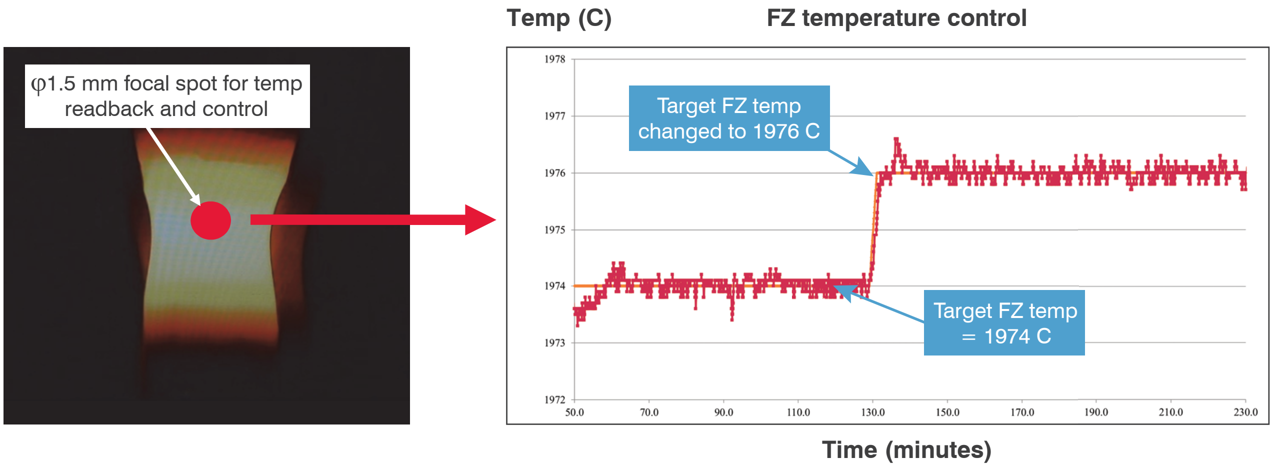
$TbMnO_3$



$TbMnO_3$ grown in the L-FZ system with a more **gradual** laser power profile illustrated above – note the absence of cracks!

The temperature can be monitored and controlled with precision and in real time:

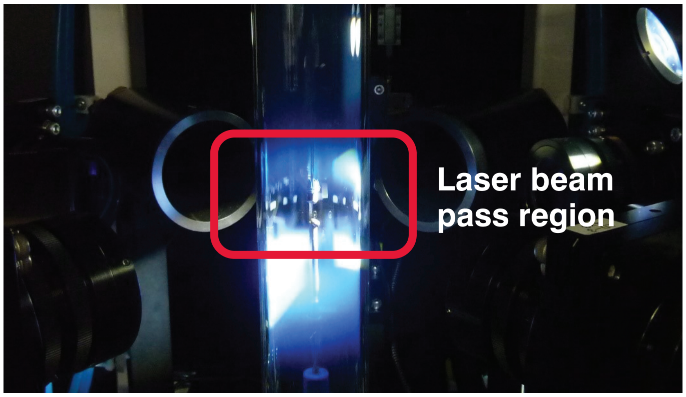
- Temperature monitored with spatial resolution of **better than φ1.5 mm.**
- Temperature of molten zone can be directly monitored and recorded over the entire temperature range **up to 3000 °C** with an integrated radiation thermometer.
- High precision single crystal growth: High precision temperature control of the desired melting zone temperature is possible.
- The temperature of the melting zone can be controlled to the target temperature on the phase diagram with minimal temperature overshooting, ensuring growth of the desired compound. In a conventional Ha-FZ furnace, control of the FZ molten region is typically visual.
- Ideal for crystal production by the TSFZ method requiring long-term, unattended temperature control over a narrow **1 °C** temperature window.
- Reproducibility of measured temperature is **within ± 1 °C**.



Ideal for materials with high volatility:

- Compared to a traditional Halogen or Xenon lamp, the laser generates a much more concentrated energy profile at the FZ region.
- Less of the feed material is exposed to the higher temperatures generated by the energy source, lessening the amount of evaporative material which can contaminate the quartz tube.
- The focused laser power acts to ablate any evaporates that may contaminate the quartz tube, leaving the quartz tube relatively clean in the laser-beam pass region.
- Optional thin-wall protective quartz sleeves are available to help further protect the inside diameter of the quartz tube from damage or contamination.

Sr_2RuO_4 (T_m~1860 °C)



The floating zone furnace could be used with both, oxygen-gas mixtures as well as oxygen-free Argon gas mixtures for alloy single crystal growth.

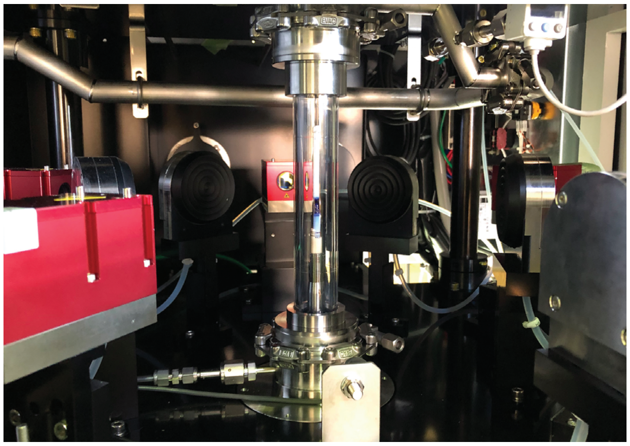
Optional accessories:

- **High vacuum pumping system:** For pumping the floating zone region down to less than 0.001 Pa.
- **Cold trap:** For trapping materials that outgas from the feed rod.
- **Gas curtain:** Generates a gas sheath flow along the inner wall of the quartz tube which helps reduce contamination of the quartz tube.
- **Mass flow controller:** Provides fine PC controlled gas flow to the floating zone region. Up to two gases may be mixed.
- **Bake-out system:** Heater that is applied to the quartz and metal tubes. During the evacuation of the floating zone region, this heater can be used to help remove any contaminants for a more thorough initial evacuation of the FZ region.
- **Variable beam profile:** The default beam profile along the z (growth) direction has a Gaussian profile 12 mm in length. This is user selectable down to as short as 3 mm in cases where higher power densities are necessary in the floating zone region.
- **Quartz sleeves:** Thin-walled quartz sleeves that just fit within the main floating zone quartz tube. These tubes prevent the main quartz tube from contamination.

Specifications*

* Subject to change without notification

Heating control	Number of laser beams/heads	5 laser beams from 5 laser heads, high power diode laser
	Laser total power in FZ region	1500 watts (300 watts ×5 beams) or 2000 watts (400 watts ×5 beams)
	Temperature range	400 °C ~ 2750 °C (based on melting of HfO_2)
	Temperature monitoring	800 °C ~ 3000 °C (radiation thermometer)
	Temperature reproducibility	±1 °C over entire temperature range
	Temperature FB control	±0.5 °C over entire thermometer temperature range
Crystal Growth Control	Crystal growth max. length	150 mm
	Crystal diameter	> 8.0 mm (material dependent)
	Growth speed, Rotation speed	0.1 to 300 mm (mm/hr) / 0.1 to 40 rpm
	FZ region vacuum / pressure	0.01 Pa / 1 MPa
	FZ Environment	User-supplied external gas
	Growth monitoring	High vision full HDTV camera
Others	Instrument footprint	W 250 x D 200 x H 220 (cm) (approximate)



Quantum Design

10307 Pacific Center Court, San Diego, CA 92121
Tel: +1-858-481-4400 • www.qdusa.com • info@qdusa.com 1105-109 Rev. A0

Learn More >