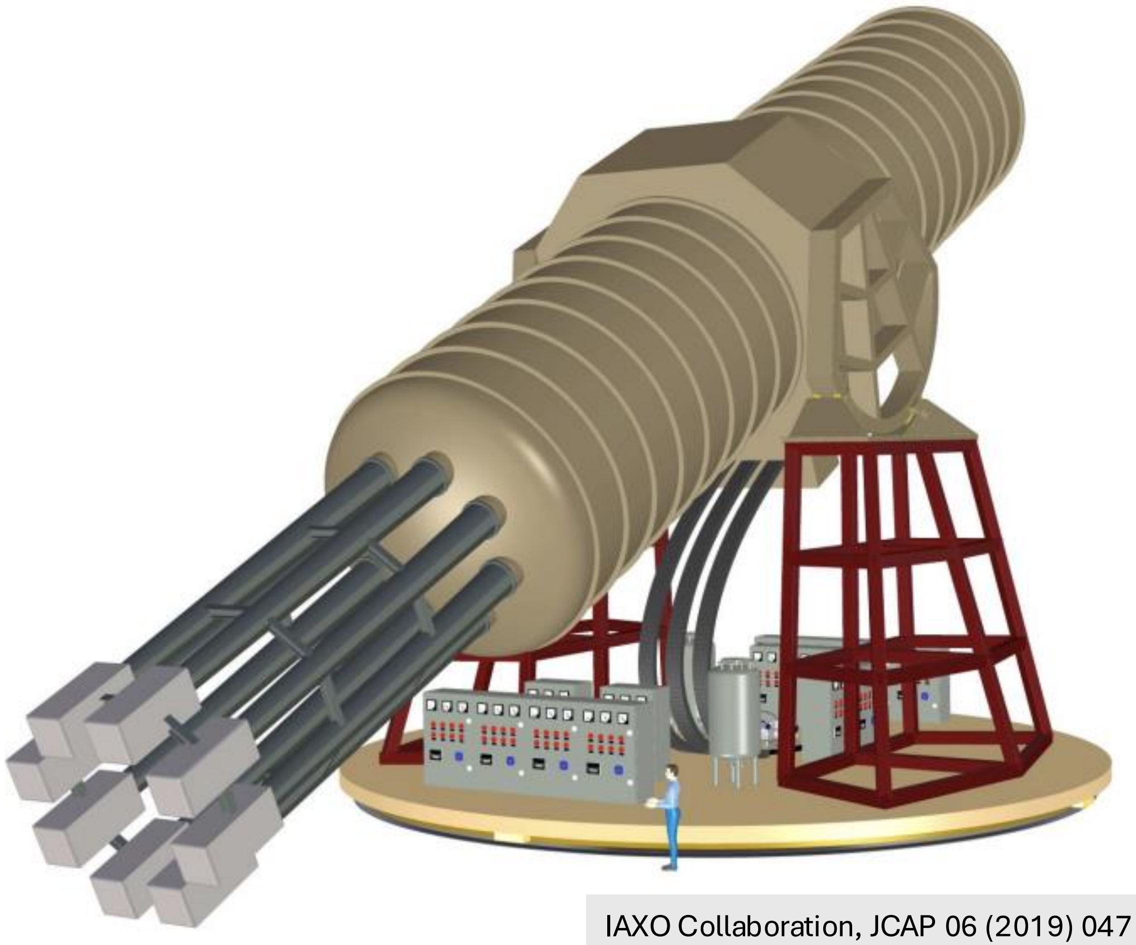
X-Ray Optics for the International Axion Observatory



IAXO Collaboration, JCAP 06 (2019) 047

Presented by: Treya Pember

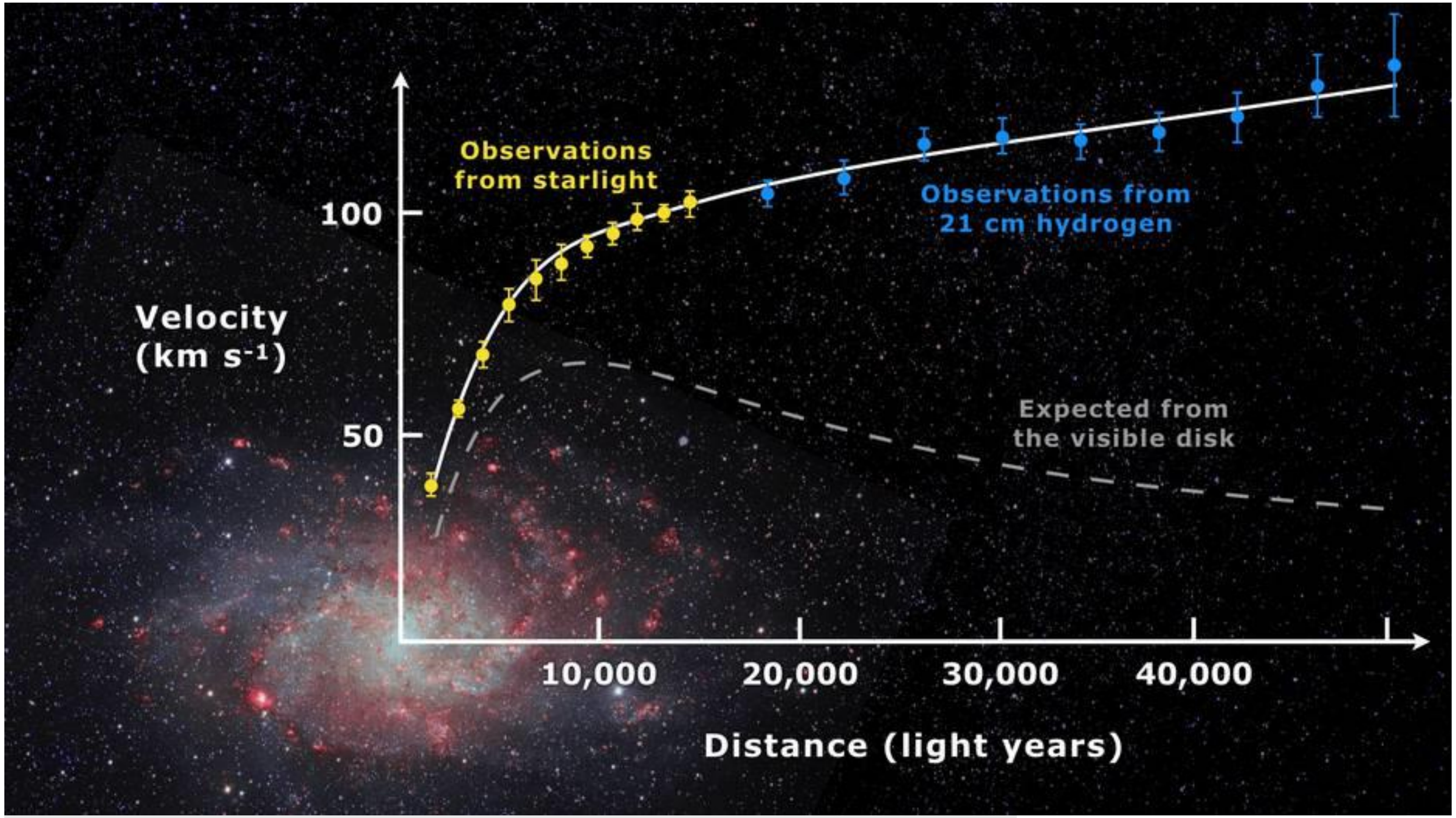
Nevis Laboratories REU Program 2024

What is Dark Matter?

Vera Rubin's
Galactic rotation curves provided early evidence

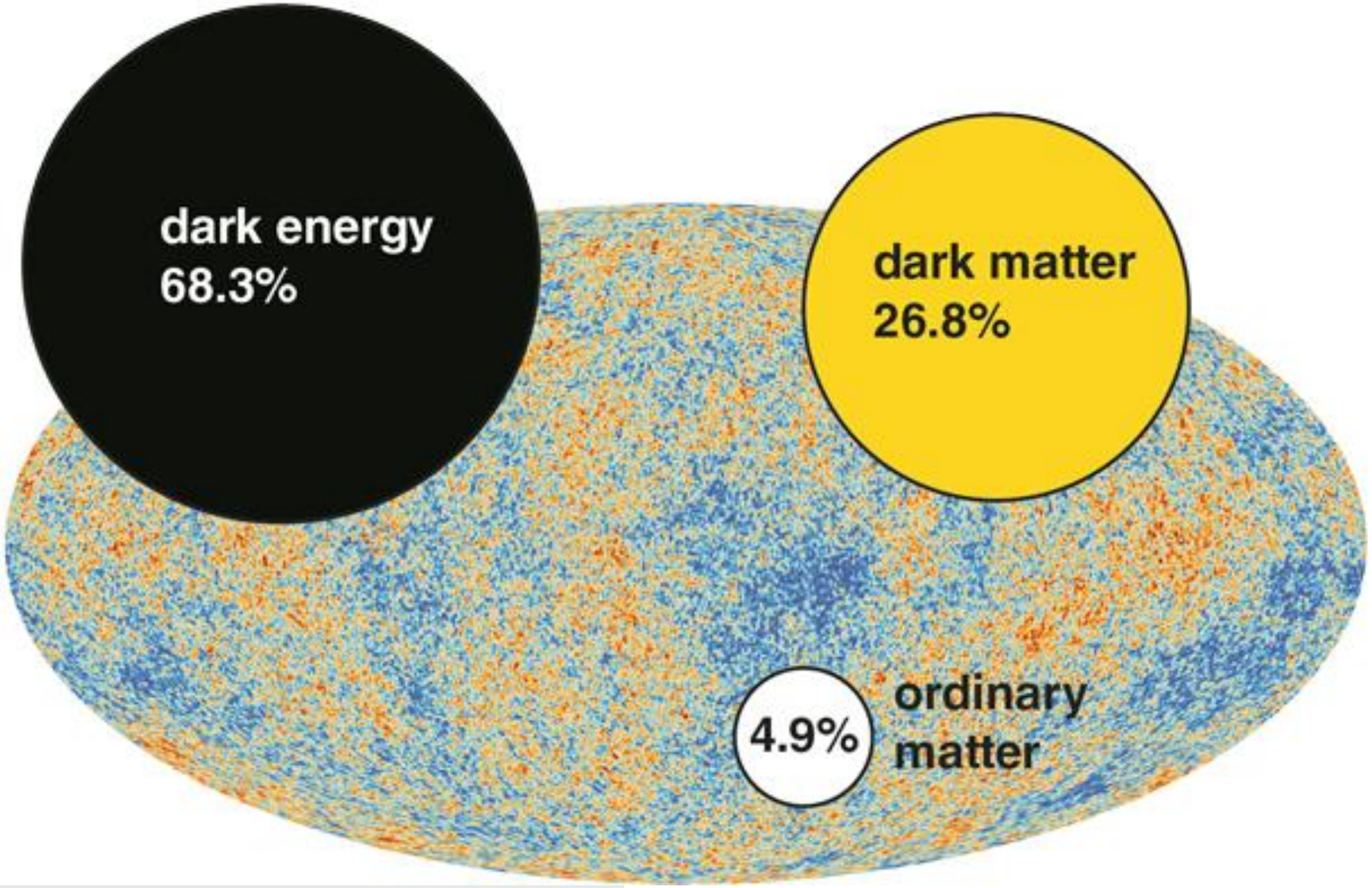
Dark matter
interacts gravitationally, but not with light

Since Rubin, we have found evidence for dark matter across the universe



Physics Feed, “Rotation Curve Method for Determining the Mass of Spiral Galaxies.”

Dark Matter and Our Universe



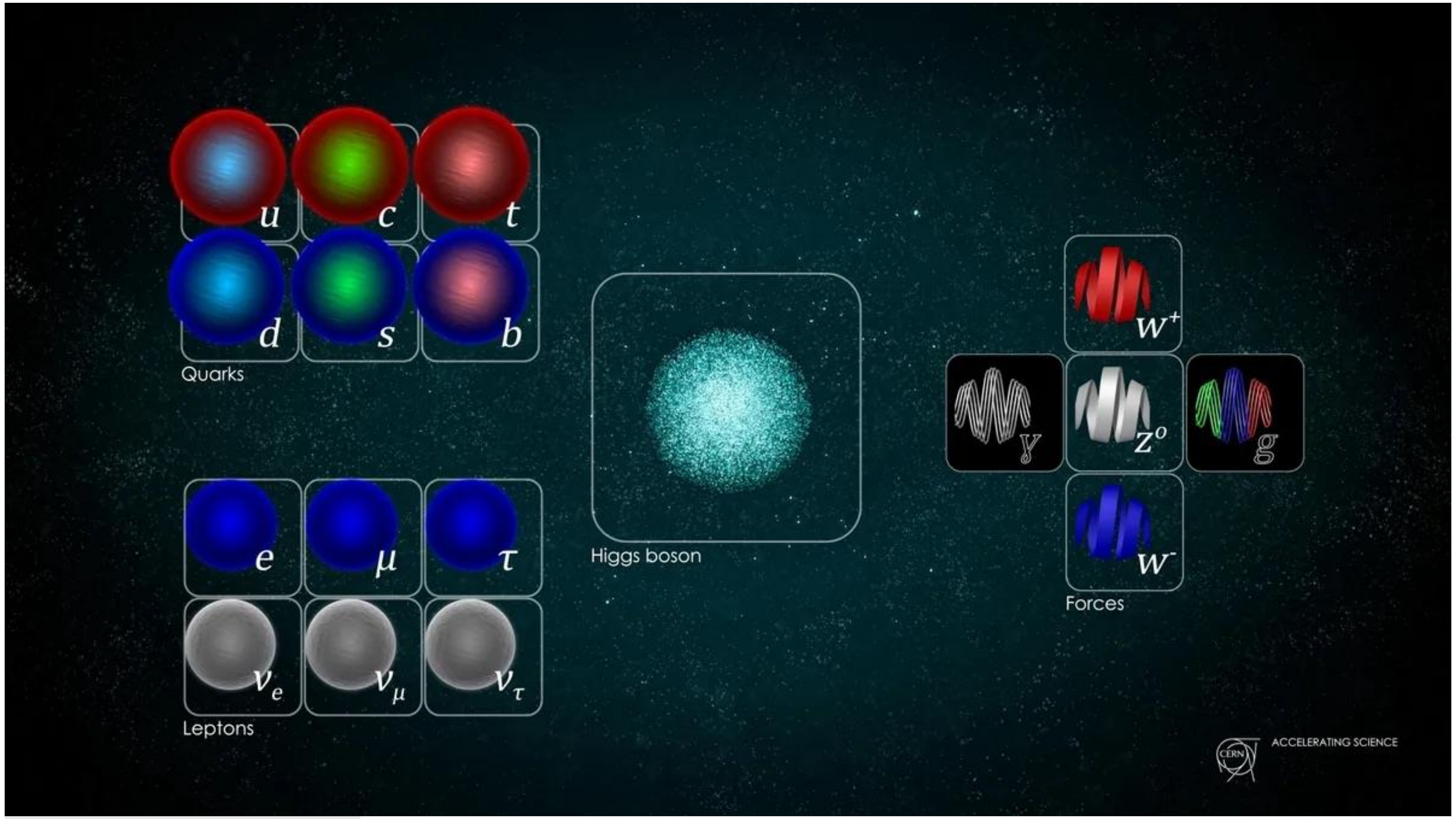
Barbara Aulicino; ESA and the Planck Collaboration

Dark matter heavily influences the larger structure of the universe

Must be stable and massive

Dark Matter and the Standard Model

- Well understood, but no dark matter candidates
- Searching in the cracks: the strong CP problem

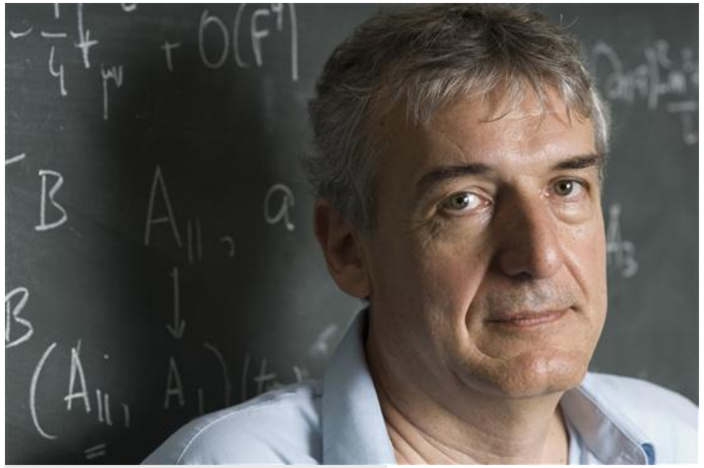


Daniel Dominguez, CERN

What are Axions?

- Strong CP Problem predicts a neutron electric dipole moment
- Peccei-Quinn Mechanism cancels the EDM and predicts a new particle, the axion.
- Axion-Like-Particles could constitute dark matter, QCD axions answer both questions

Pierre Sikivie



Claudia Marcelloni, CERN

Helen Quinn

Wikipedia, Dan Quinn

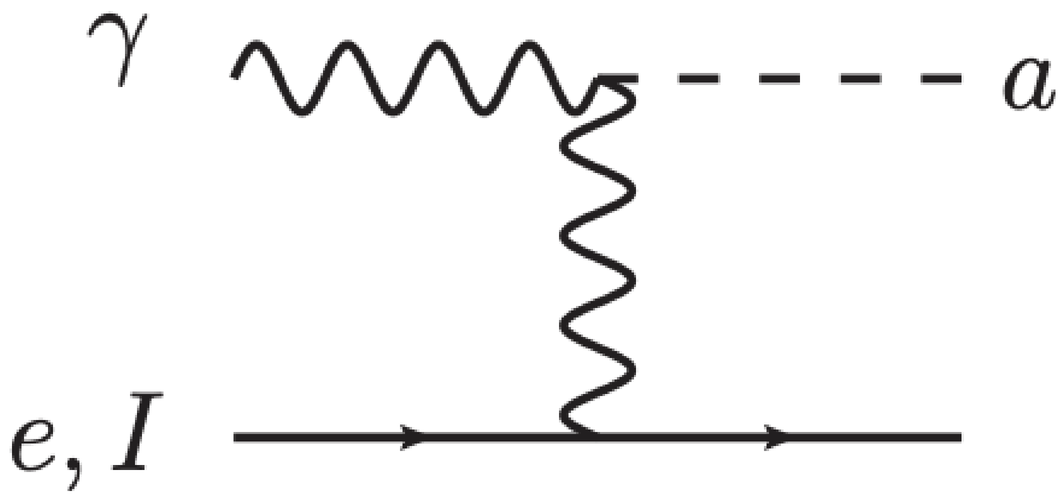
Roberto Peccei

UCLA, “In Memoriam: Roberto Peccei.”

Axion Detection

Experiments are looking to measure axions via the Primakoff effect. Methods include:

- Helioscopes
- Haloscopes
    - Resonant Cavities
    - Electromagnetic Probes



IAXO Collaboration, JHEP 05 (2021) 137

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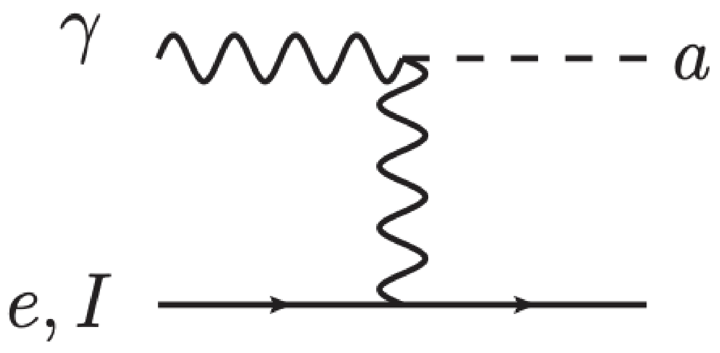
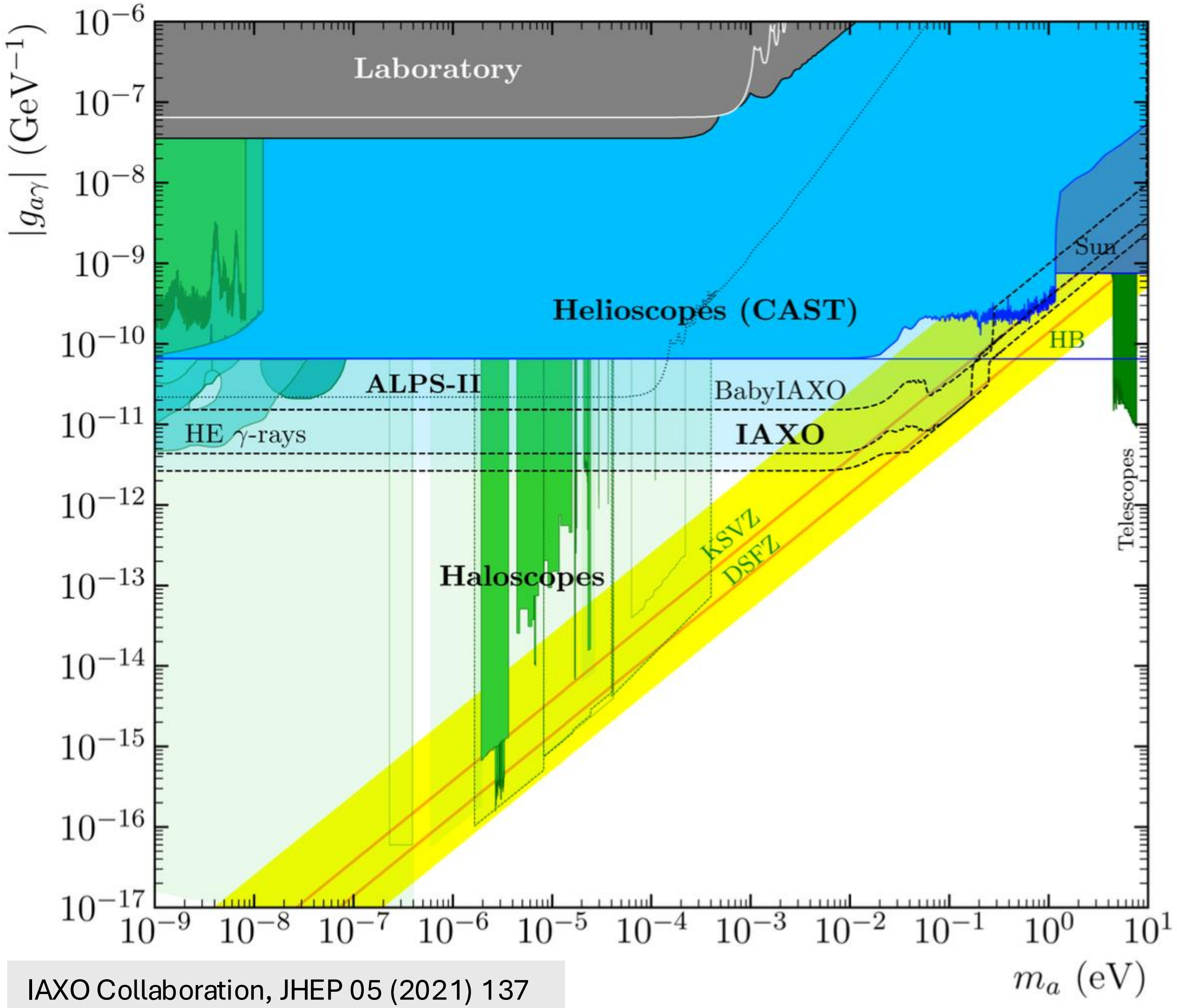


IAXO Collaboration, JHEP 05 (2021) 137

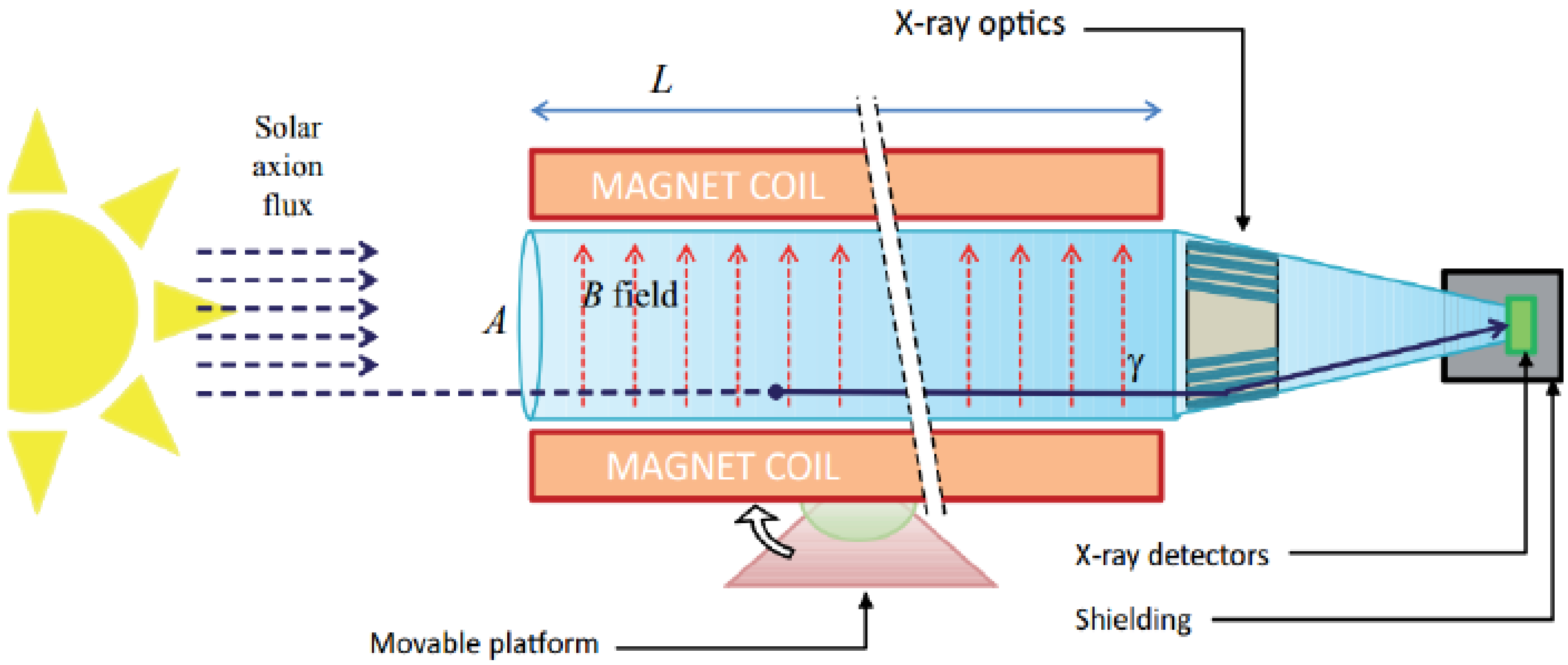


IAXO Collaboration, JHEP 05 (2021) 137

IAXO Design

The Sun, with its strong electromagnetic fields is an axion factory

Once axions get through our atmosphere, we reconvert them back to x-ray photons



IAXO Collaboration, JCAP 06 (2019) 047

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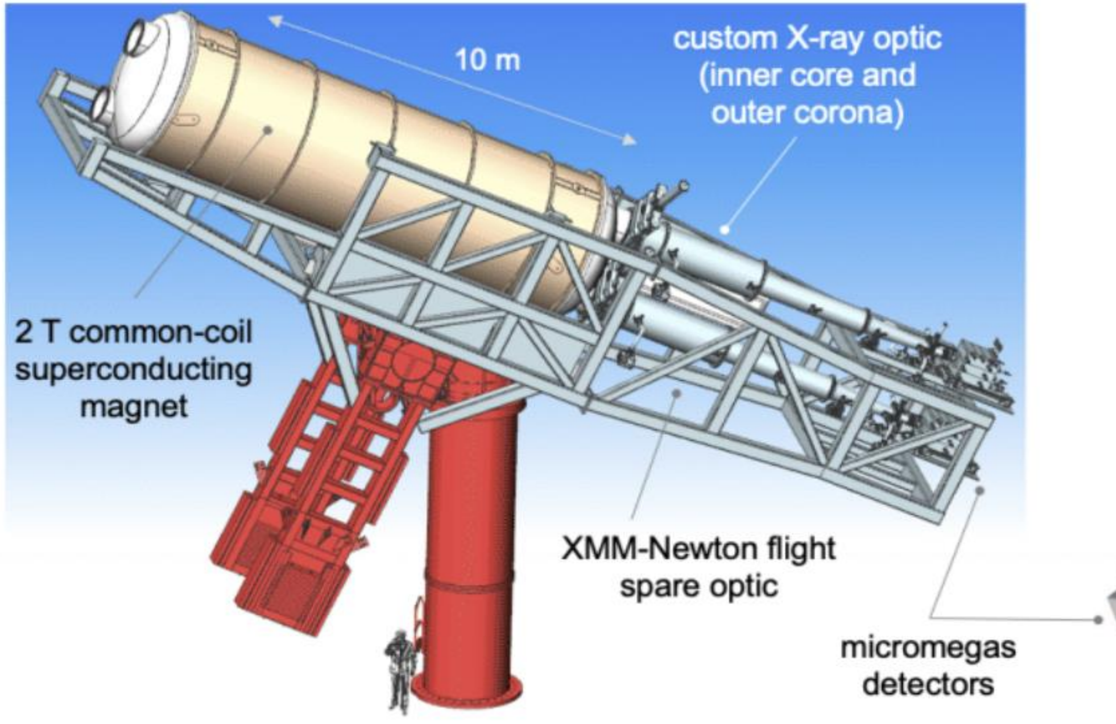
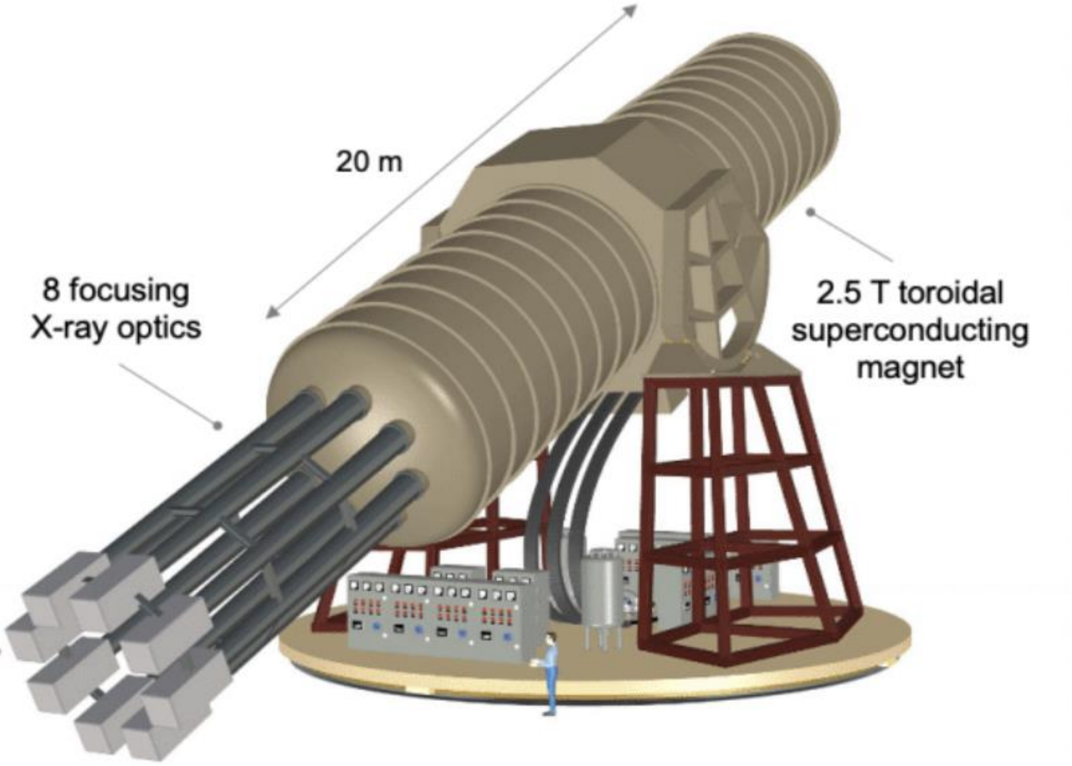




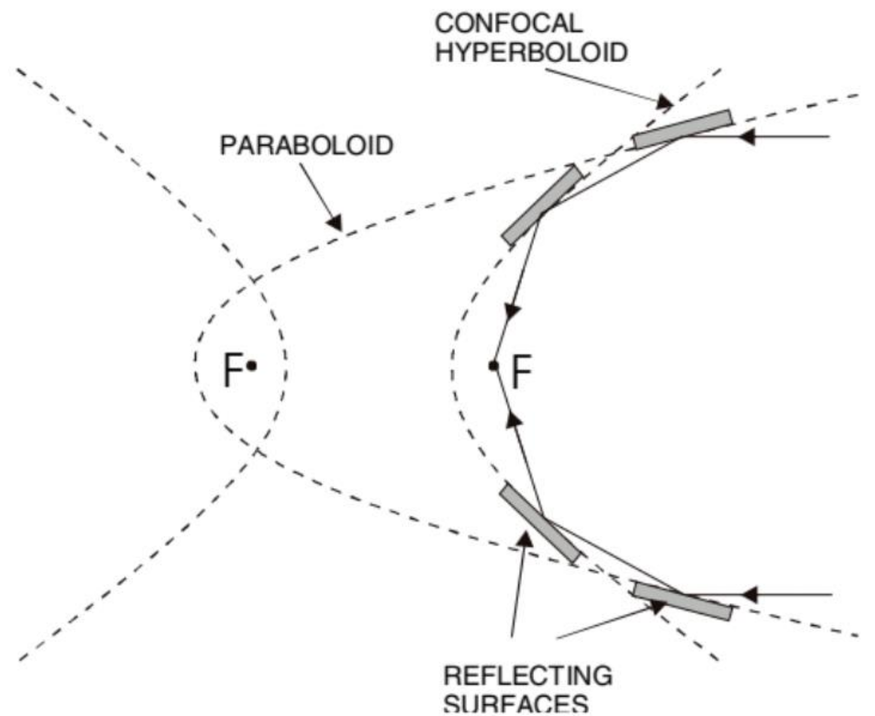
IAXO Collaboration, JHEP 05 (2021) 137; IAXO Collaboration, JCAP 06 (2019) 047

X-Ray Reflection Techniques

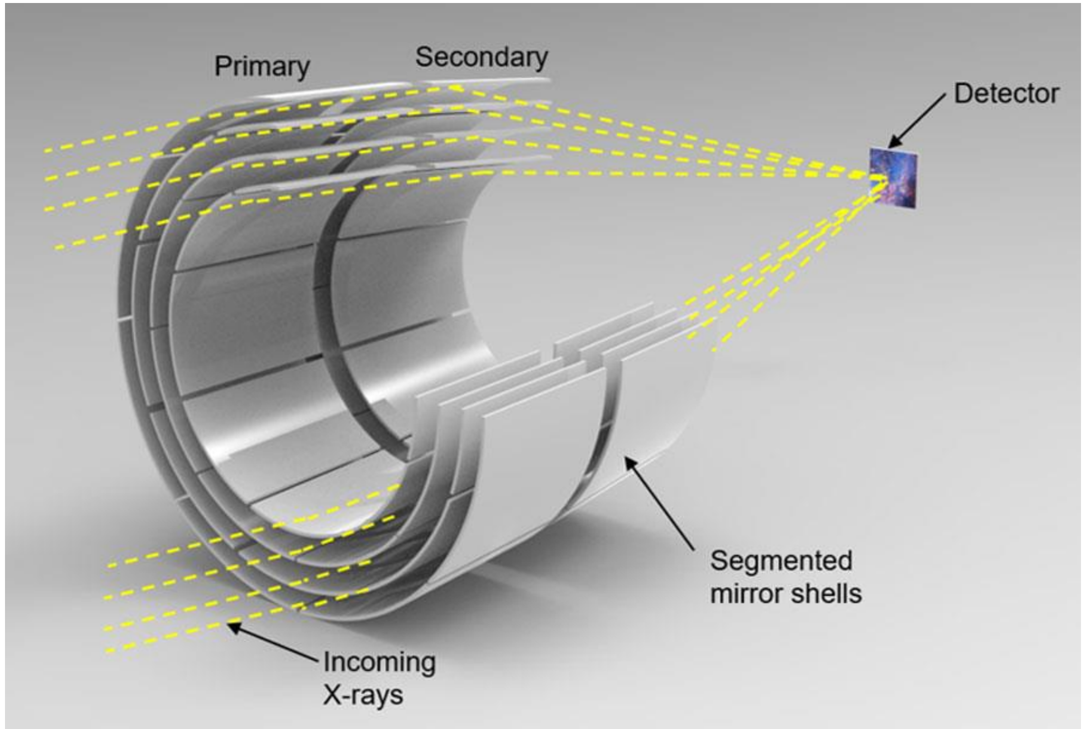
Grazing incidence angles reflect x-rays

Increasing collection area requires building many concentric shells

X-ray reflection is increased by a graded multilayer coating



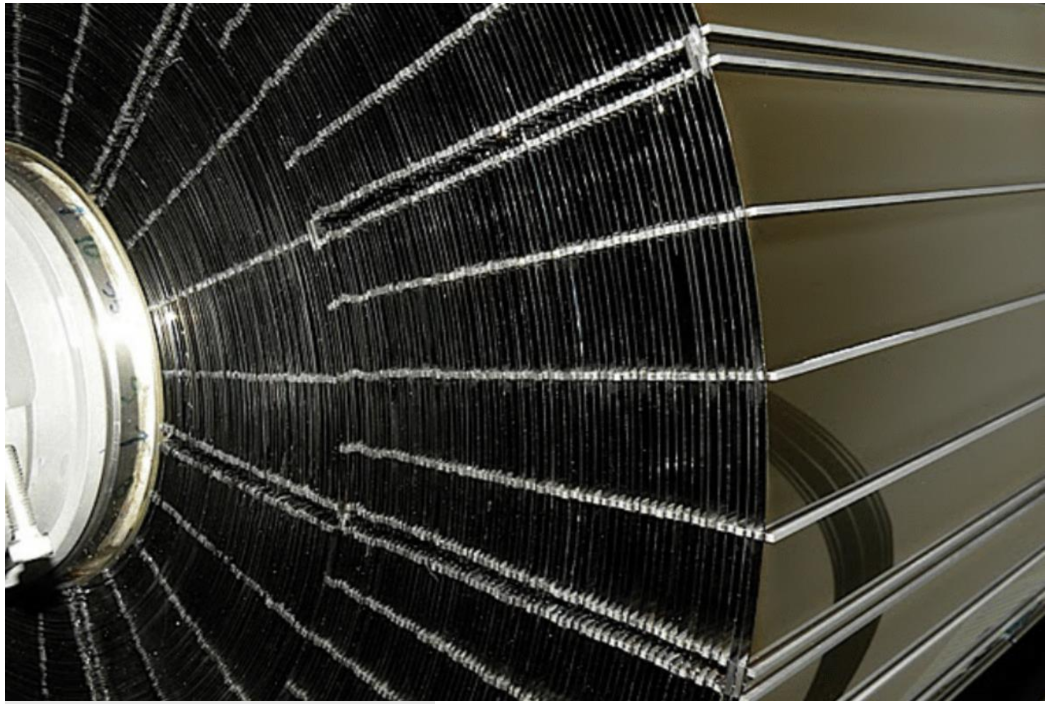
Reid. Encyclopedia of Astronomy & Astrophysics. (2001)



Goddard Space Flight Center

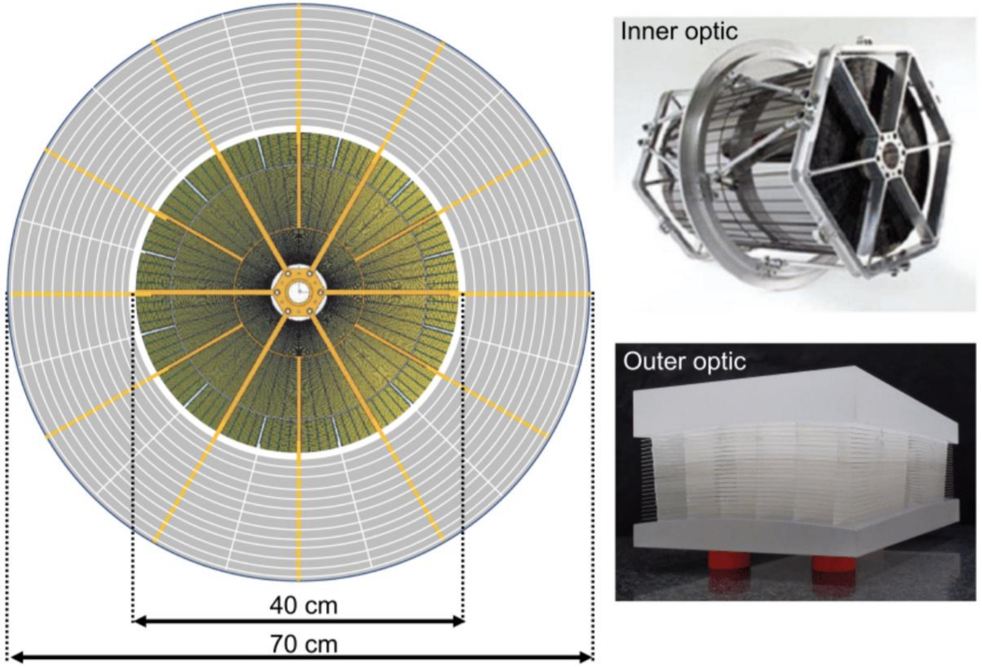
X-Ray Optics Design

NuSTAR:
133 Layers
2376 pieces of glass



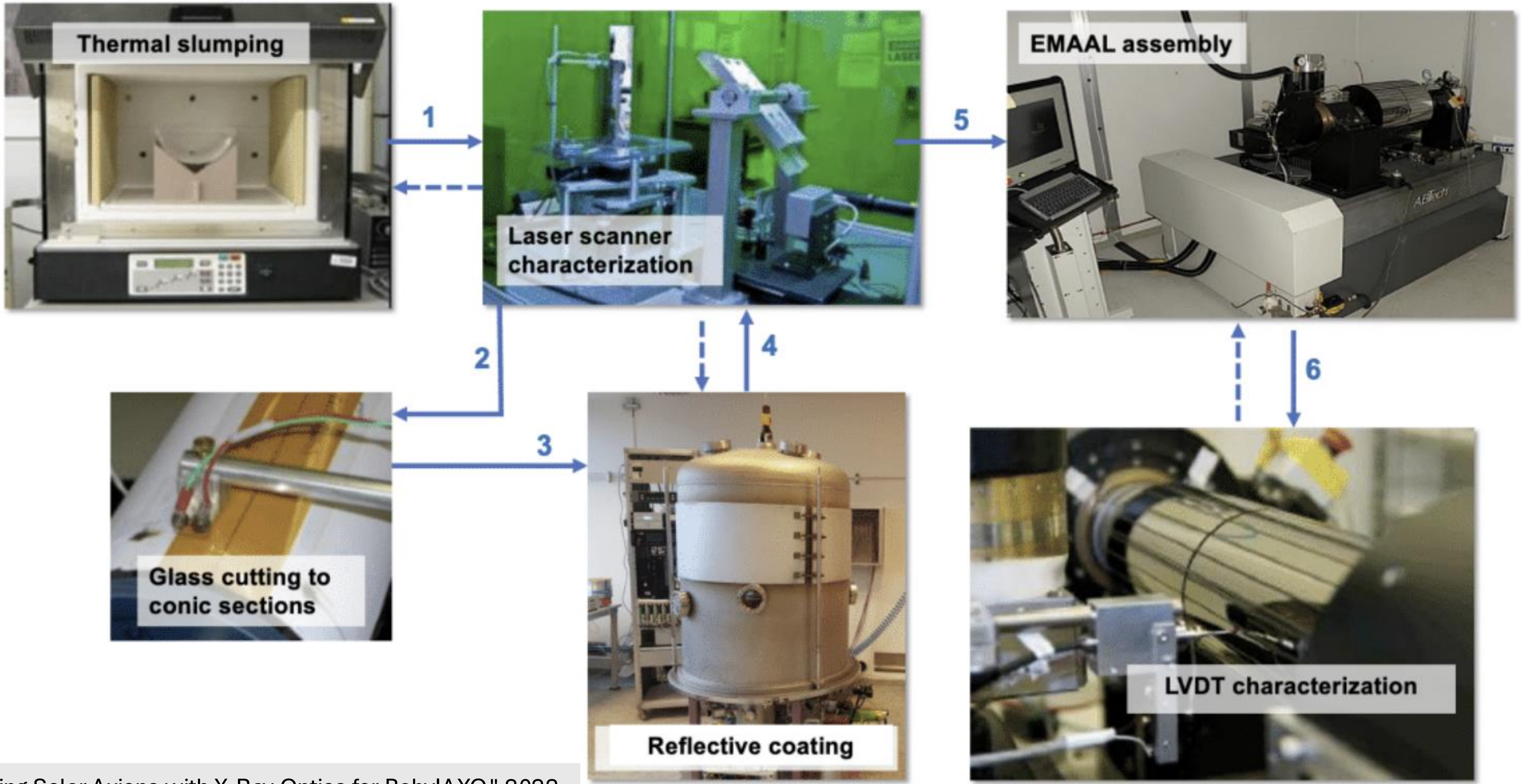
Craig, et al. SPIE 8147 (2011)

IAXO:
97 Inner Layers, 26 Outer Layers
2172 pieces of glass



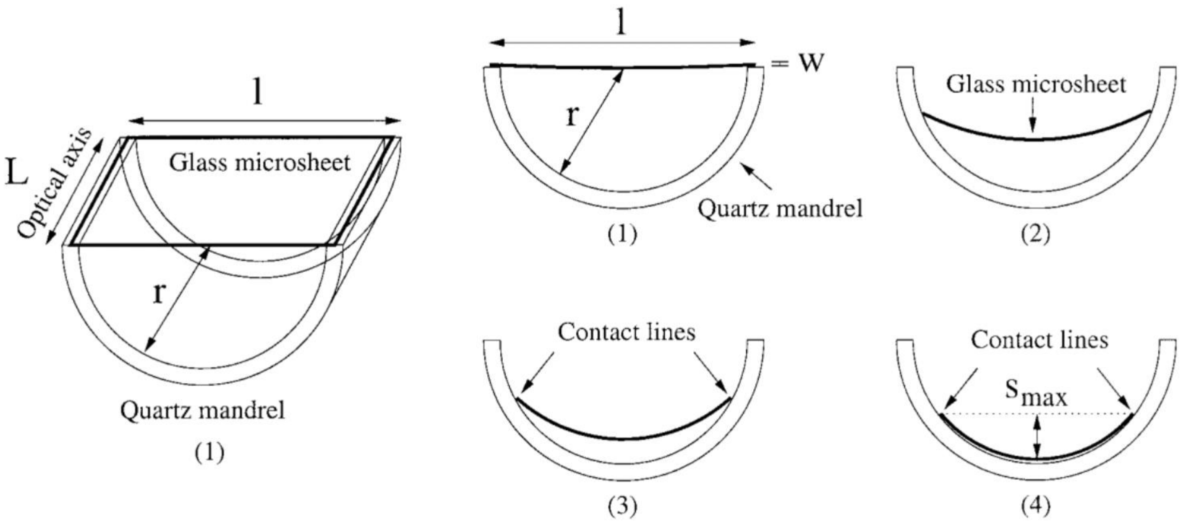
IAXO Collaboration, JHEP 05 (2021) 137

Optic Assembly

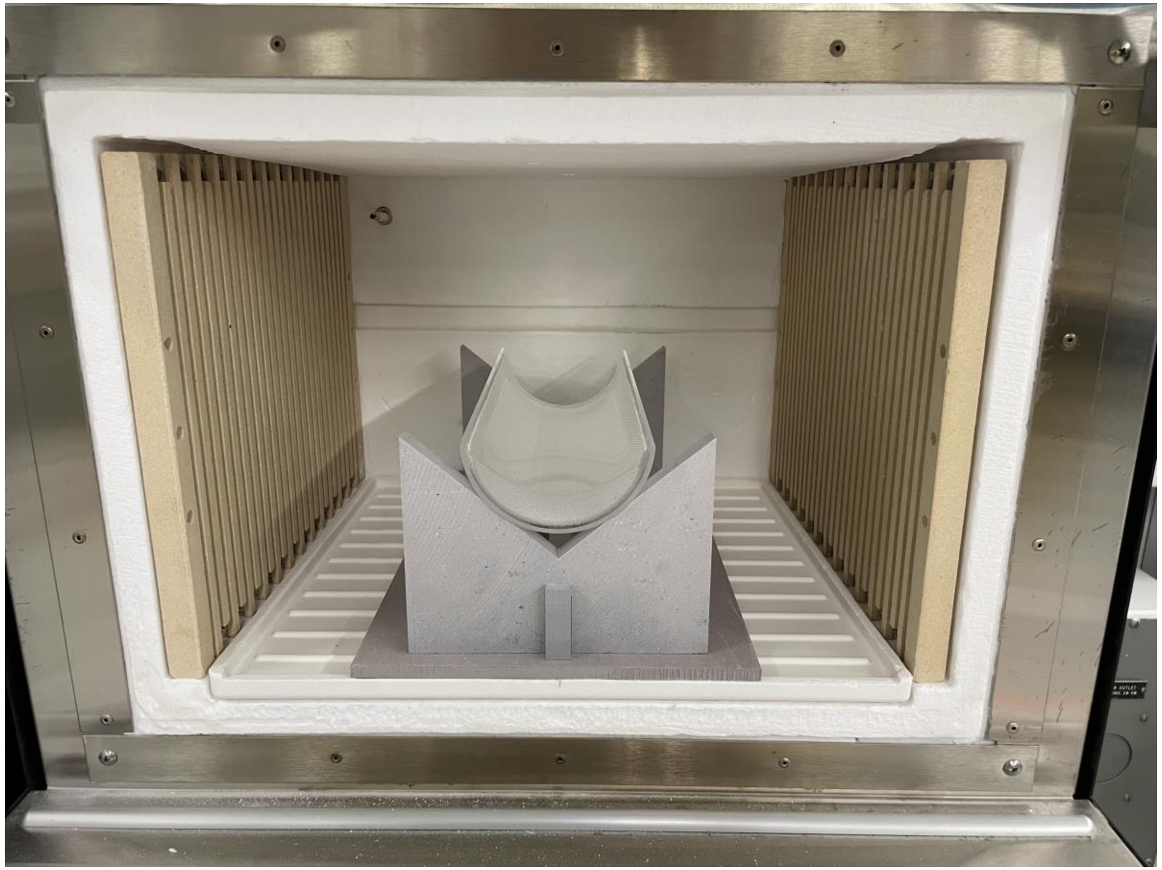


Perez. "Probing Solar Axions with X-Ray Optics for BabyIAXO." 2022.

Thermal Slumping



Jimenez-Garate et al. Appl. Opt. 42, 724 (2003)

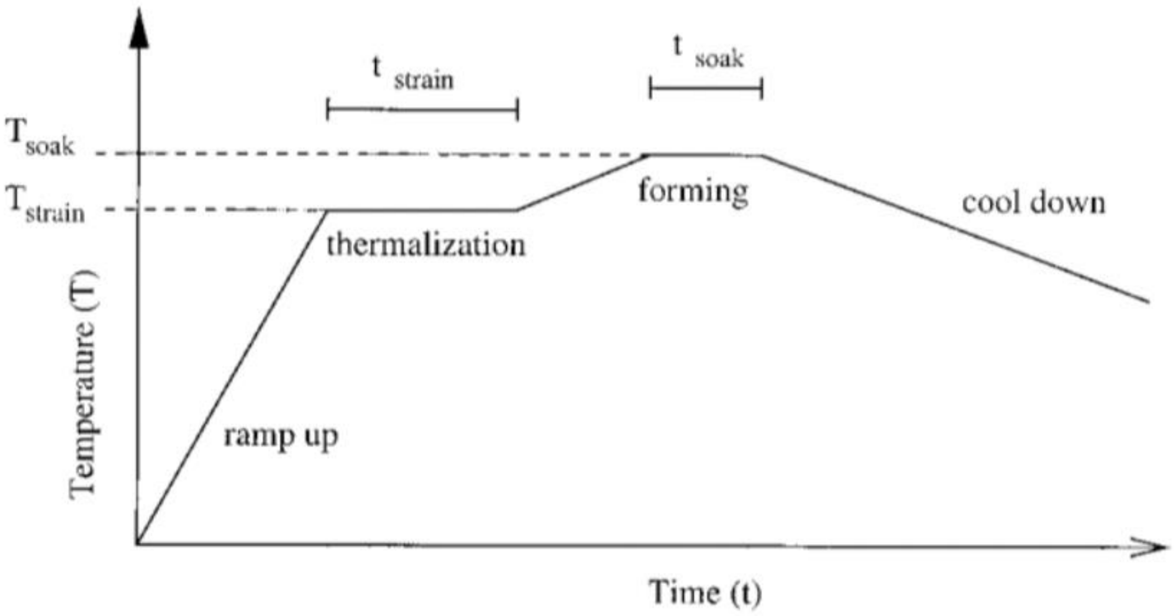


Visual Inspection Qualities: Skew, Divots, Diameter

Slumping Parameters

Viscosity Stages: Strain, Soak, and Soften

Experimental Parameters: Rate, Temperature, and Time



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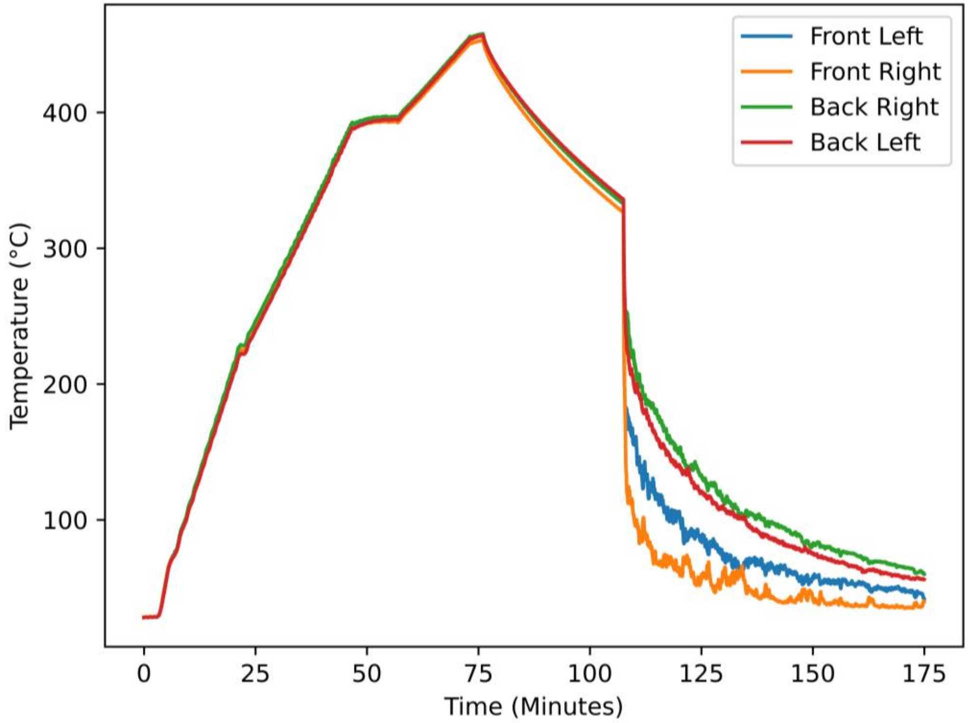


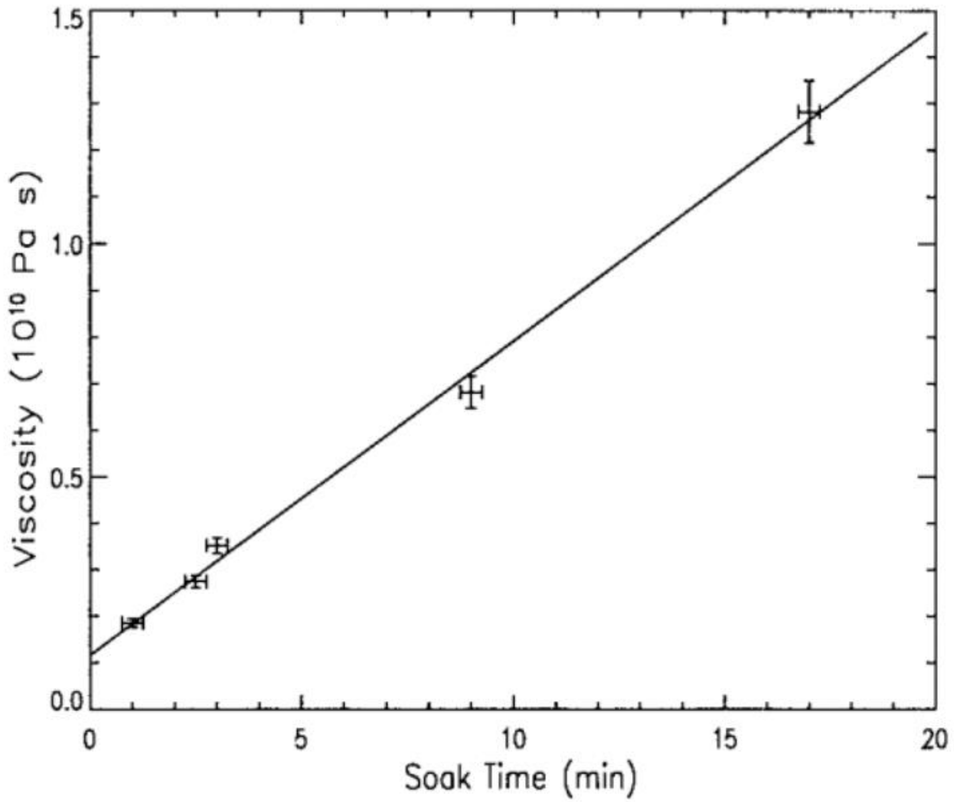
Modeling Ideal Slumping

$$\frac{\eta_{\text{soak}}}{t_{\text{soak}}} = \frac{5C\rho g l^4}{64 s_{\max}(1+\nu)w^2} \propto \frac{\rho g l^3}{w^2},$$

Jimenez-Garate et al. Appl. Opt. 42, 724 (2003)

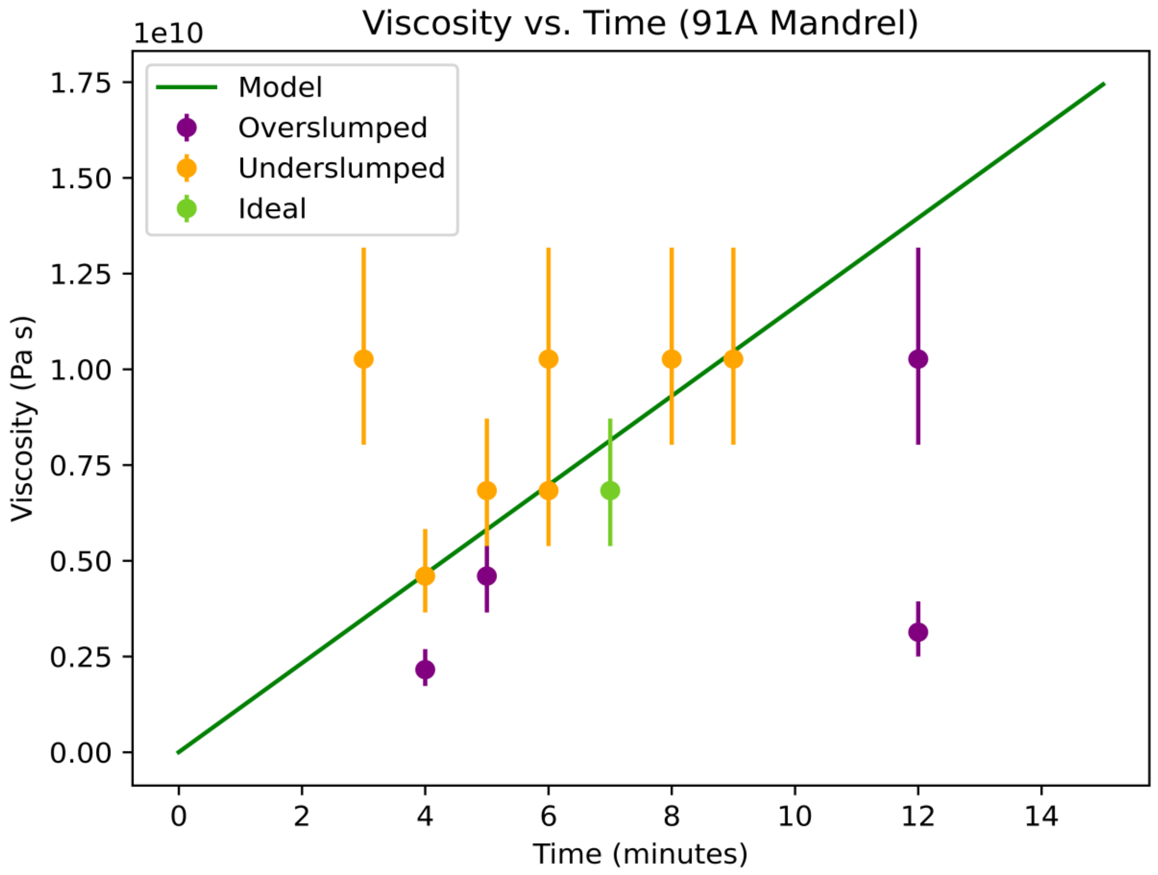
Calculates a viscosity and time relationship for ideal slumping using:

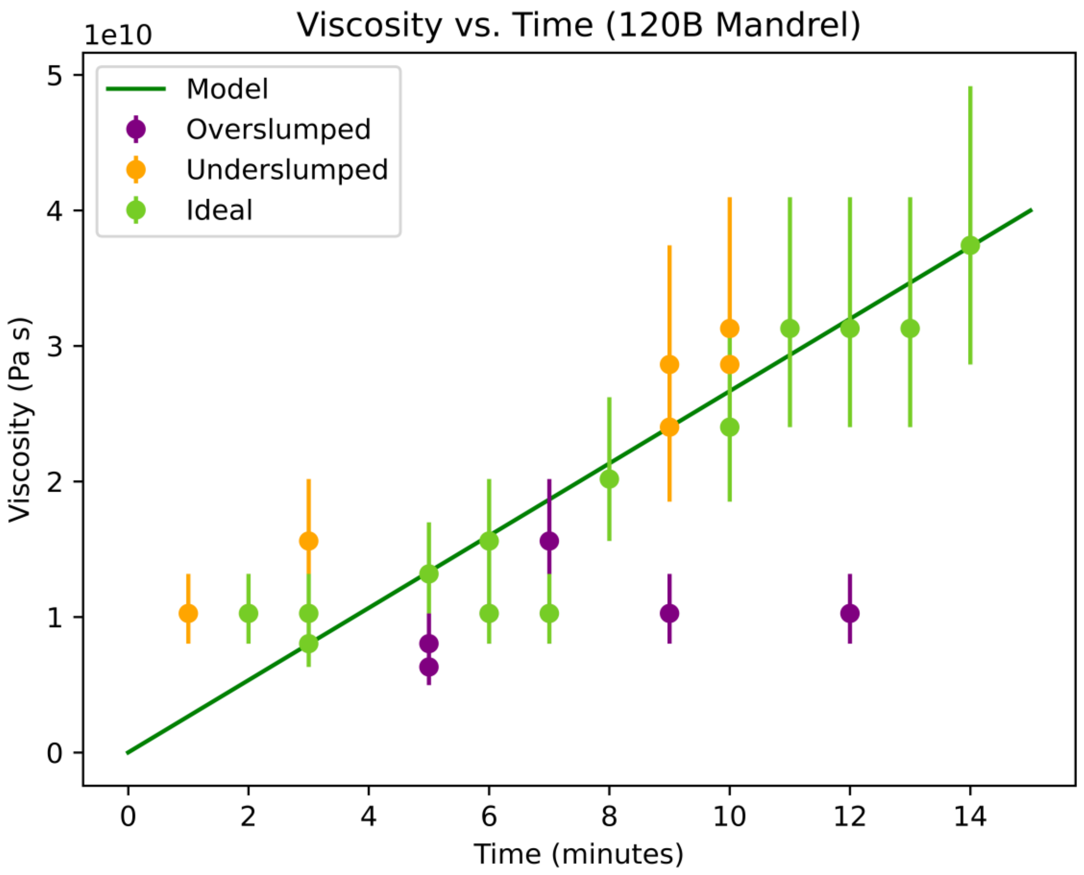
- Type of glass
- Size of piece
- Gravity's influence



Jimenez-Garate et al. Appl. Opt. 42, 724 (2003)

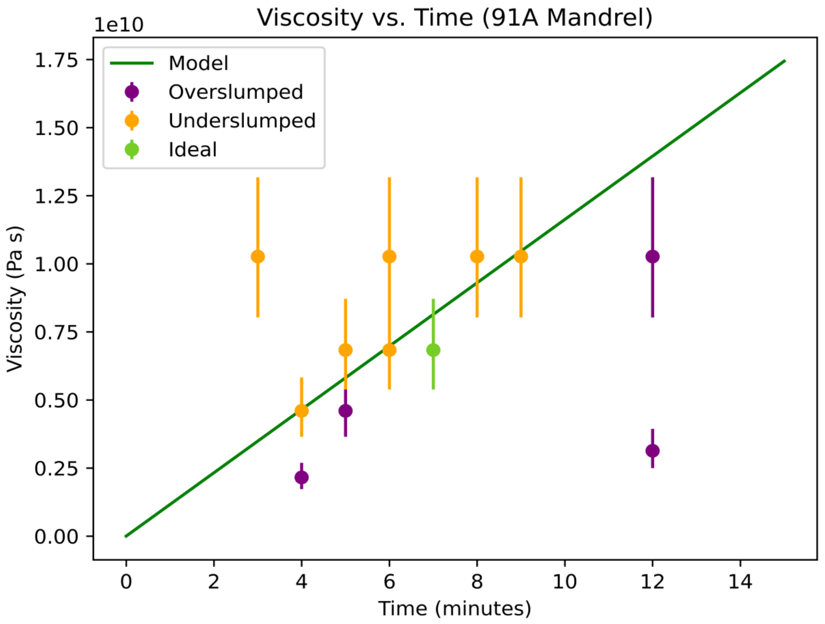
Experimental Results

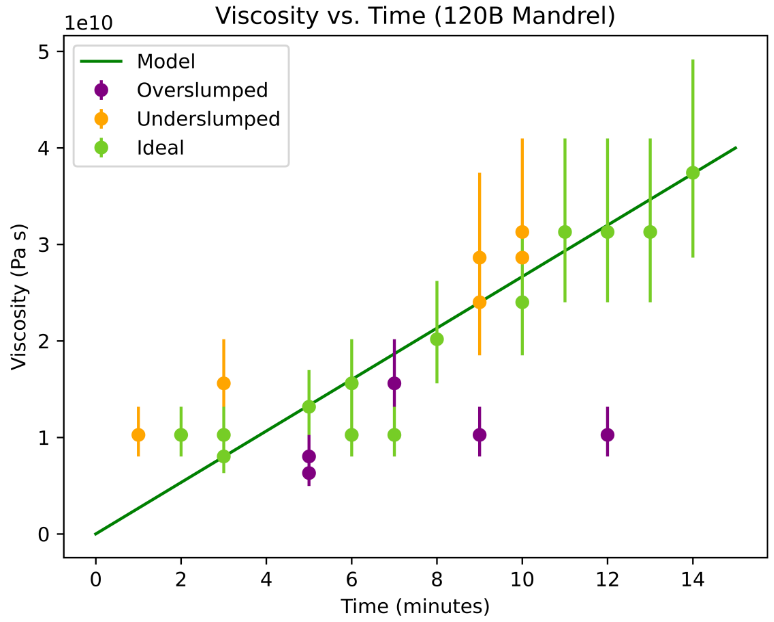


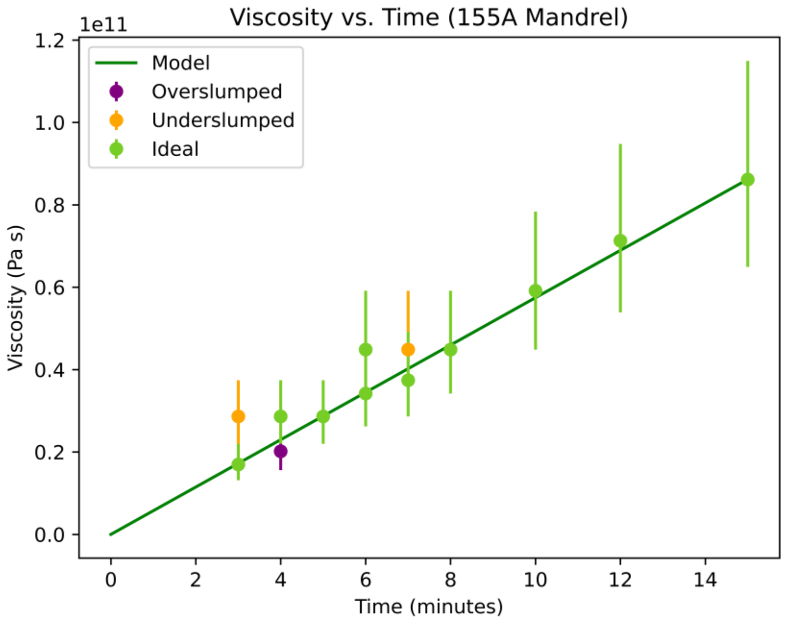


Without Model: 11.6% passed visual inspection   With Model: 74.1% passed visual inspection

Experimental Results







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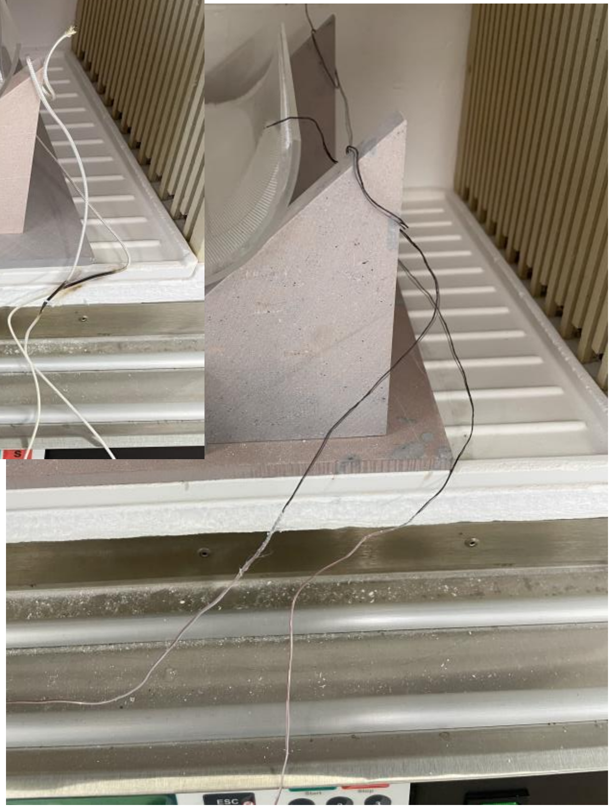
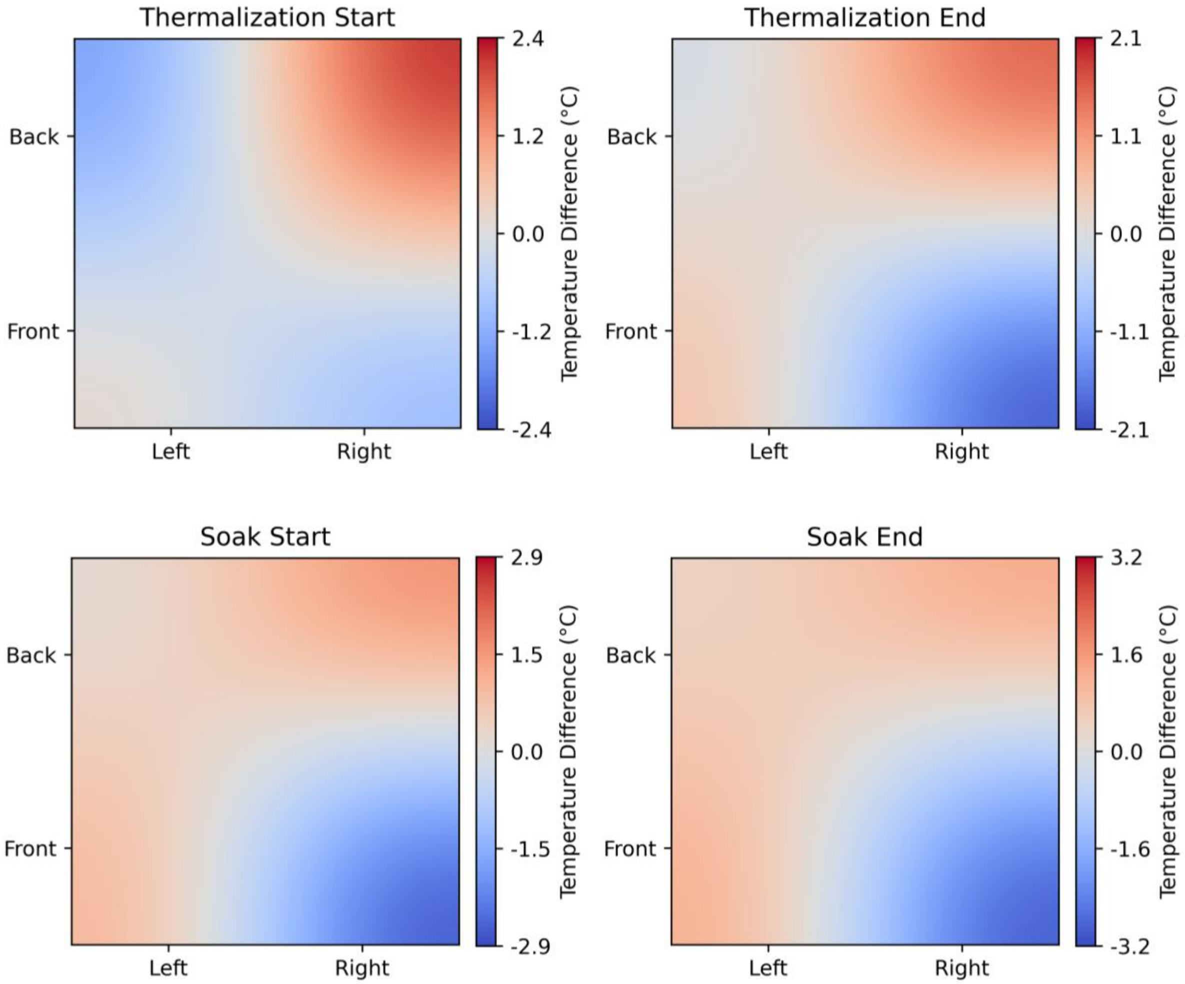
Oven Characterization

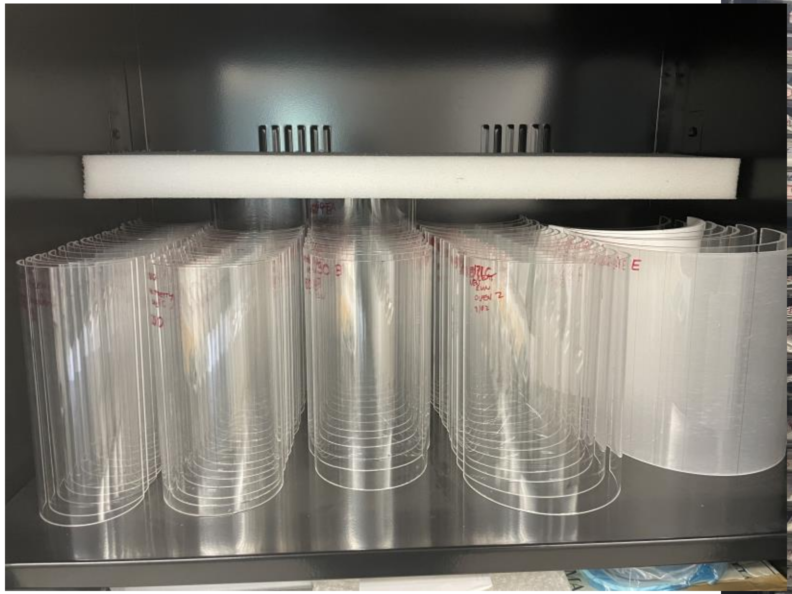




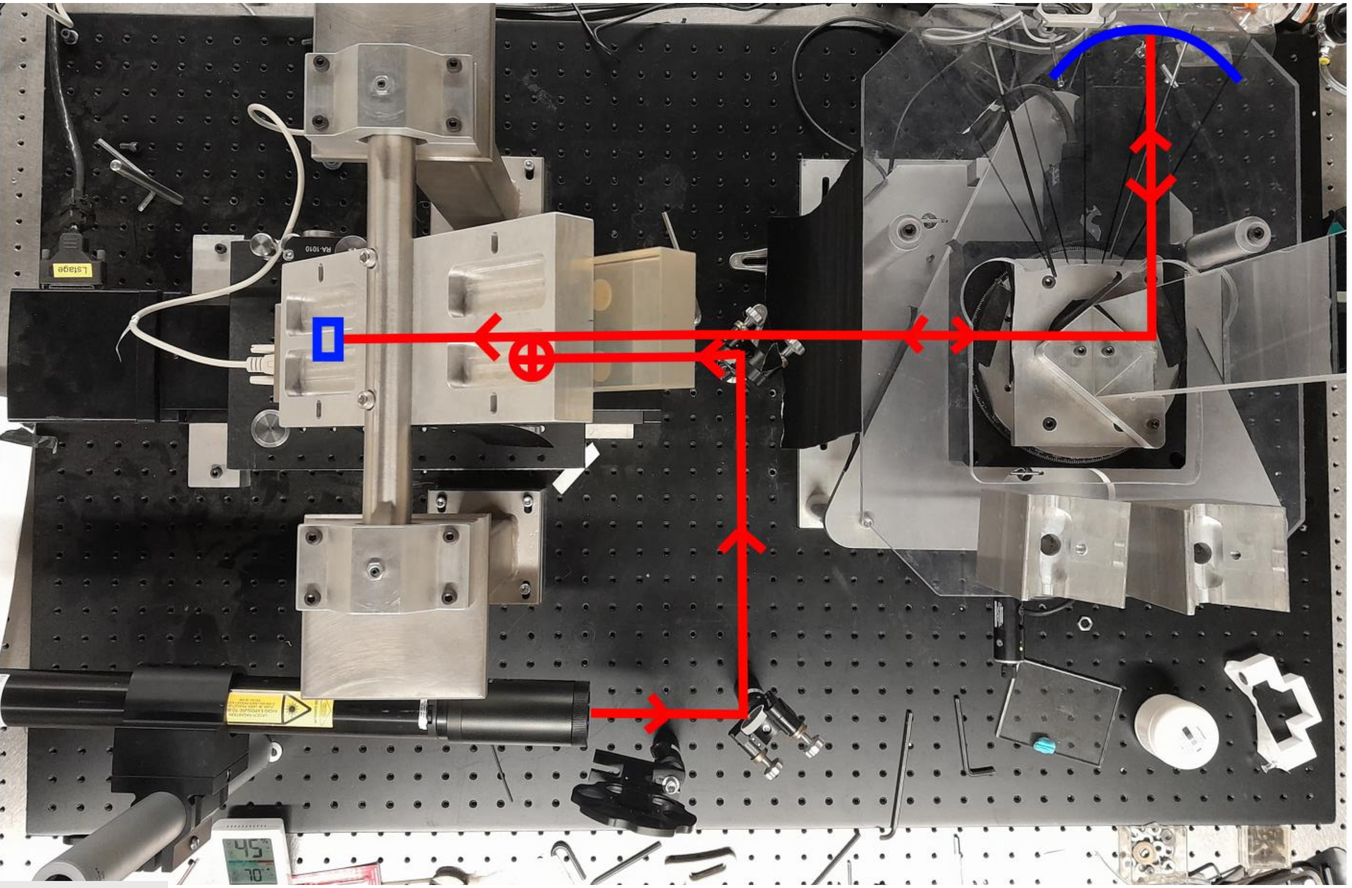
Adapting NuSTAR and HEFT

We have:

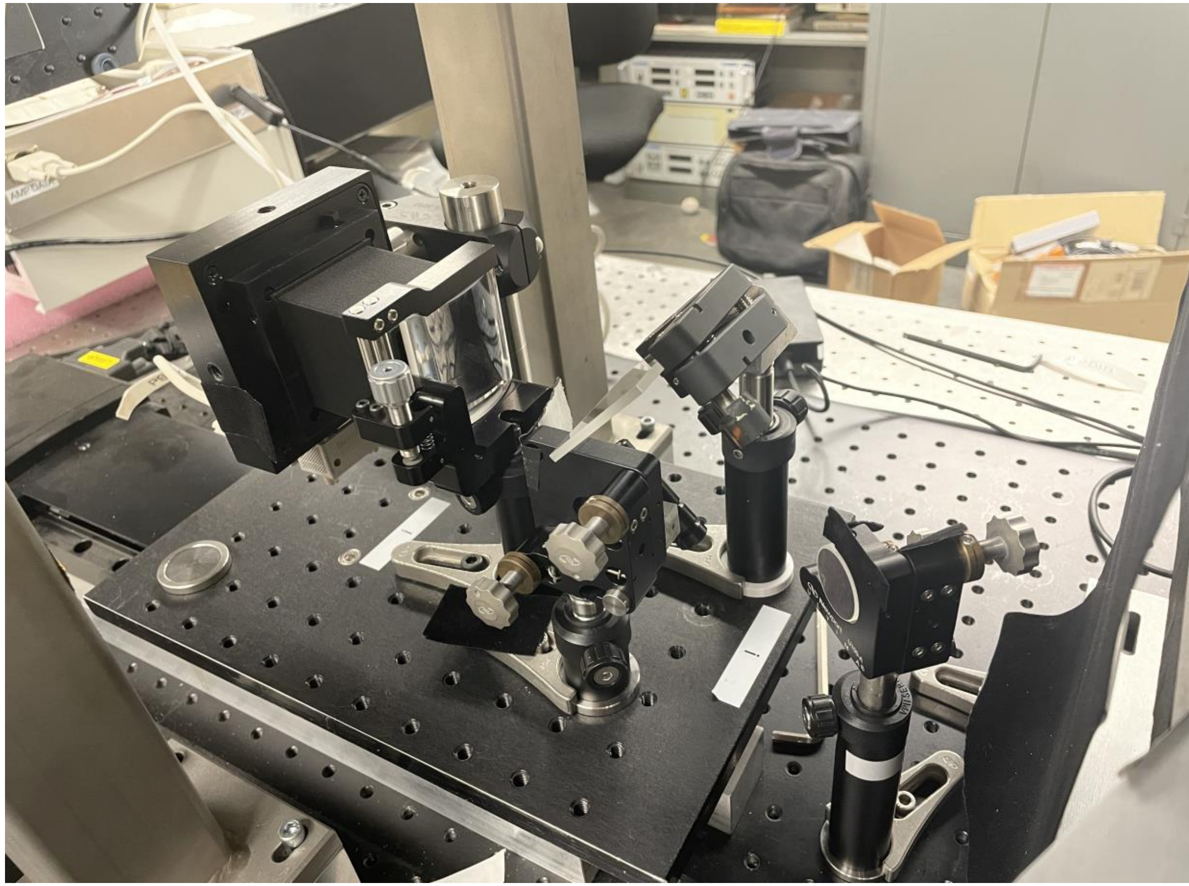
- 6728 pieces of glass
- 875 pieces telescope ready
- 2209 coated pieces that should be laser scanned
- 1143 pieces that should be coated
- 262 pieces that need to be thermally formed



Laser Scanner



Mike Law



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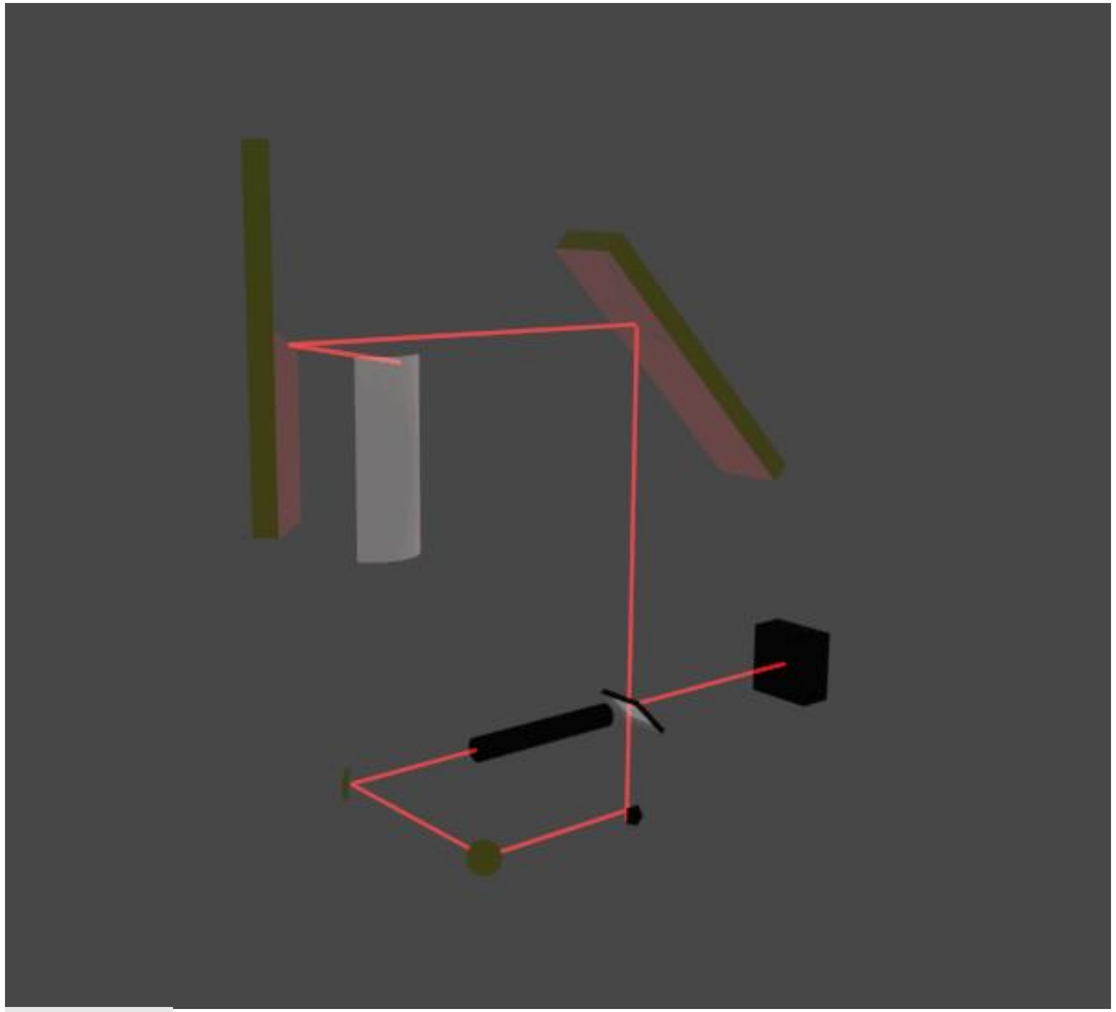

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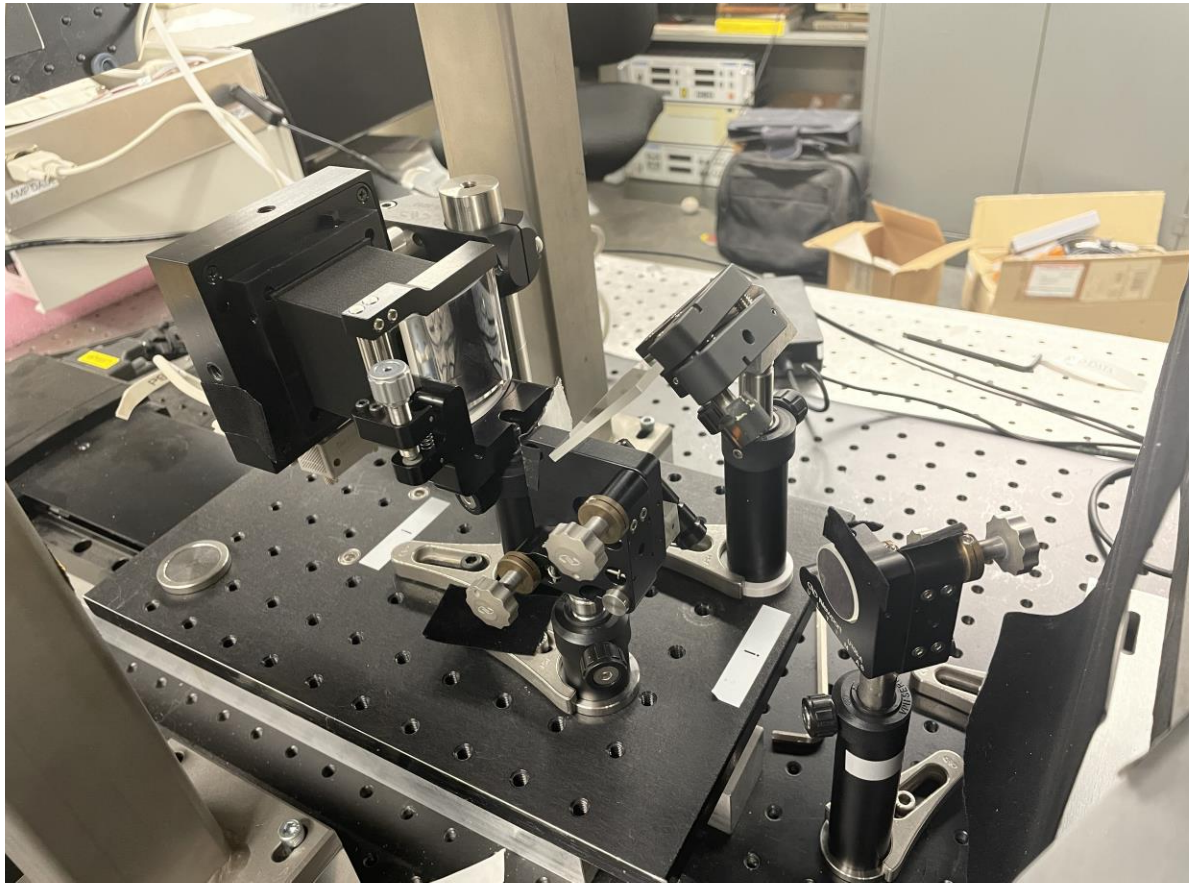


Conclusion and Next Steps

We know:

Effective, repeatable recipes for slumping

How to determine recipes for other mandrels

How to adapt recipes according to discrepancies between ovens

What glass we need to form, coat, and scan to complete an optic

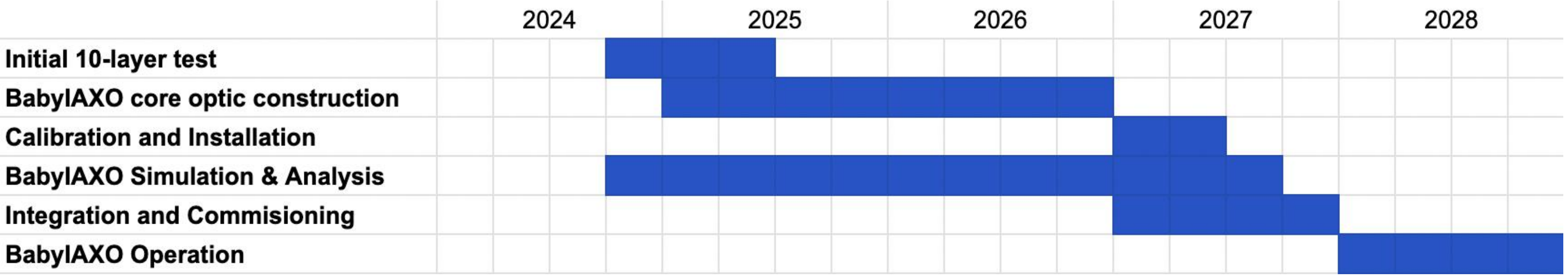
Next steps:

Continue to adapt slumping model

Complete inventory

Improve thermocouple setup

Laser scan!



Acknowledgements

Thank you to Dr. Kerstin Perez, Mike Law, and Marcela Stern for their guidance and support this summer. Thank you to Dr. Georgia Karagiorgi, Dr. Reshmi Mukherjee, and Amy Garwood for the organization of this REU program.

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