Growth of large diameter high-purity germanium crystals for Nuclear Physics research

Principal Investigator: Richard Pehl, Ph.D.
Presented by Ethan Hull, Ph.D.

DE-SC0004256
Phase II: 8/15/11-8/14/13

Extremely large diameter (150-200 mm) high-purity germanium crystals are being developed for large diameter Nuclear Physics planar detectors. A high-purity germanium crystal puller has been demonstrated to grow crystals having sufficient purity and charge-collection properties to produce detector-quality germanium. The puller has the capacity to grow very large diameter (~ 200 mm) germanium crystals. The diameter of the germanium crystals and purity levels are being iteratively improved. The results are being constantly monitored through test detector fabrication and gamma-ray spectroscopy measurements.

Collaboration with Kim Lister at UMass Lowell

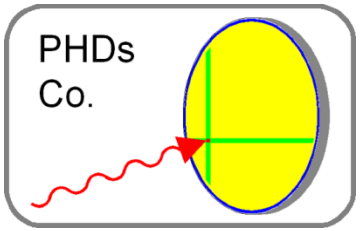
- Material Processing and Crystal Growth at PHDs Co.
- Crystal Measurements and Properties
  - Large diameter challenges
  - Impurity concentration and doping
  - Charge collection
- Products – Nuclear Physics is the basis

PHDs Co. 3011 Amherst Rd, Knoxville, TN www.phdsco.com

- Germanium Detector Systems
  - Concept
  - Germanium refinement and crystal growth
  - Mechanical-Vacuum-Cryogenic Engineering
  - Detector Fabrication
  - System Integration
  - Information output

- Est. Fall 2004, Ethan Hull CEO, Richard Pehl CFO
- 9 FTEs + 2-3 Consultants – Technical Emphasis

- PHDs Co. sells germanium detector system products
  - Nuclear Physics - NPX-M
  - Security Applications - GeGI and SPG
  - Nuclear Medicine - MIX

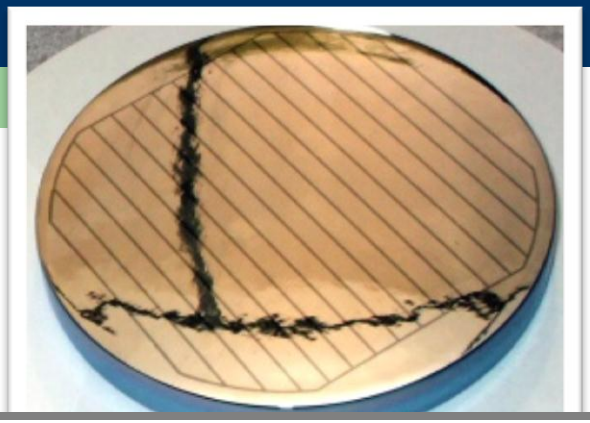


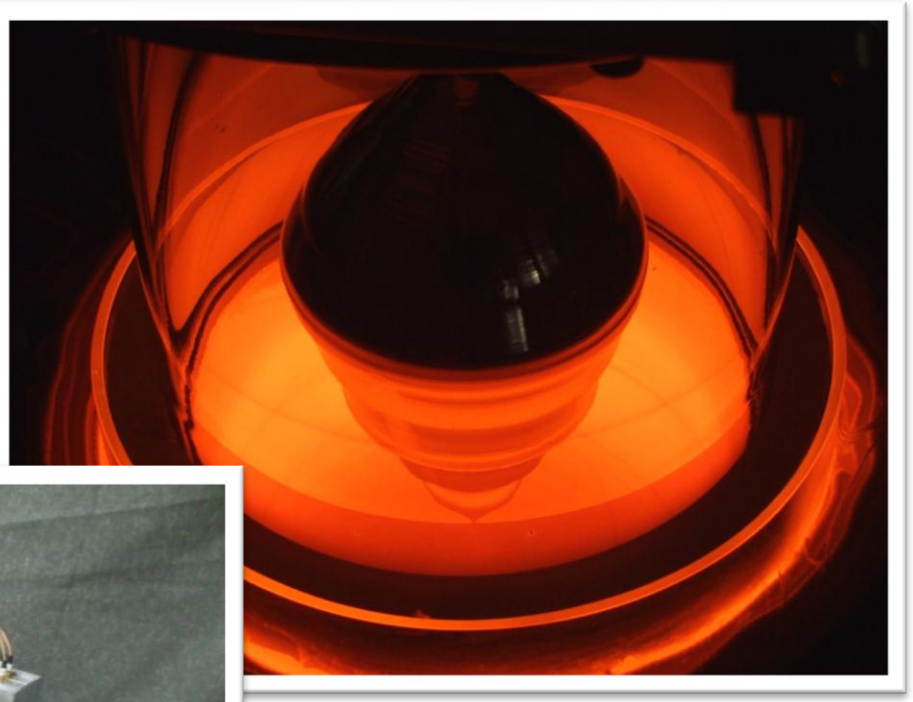
PHDs Co.

10,000 ft² Facility
Knoxville, TN

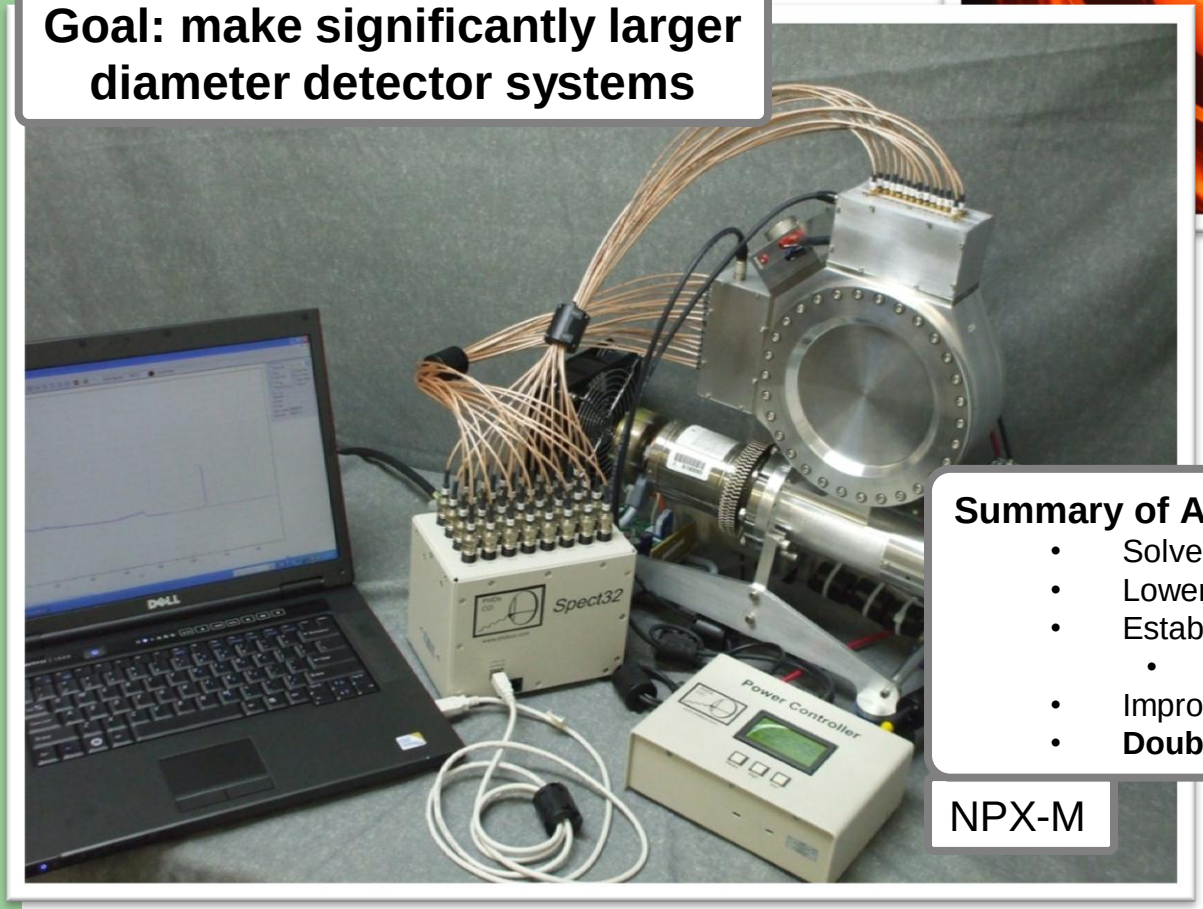
Technical area (~ 8000 ft²)

Office area (~ 2000 ft²)





Goal: make significantly larger diameter detector systems



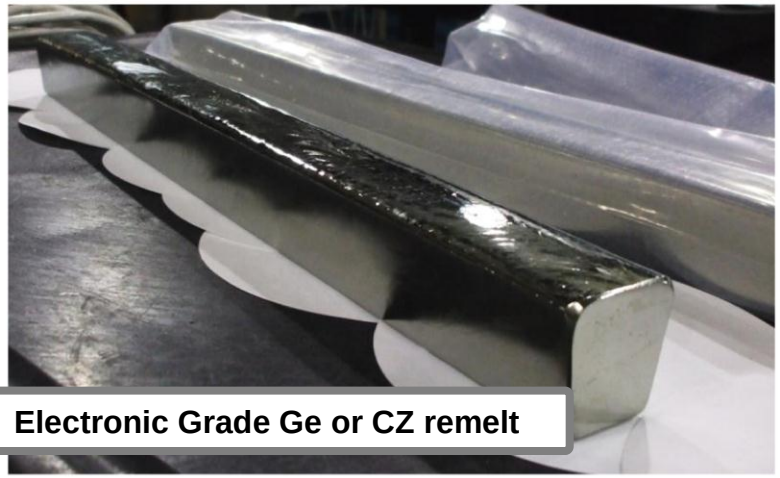
NPX-M

Summary of Accomplishments

- Solved some large-diameter challenges ~ N(r)
- Lowered Impurity concentration to tolerable levels
- Established a viable doping method
  - Sources of contamination
- Improved understanding of trapping
- **Doubled the mass and area of the crystals!!!!**

Material Processing and Crystal Growth at PHDs Co.

PHDs Co.



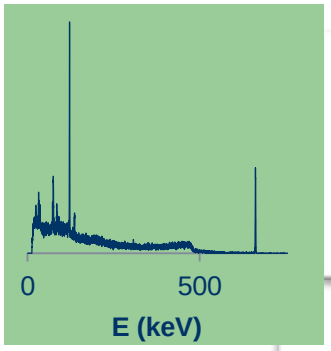
Electronic Grade Ge or CZ remelt

High Purity Zone refinement, SiO_2, H_2

High Purity CZ Puller, SiO_2, H_2

Evaluation

Detectors



10 kg HP ZR Ge
In the puller

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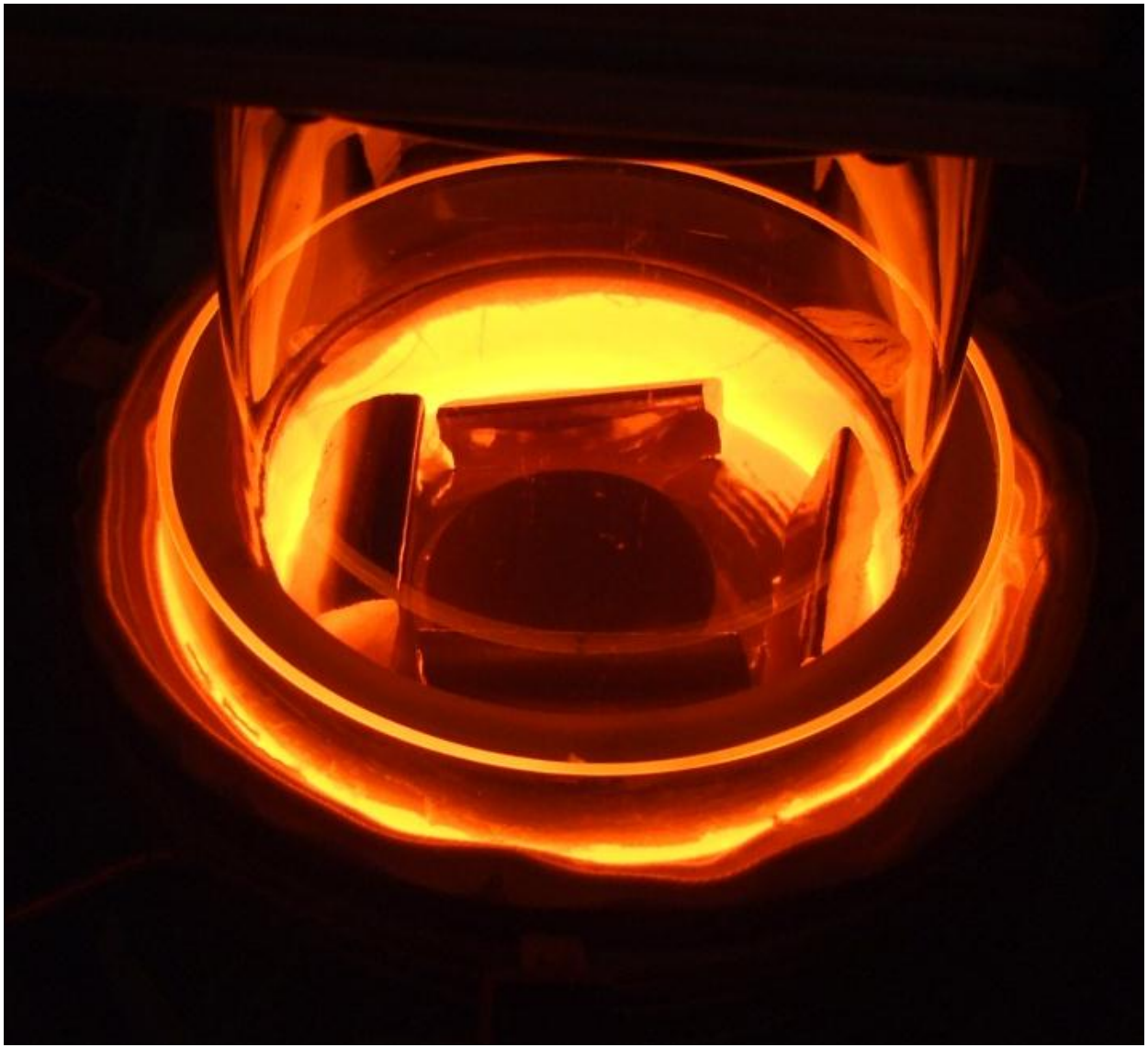

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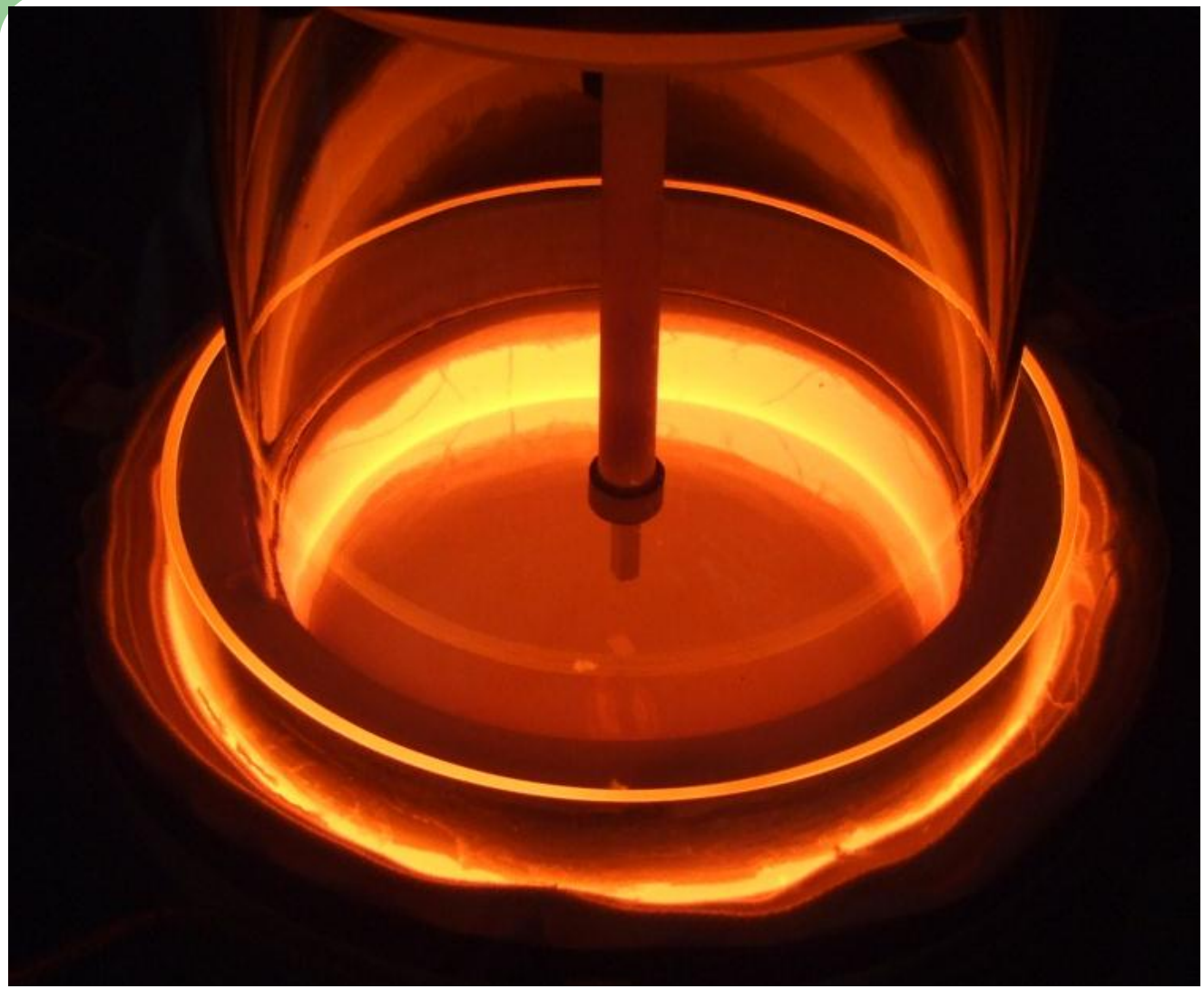

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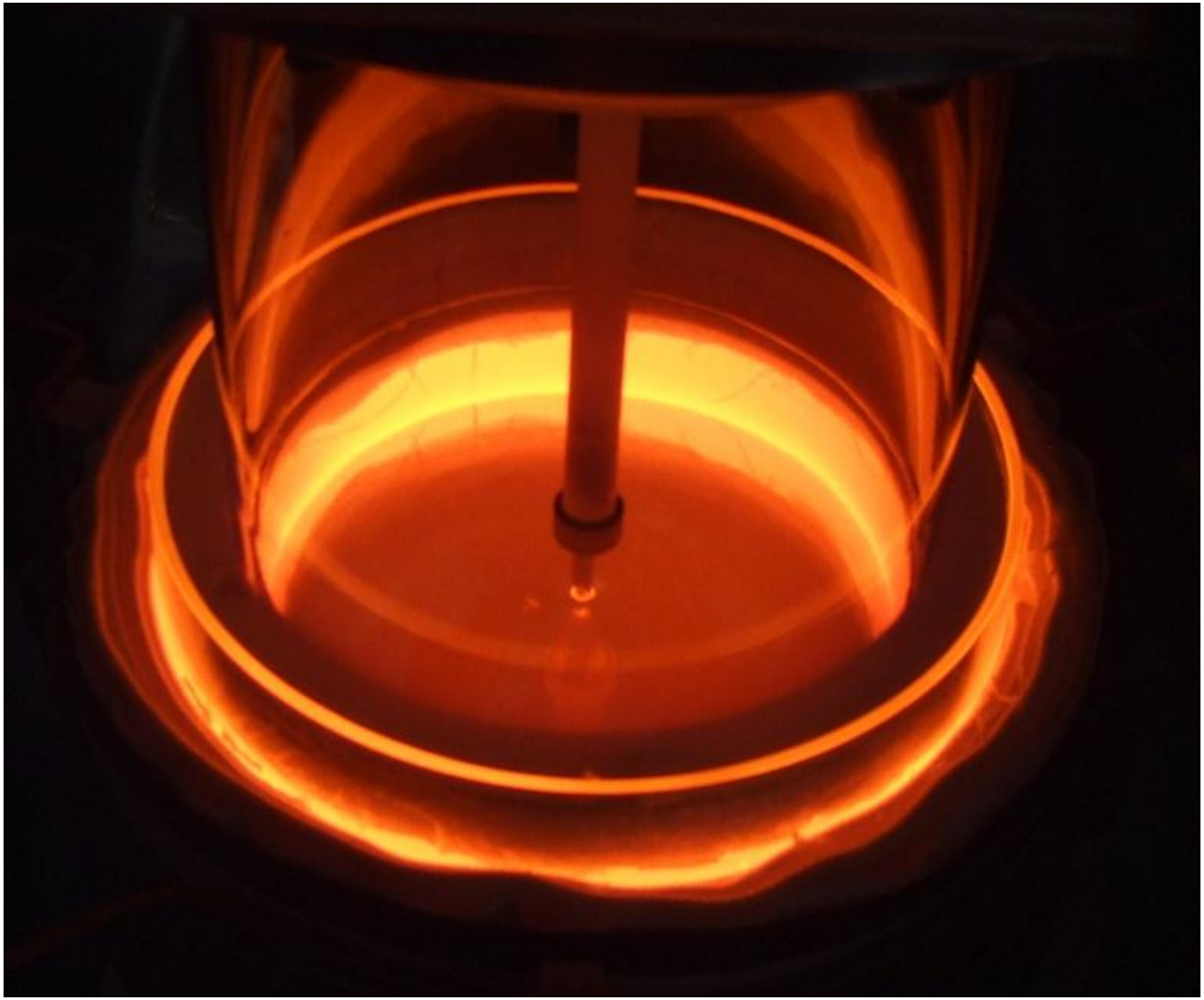

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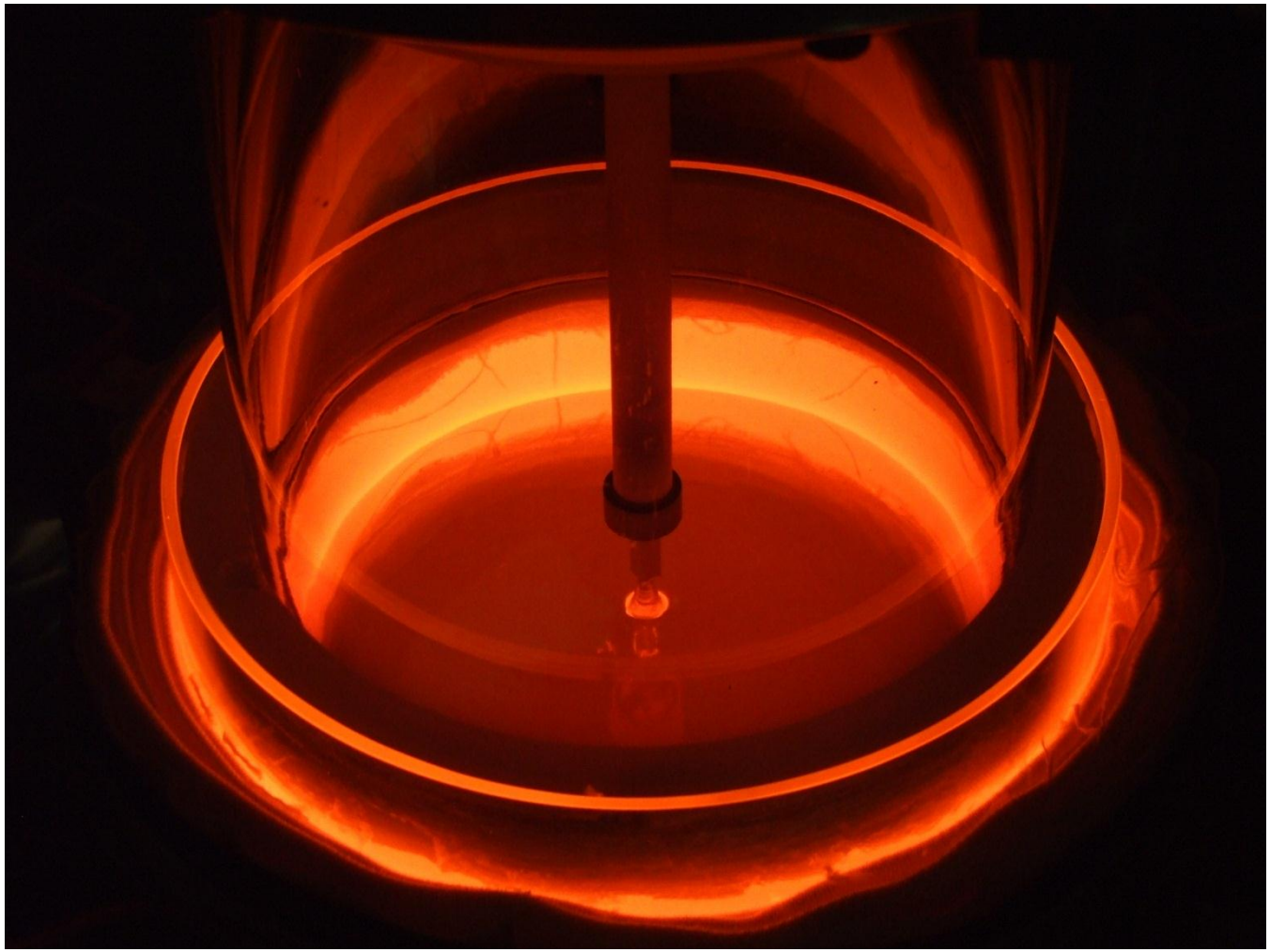

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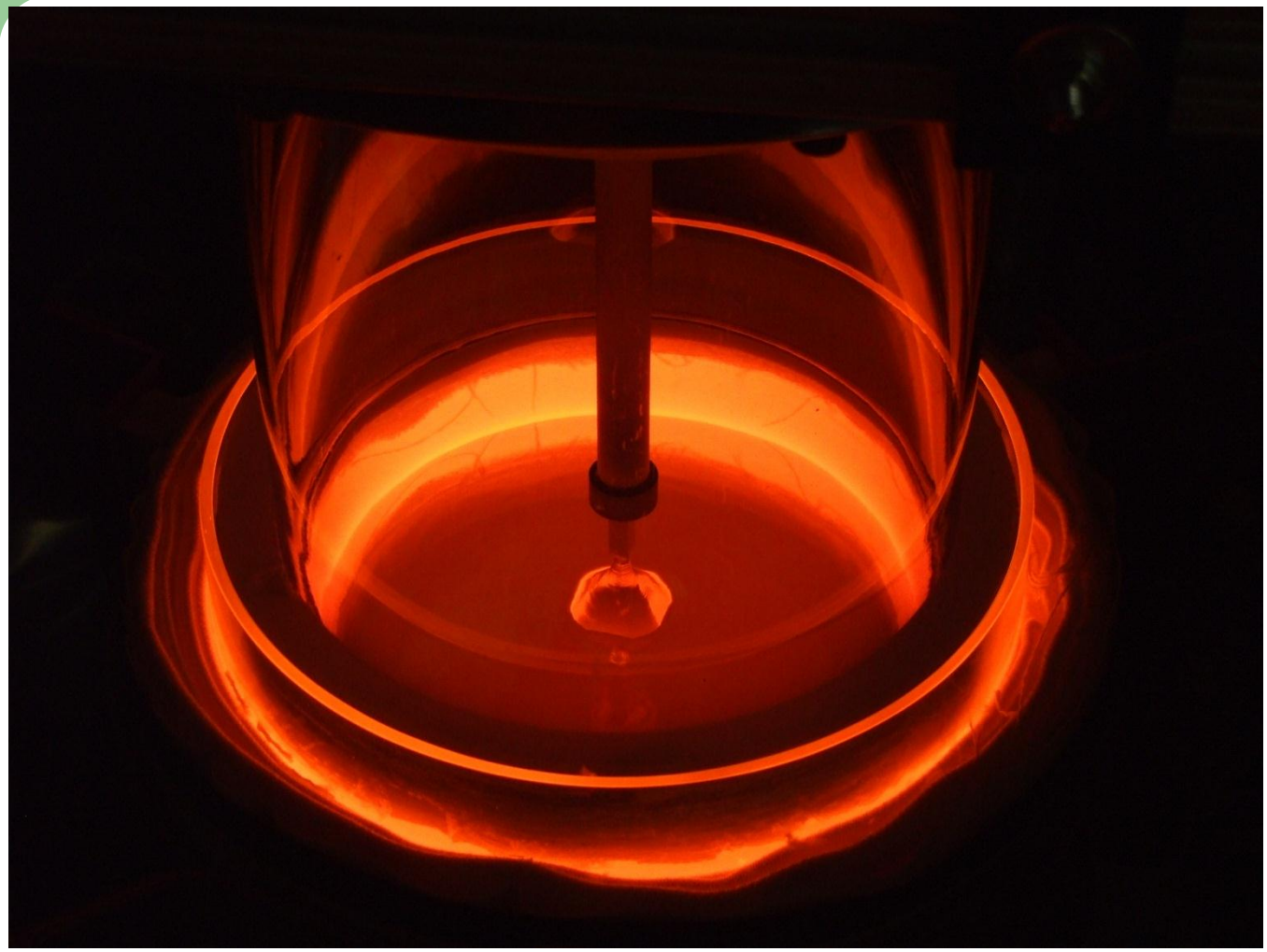

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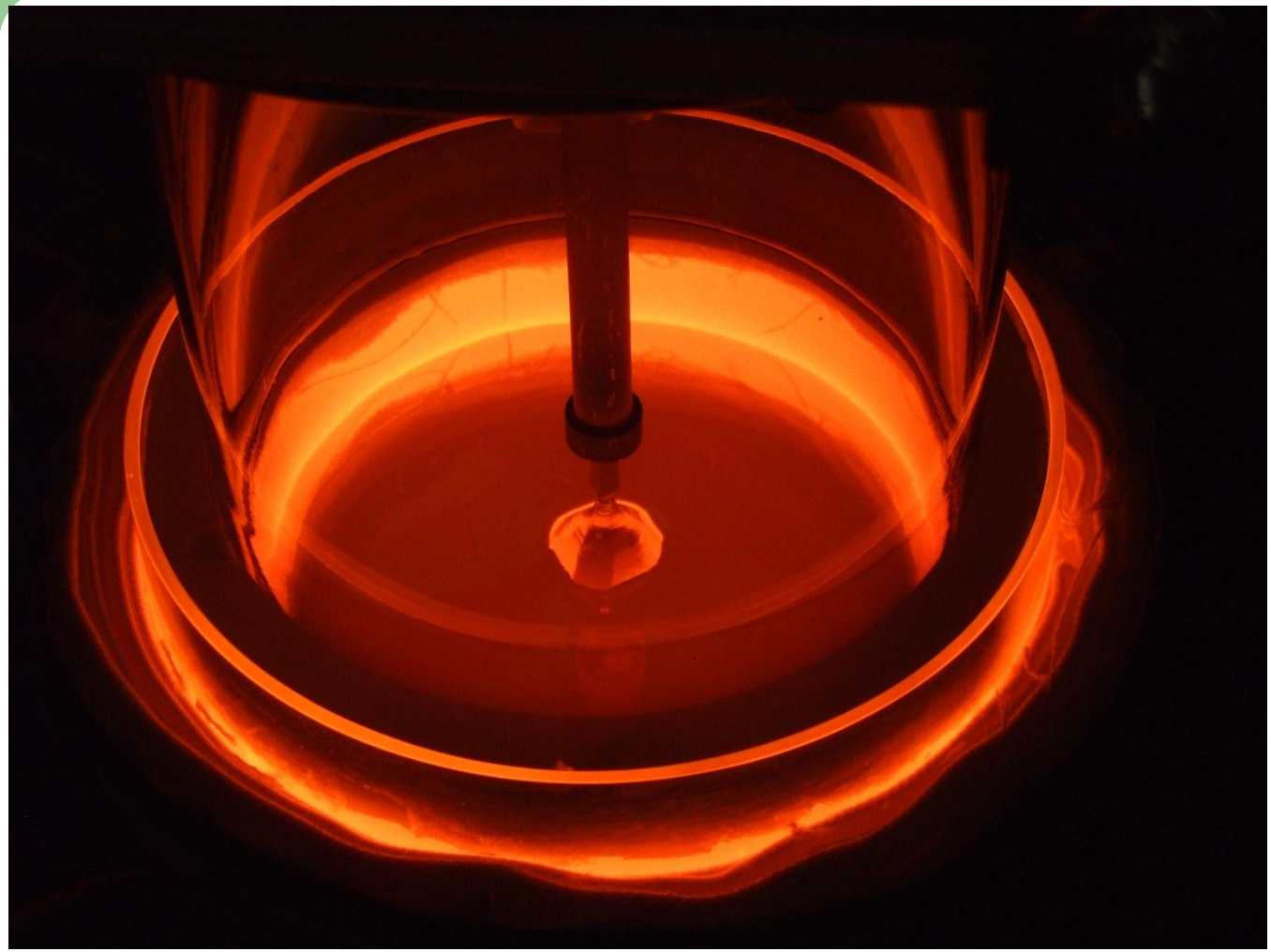

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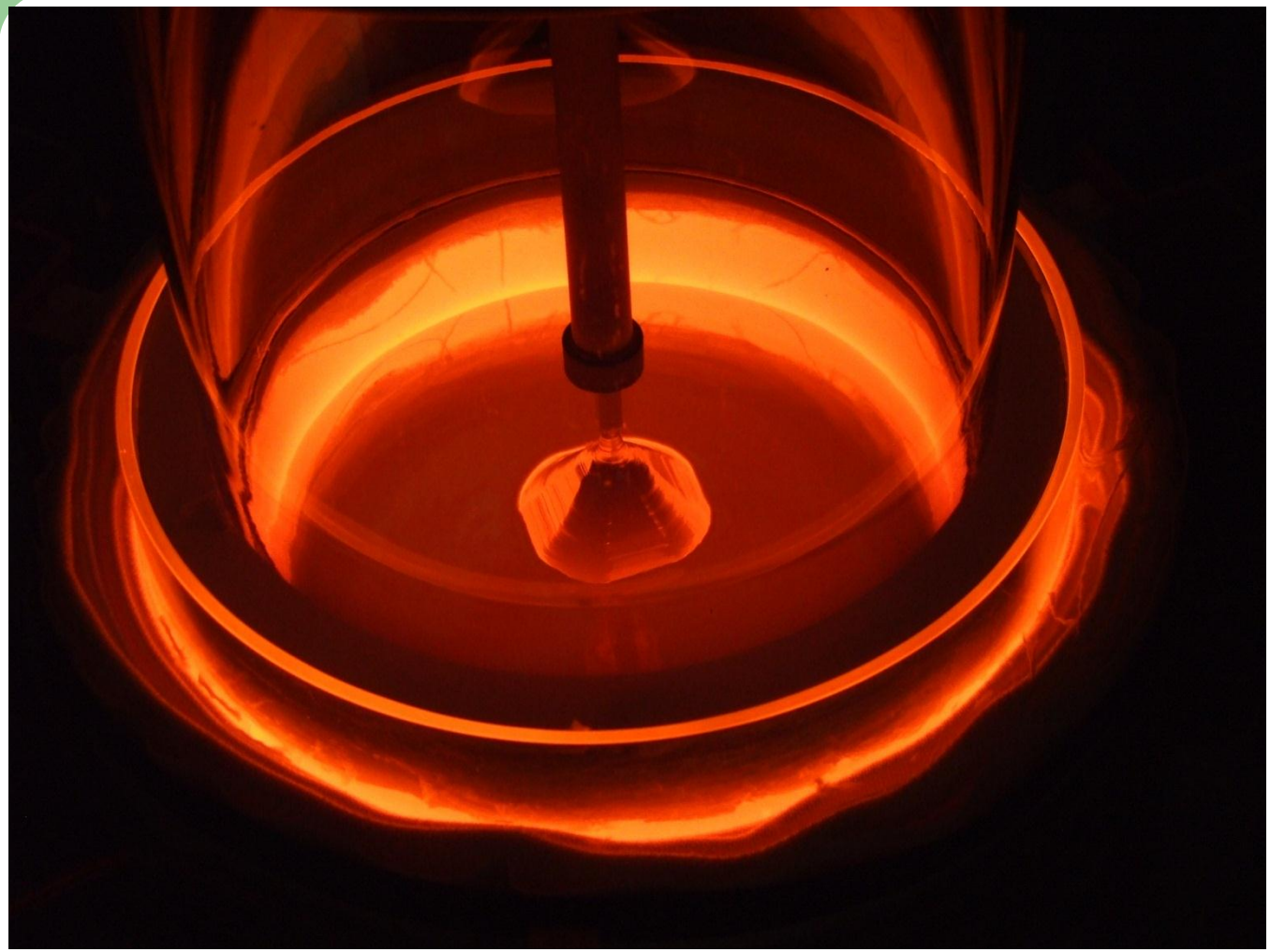

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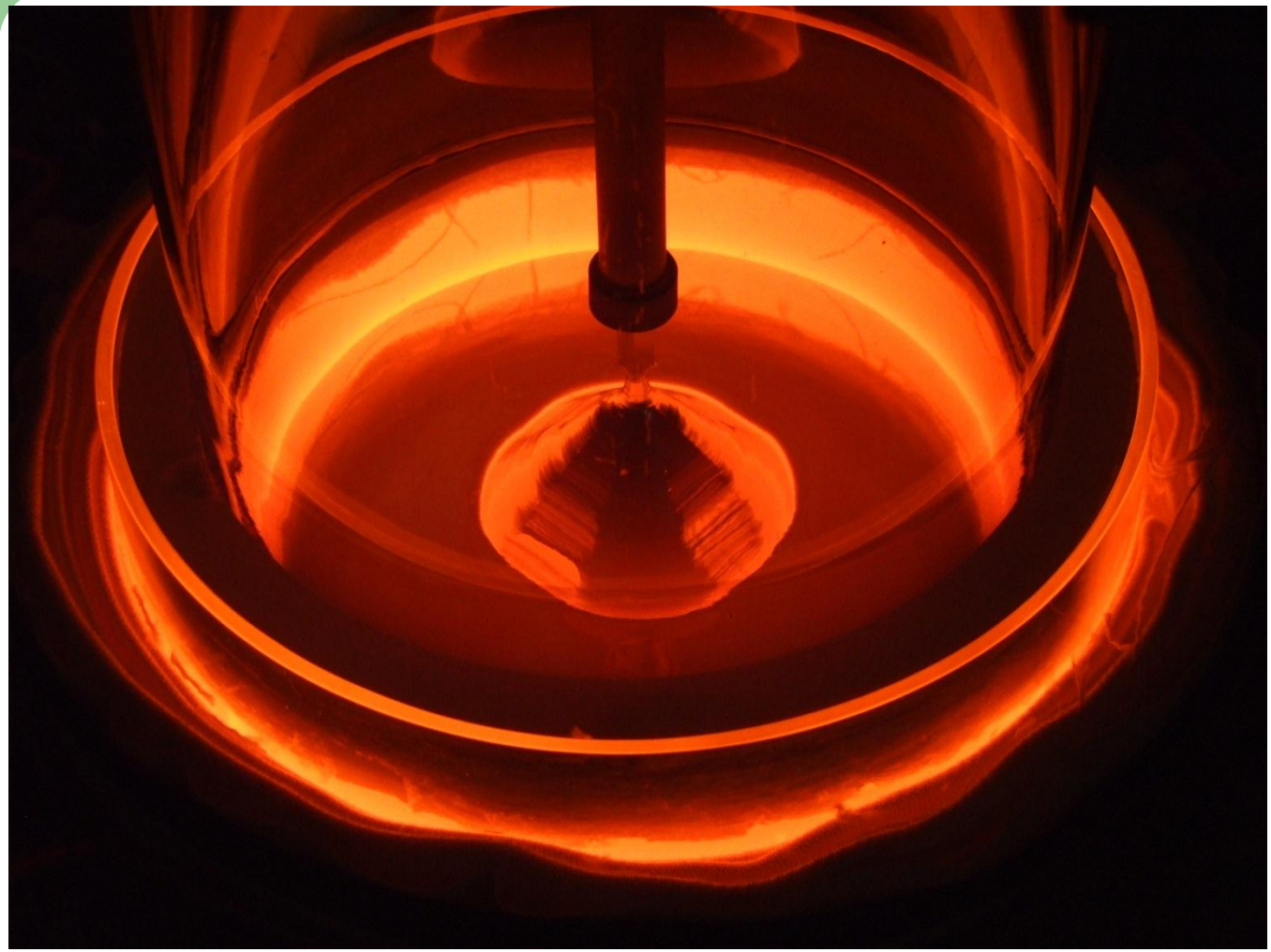

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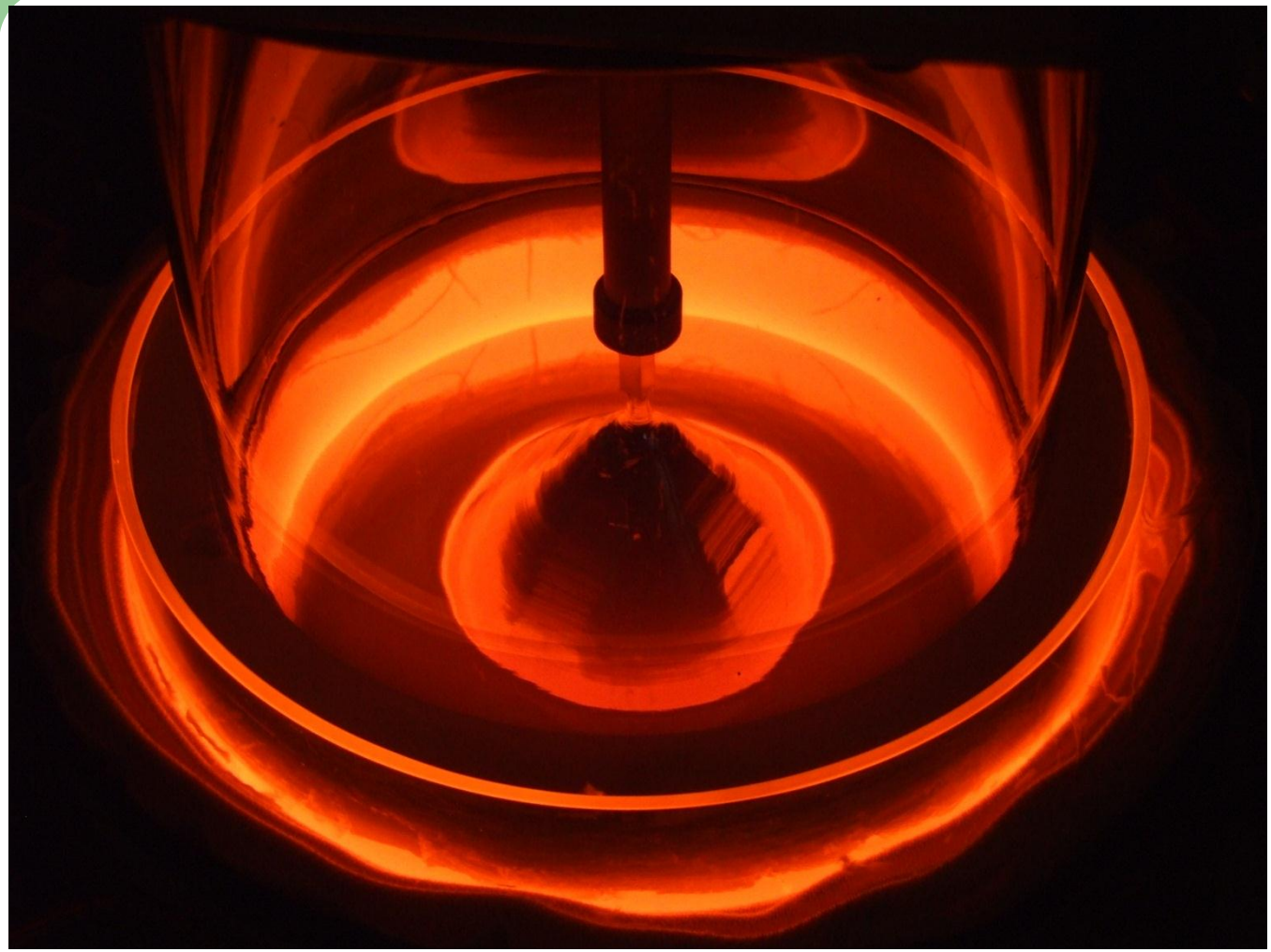

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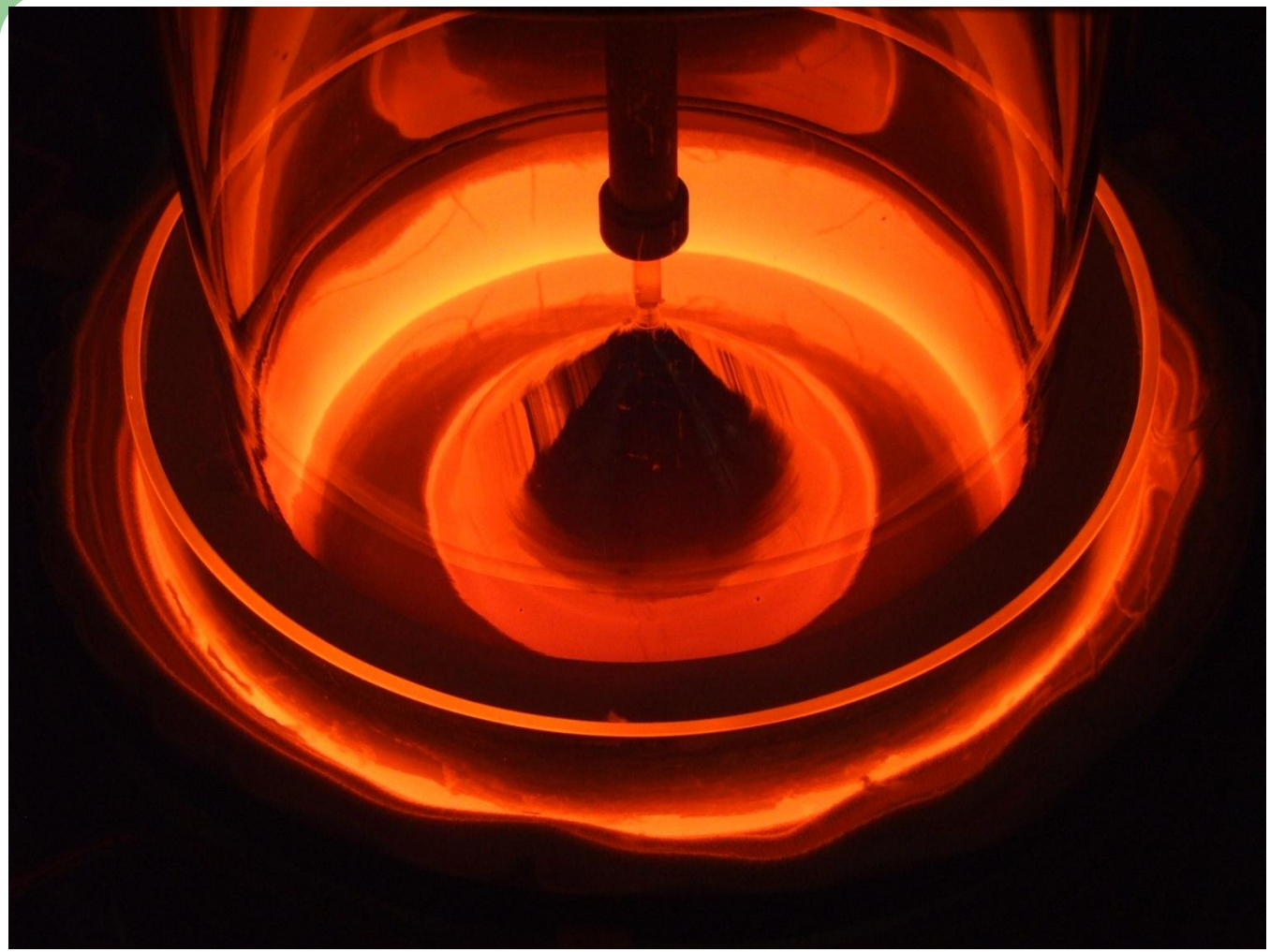

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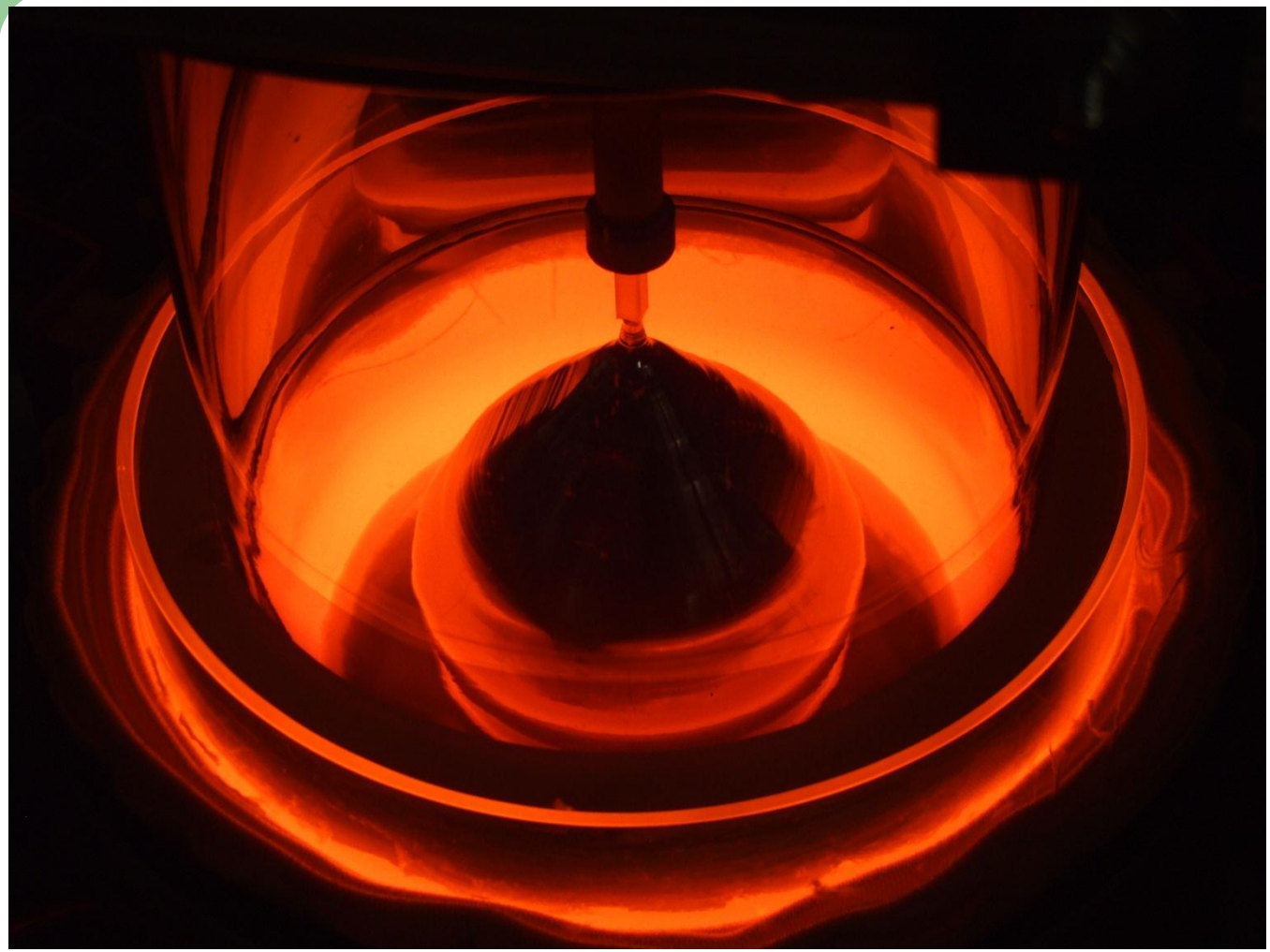

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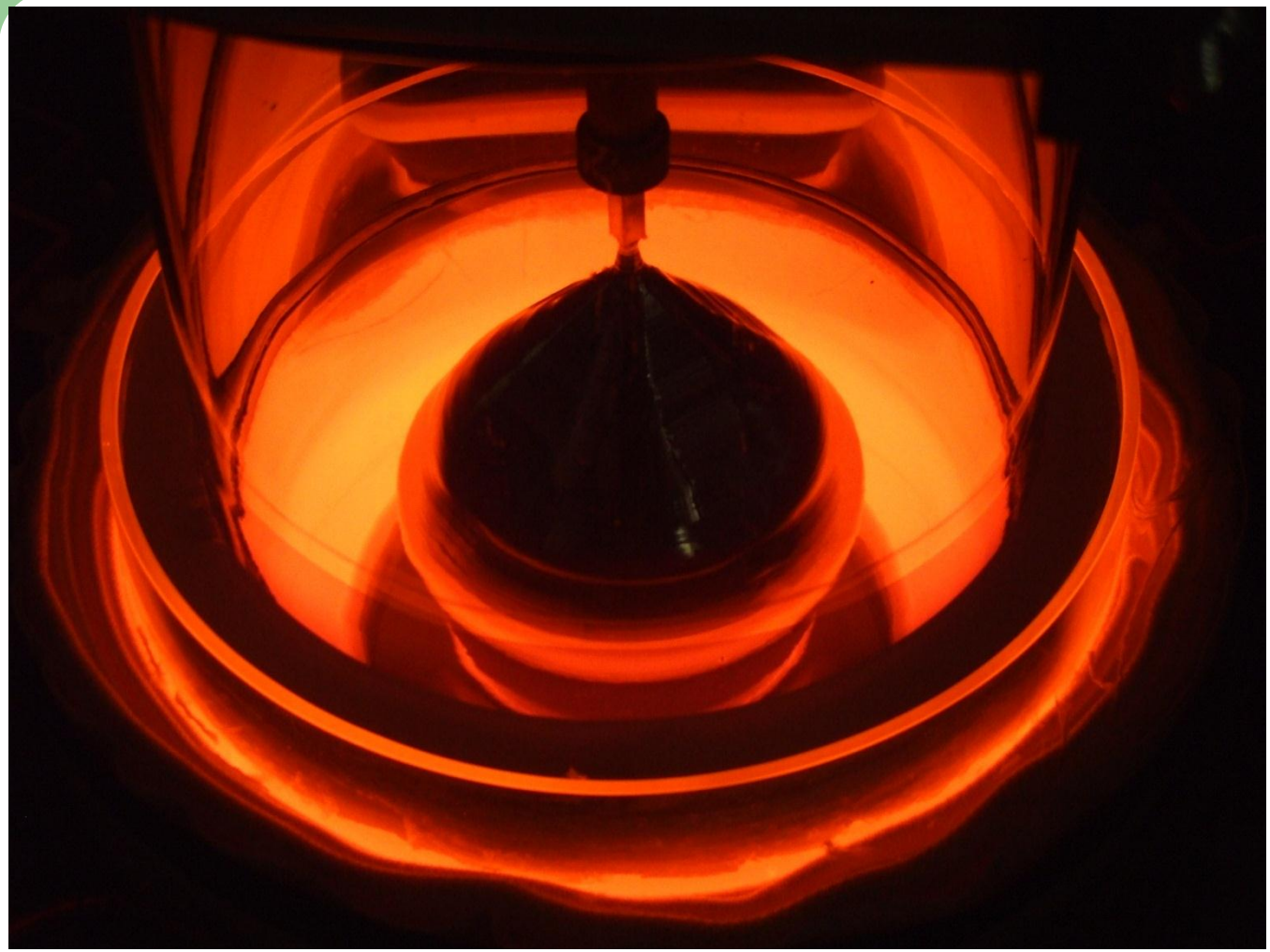

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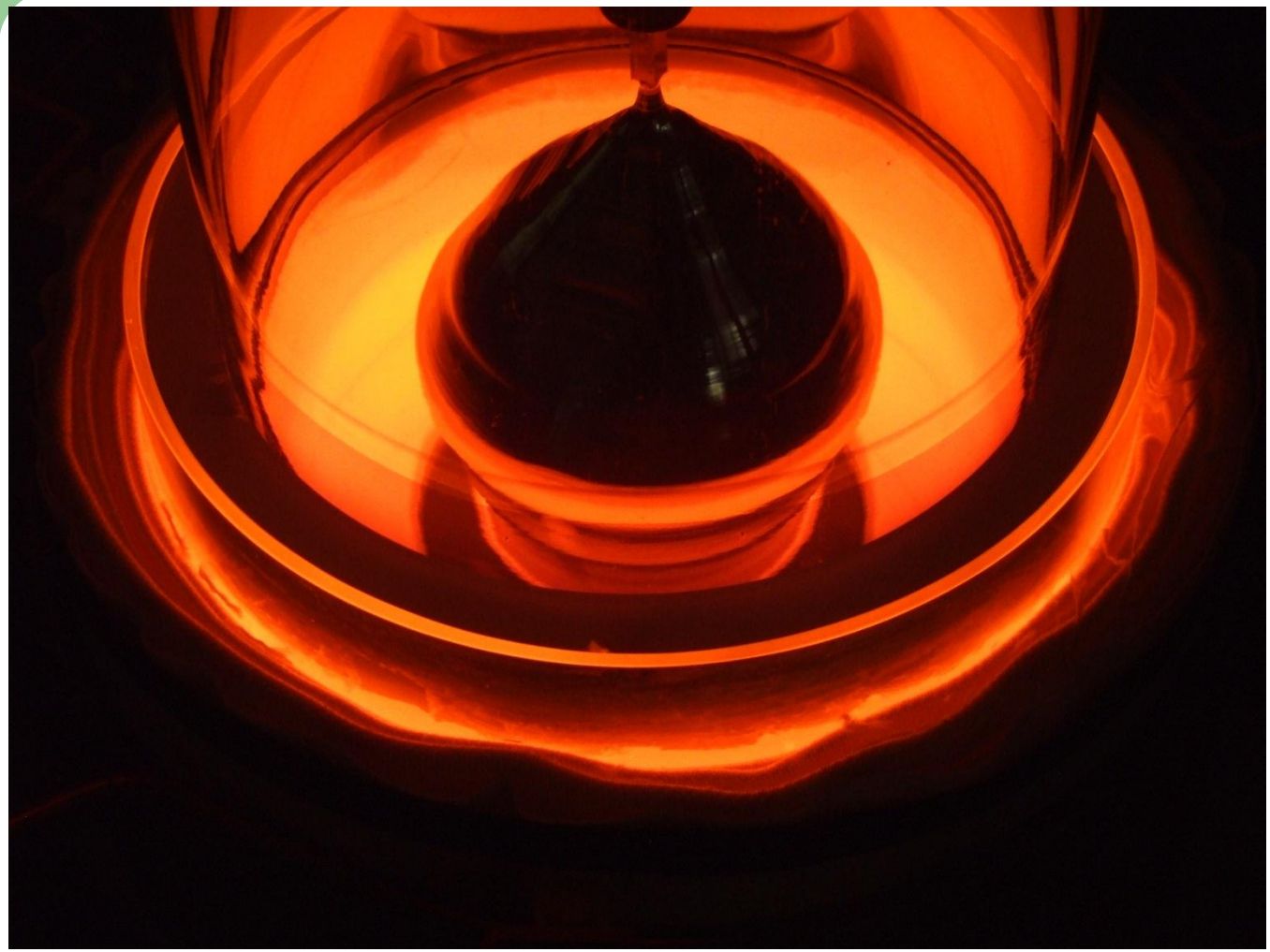

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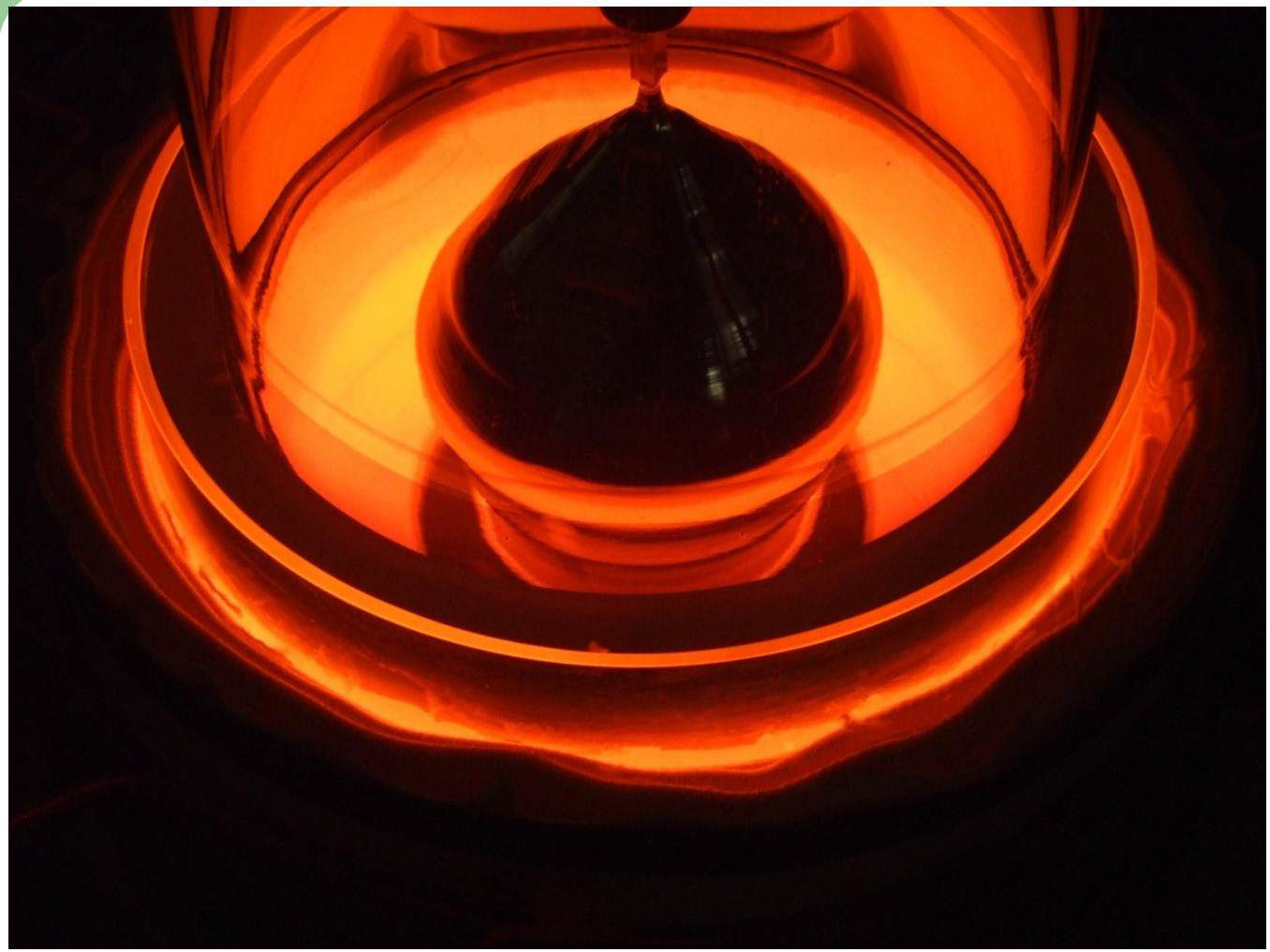

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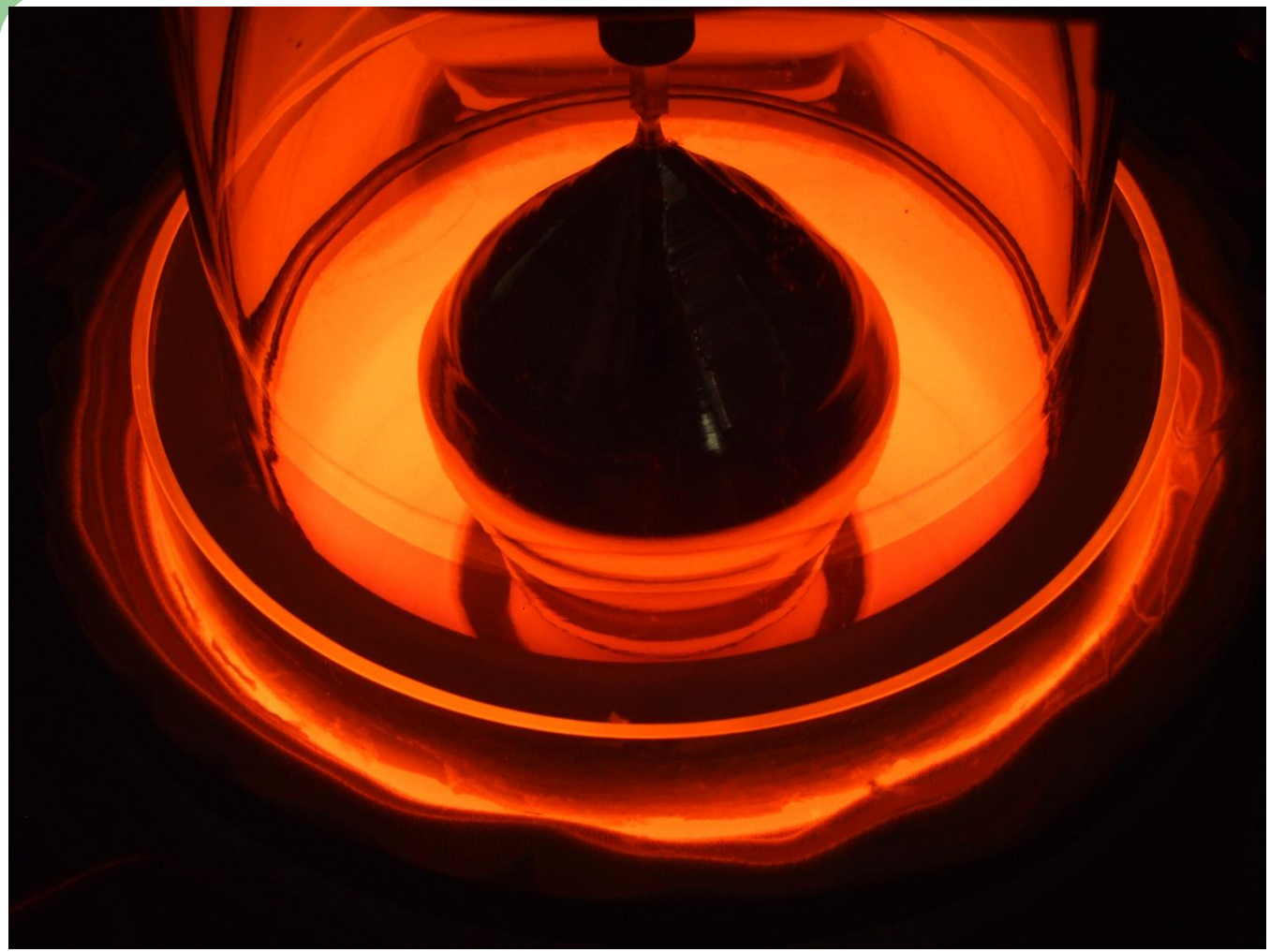

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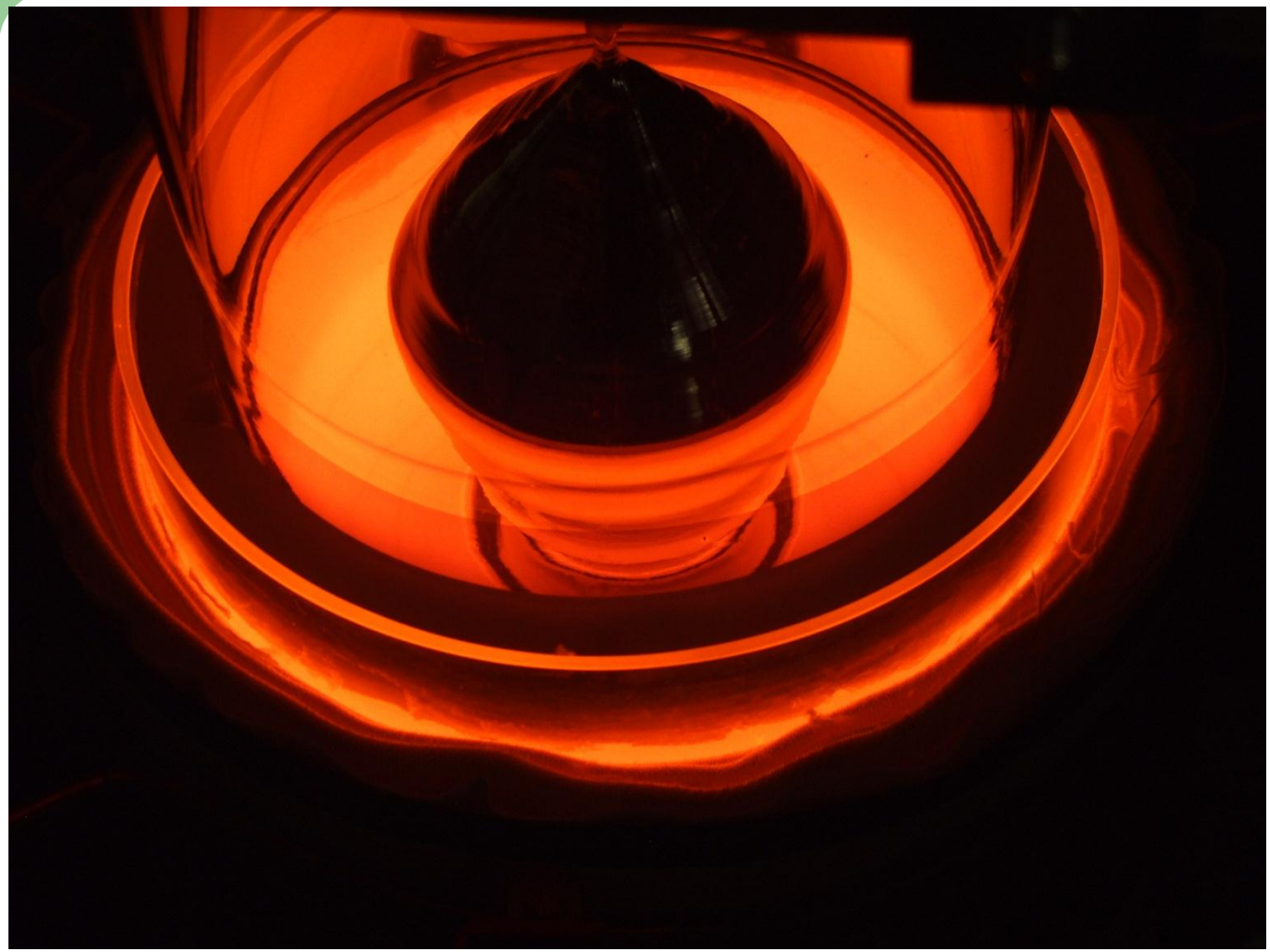

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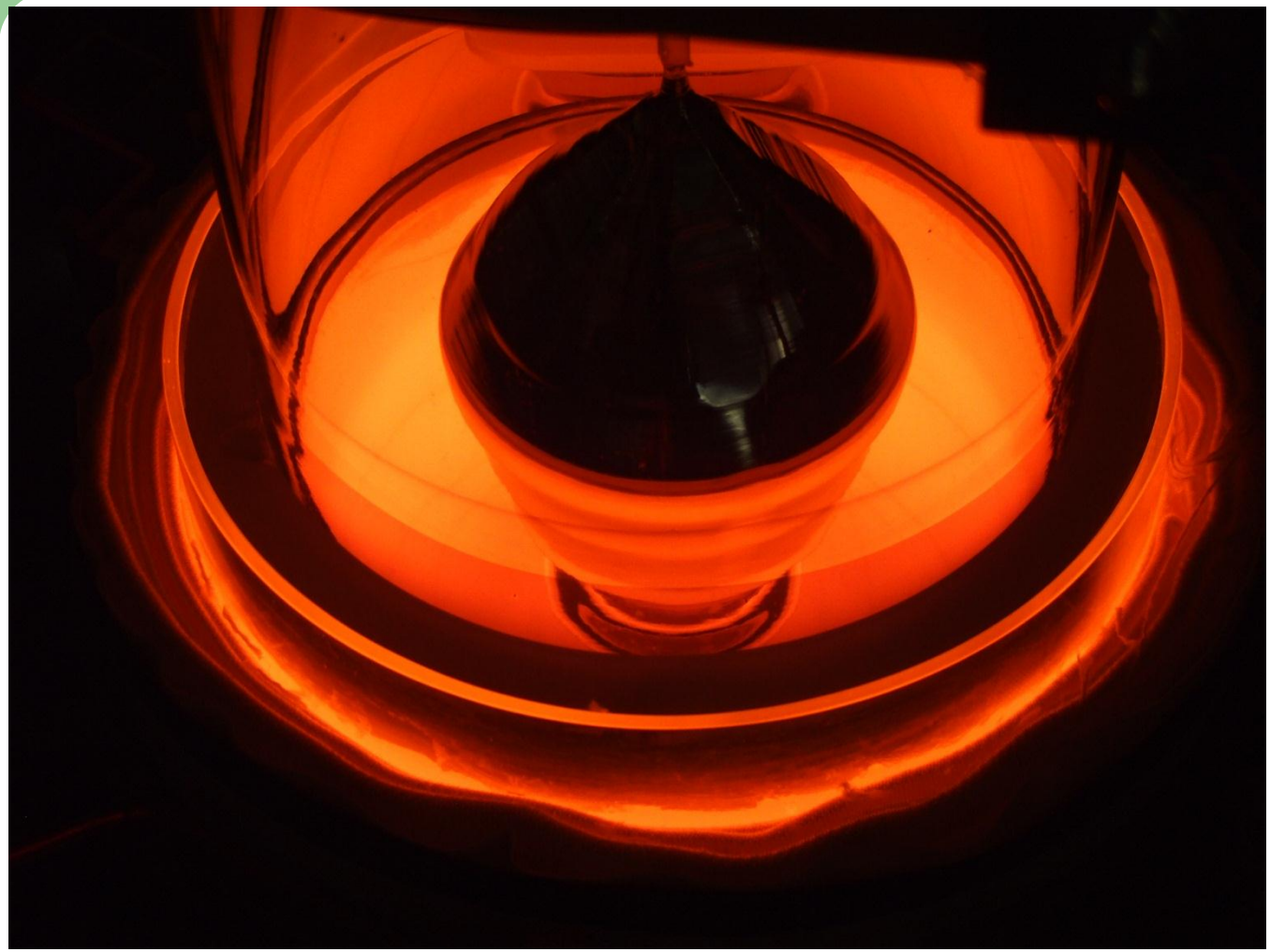

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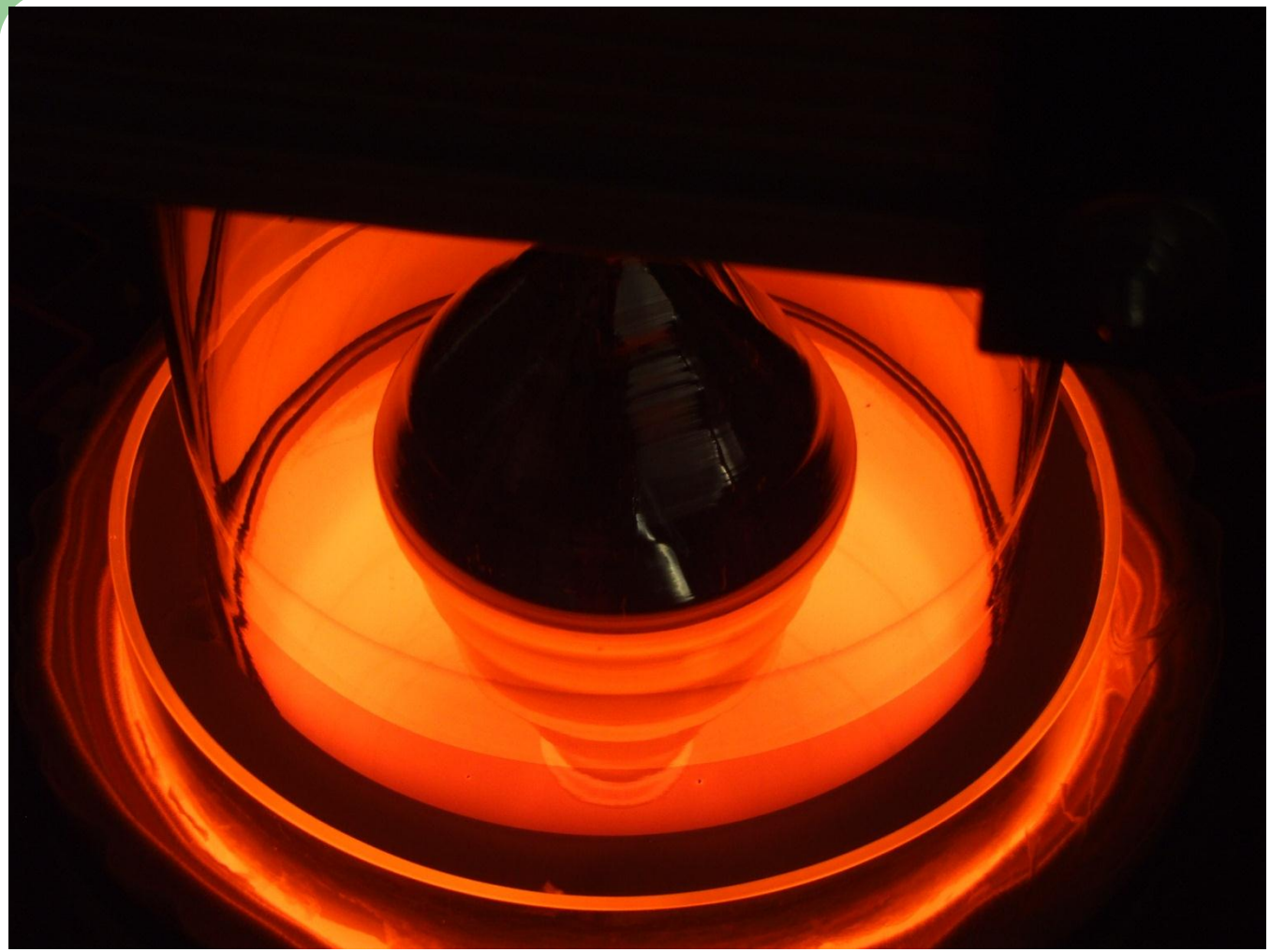

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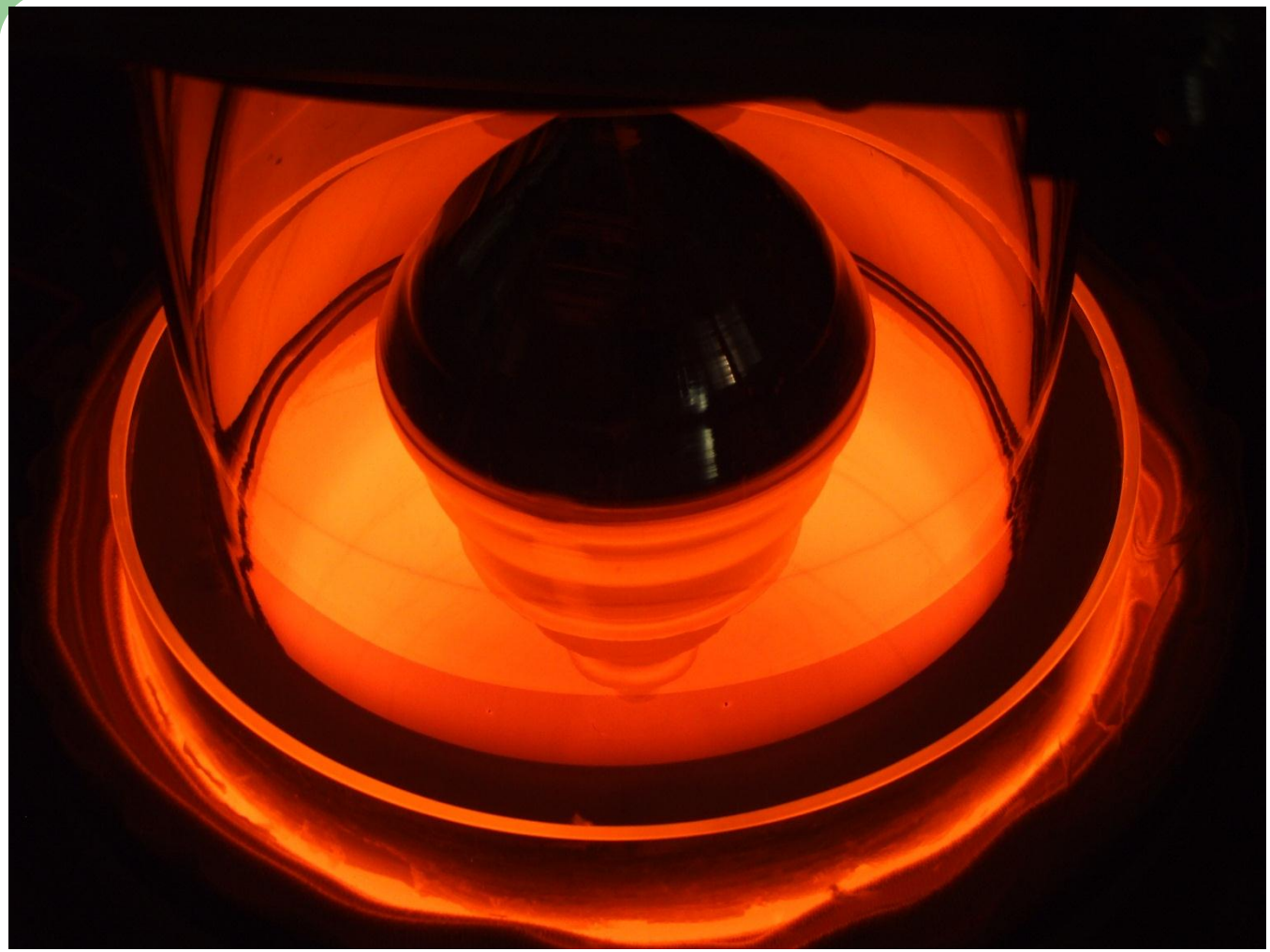

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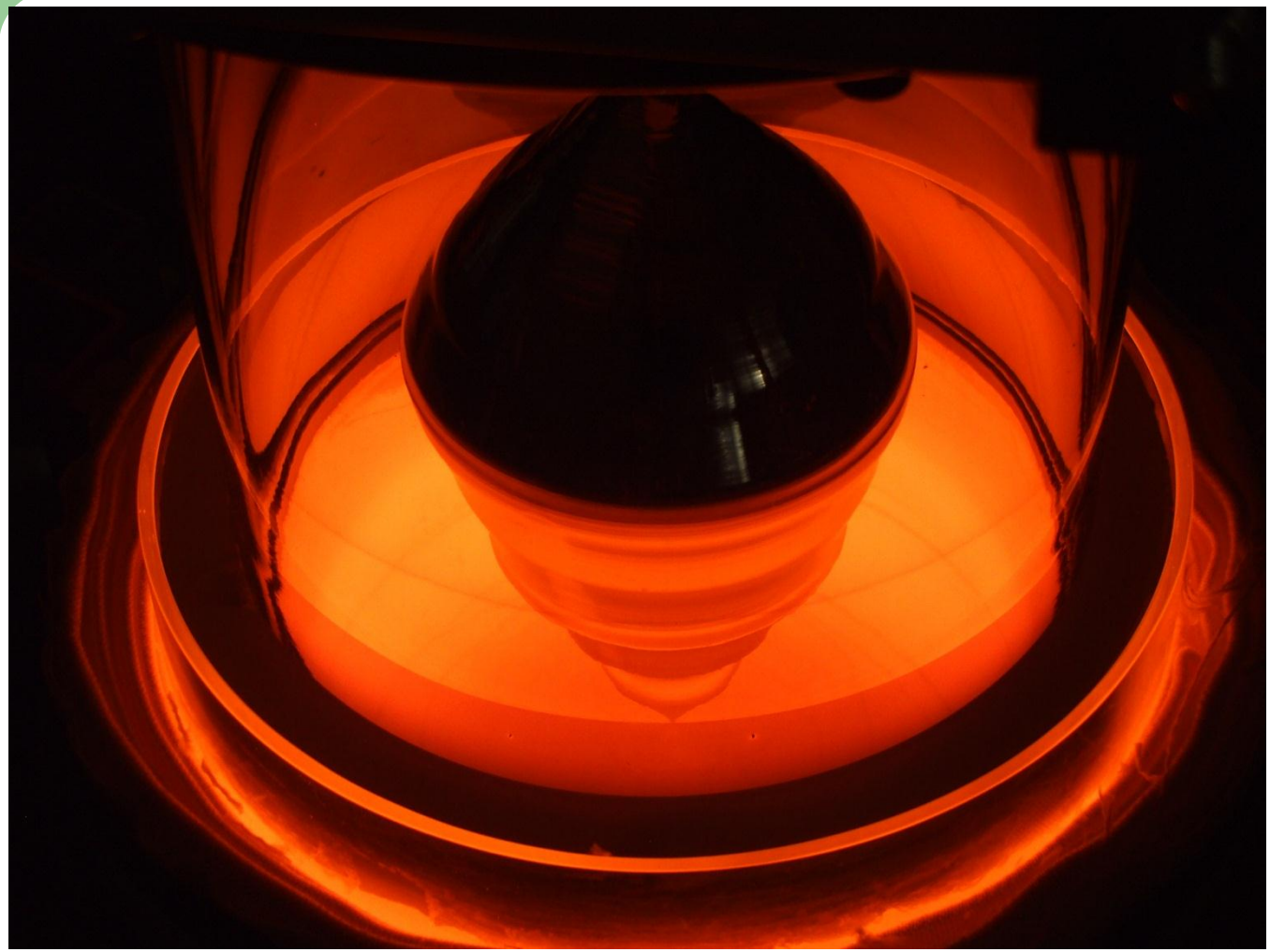

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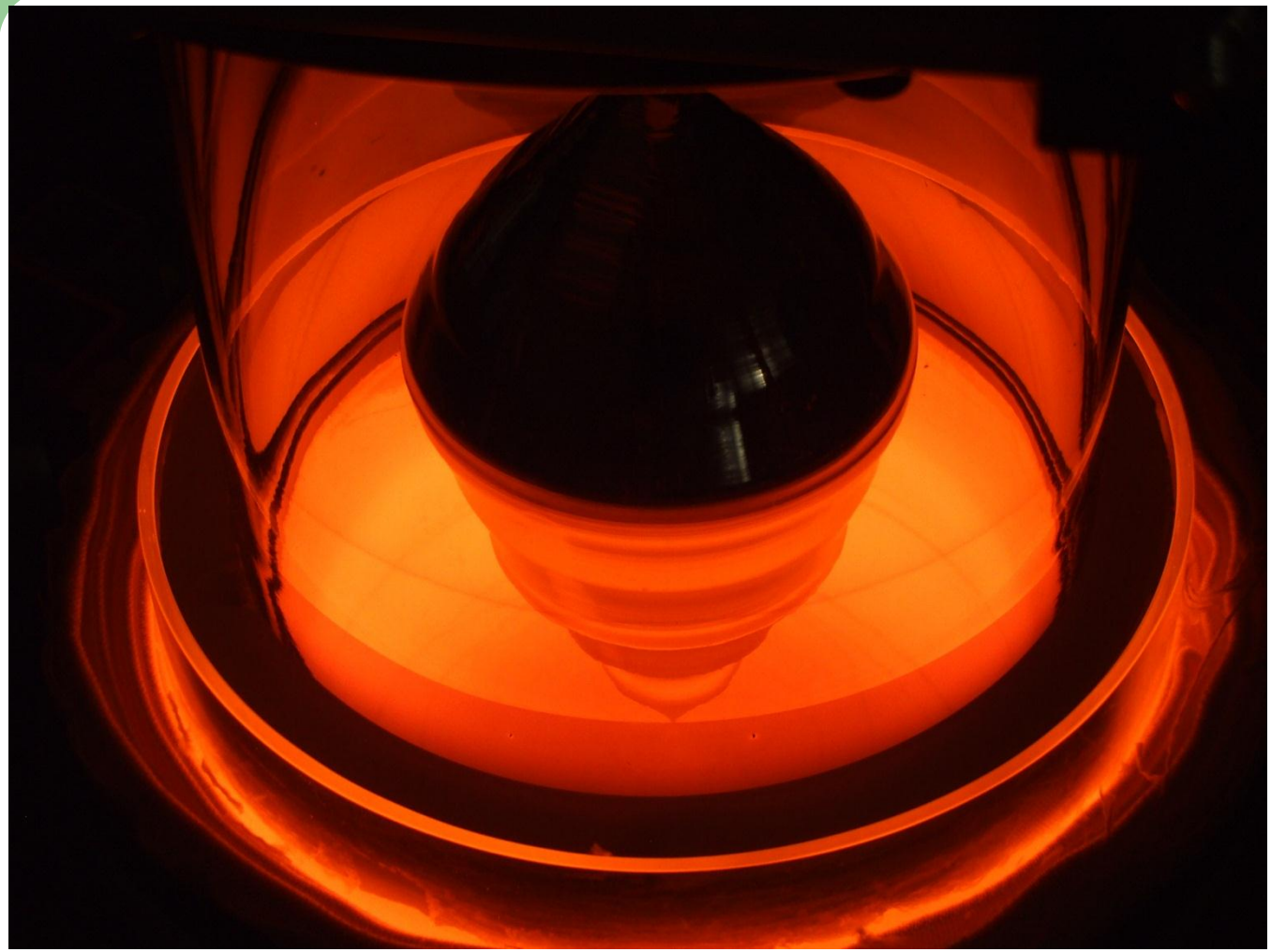

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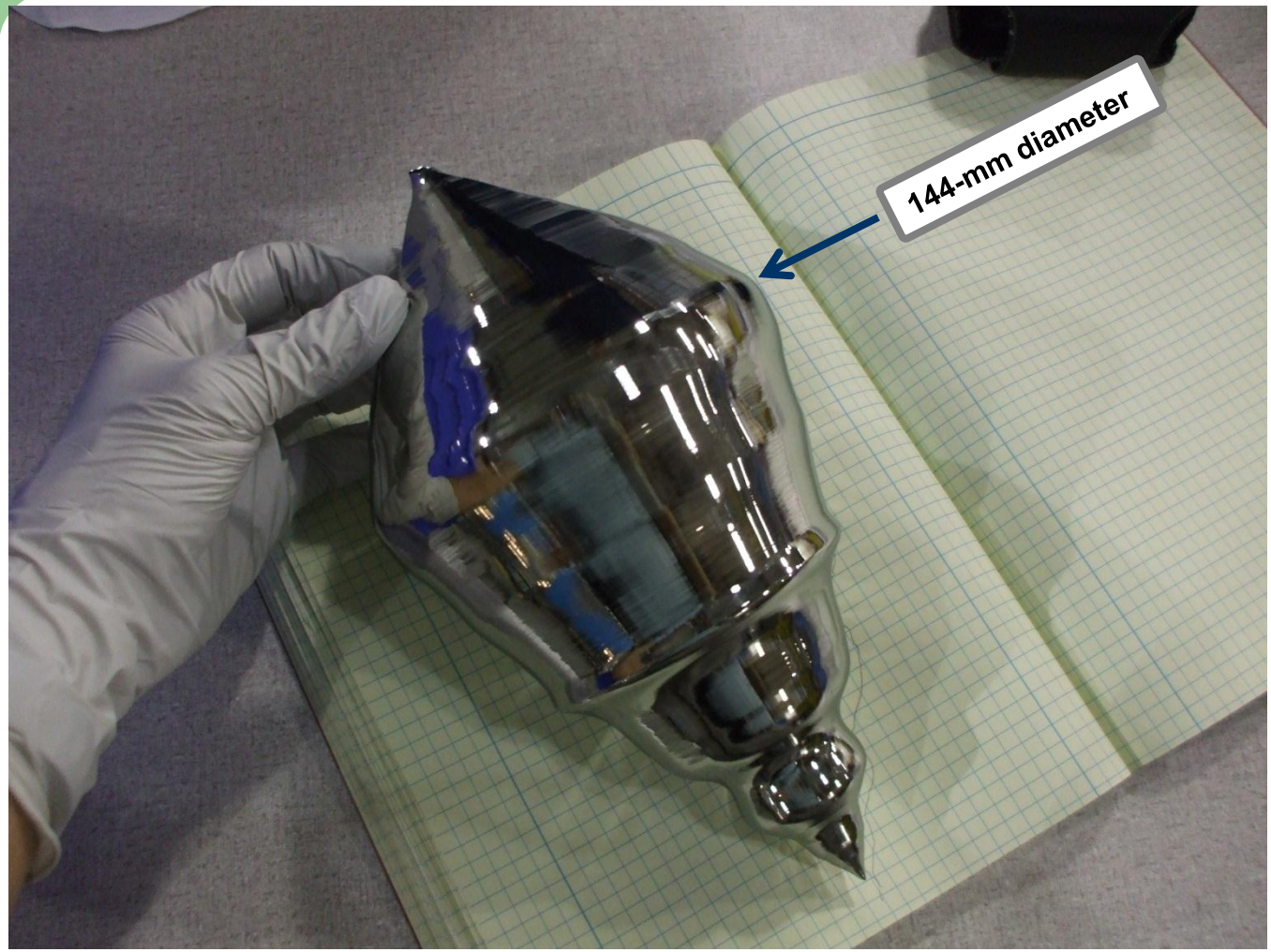

Material Processing and Crystal Growth at PHDs Co.

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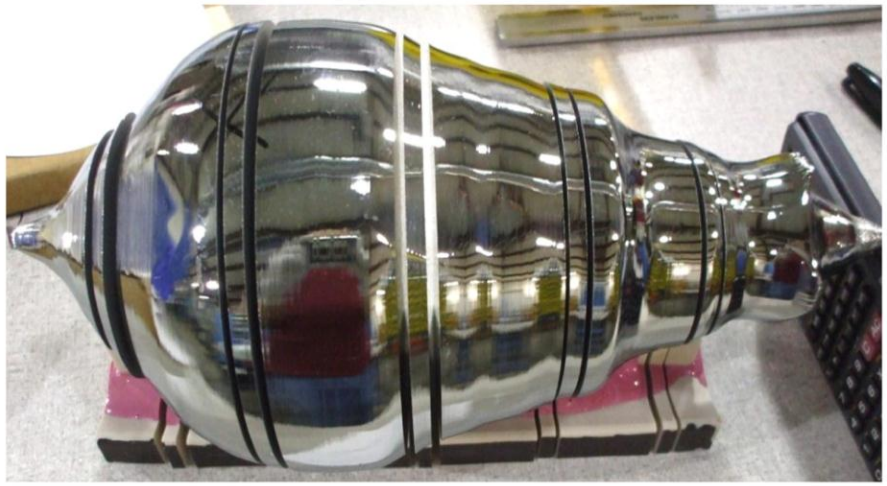
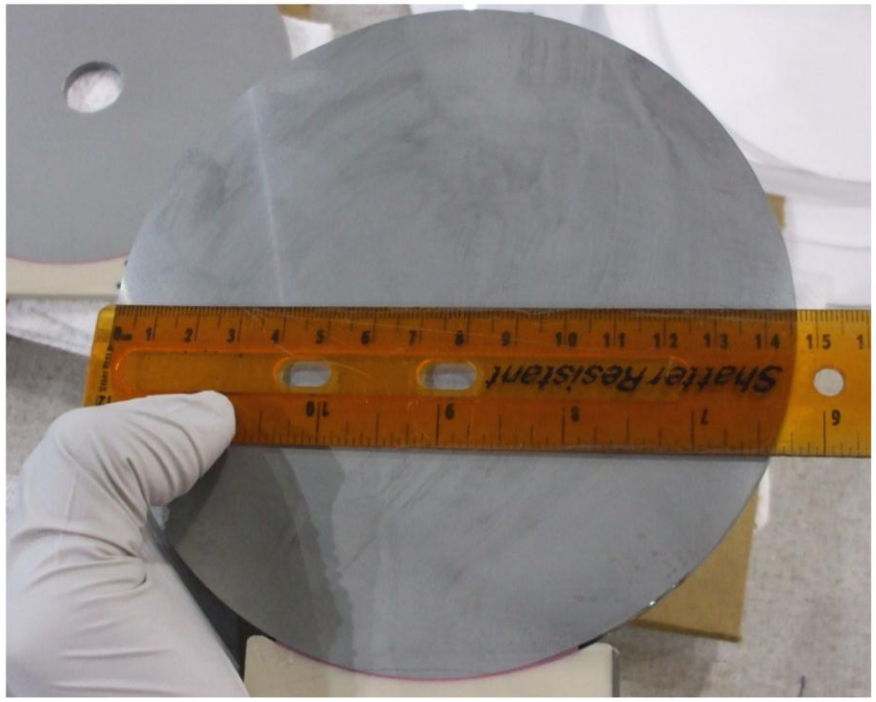
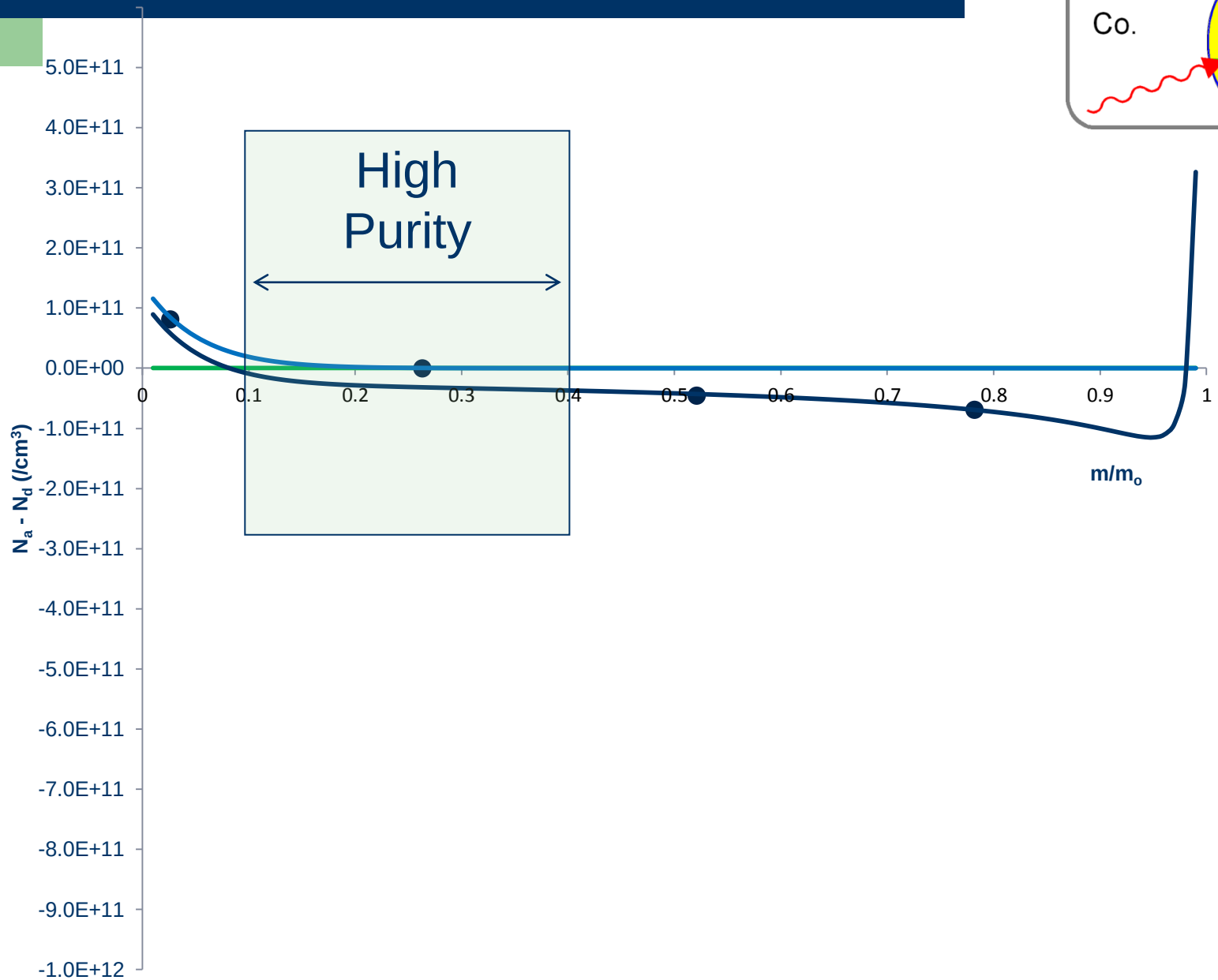
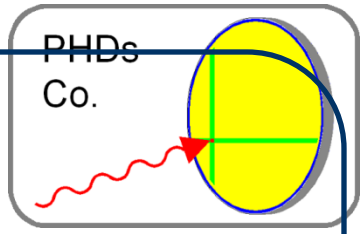




Increased the crystal diameter from 90 mm to 140 mm
Area increased by a factor of 2 !!!!


PHDs
Co.
High
Purity
5.0E+11
4.0E+11
3.0E+11
2.0E+11
1.0E+11
0.0E+00
-1.0E+11
-2.0E+11
-3.0E+11
-4.0E+11
-5.0E+11
-6.0E+11
-7.0E+11
-8.0E+11
-9.0E+11
-1.0E+12
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
$N_a - N_d$ (/cm^3)
m/m_o



122 keV
FWHM = 1.05 keV
FWTM = 2.03 keV

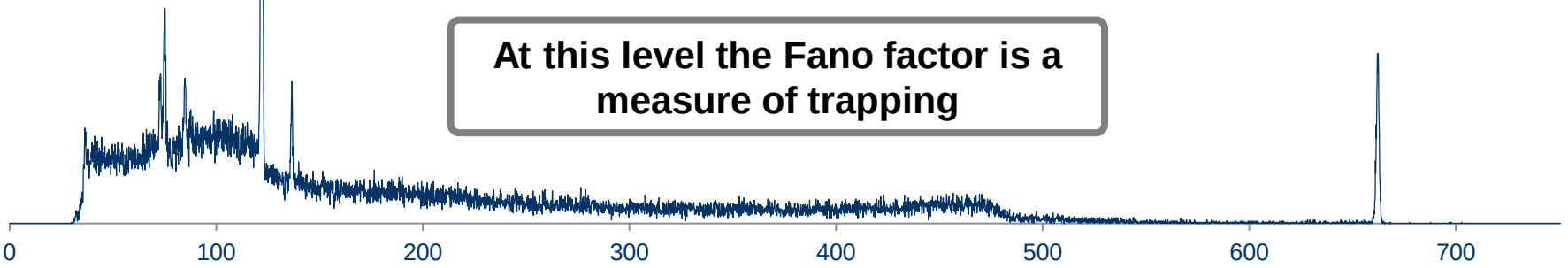
Detector #2
Slice #3
Crystal 41012

Fano Factor:
$[\![FWHM]\!]\_Detector = 2.355\sqrt{\epsilon FE}$

Fano Factor
FWHM = 0.11
FWTM = 0.10

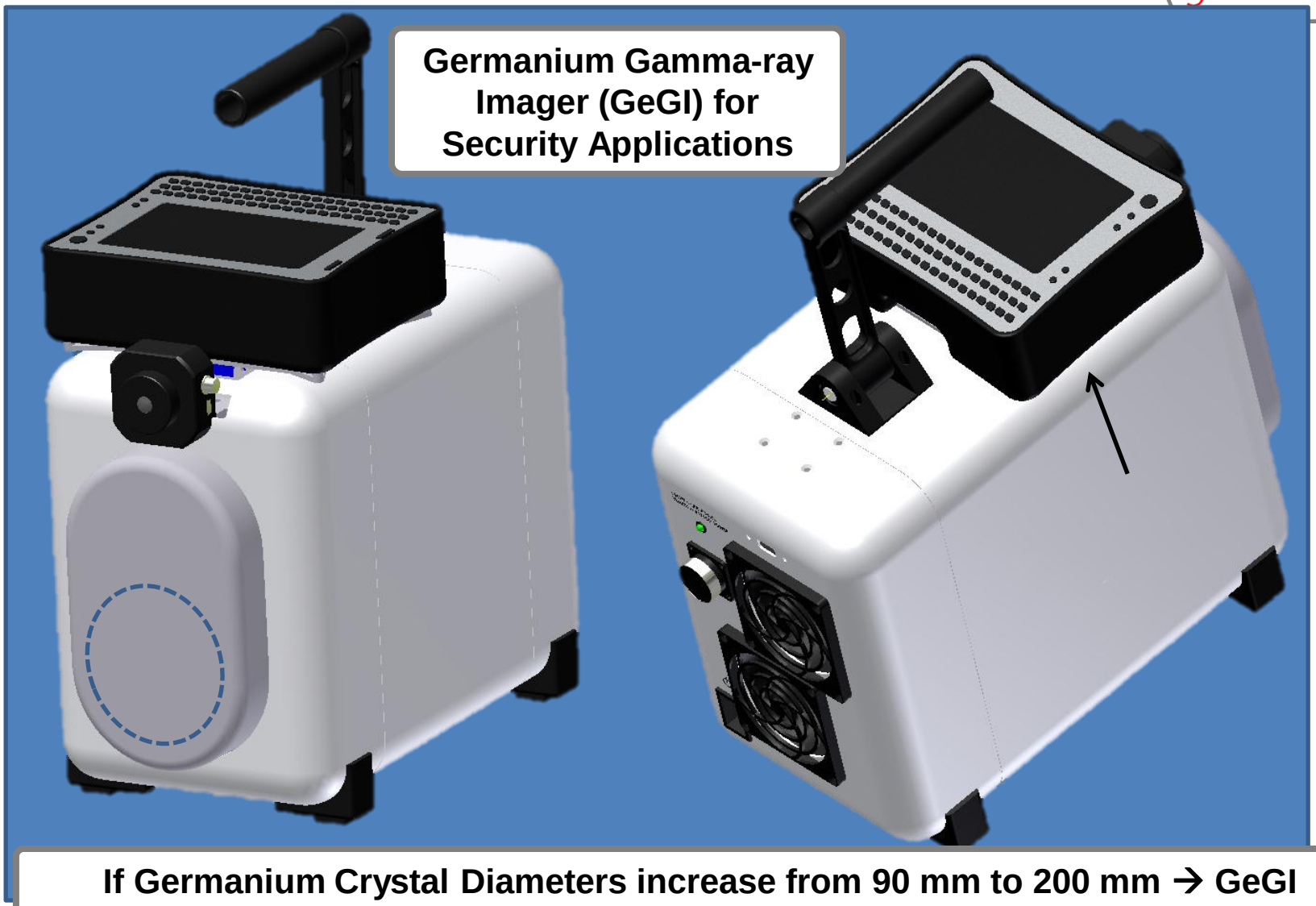
662 keV
FWHM = 1.44 keV
FWTM = 2.69 keV

At this level the Fano factor is a measure of trapping



Impact of Larger Diameter Crystals

PHDs Co.



If Germanium Crystal Diameters increase from 90 mm to 200 mm → GeGI becomes ~10x more sensitive for SNM detection.

Impact of Larger Diameter Crystals

PHDs Co.

New Germanium Gamma Cameras for Nuclear Medicine