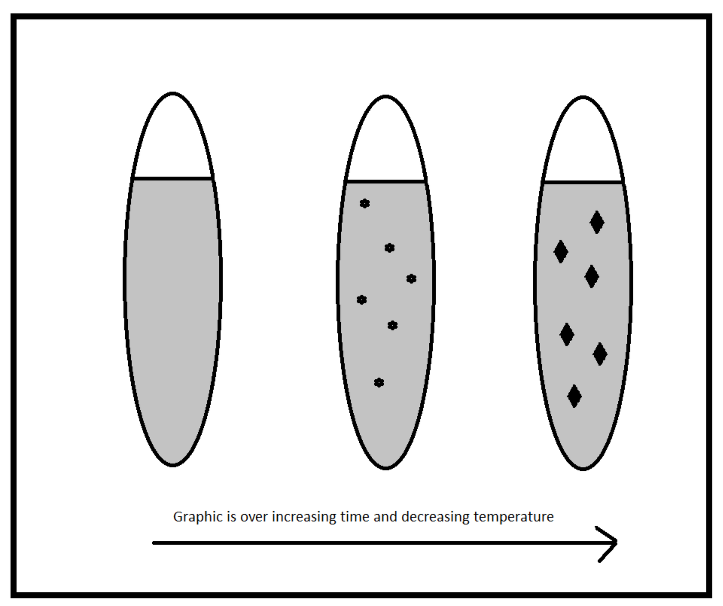
Design and Development of Temperature Controller for Flux Growth

Patrick C. Stetz, Seita Onishi, Jacob Bryon, Joey Barreto, Kevin Nuckolls, A. Zettl

Department of Physics, University of California, Berkeley

Background

- Flux Growth- Crystal precursors are sealed in an ampoule with another material, the flux, which acts as a solvent at high temperatures. As the temperature is slowly lowered so does the solubility of the flux which release some crystal precursors from its grasp. These excess precursors are then able to attach themselves to a nucleation site creating a crystal



- Rock Candy-

- Earth's Core- Once suspected to be a single giant crystal of radius 1,200 km, Earth's inner core is solid iron. Outside of this core is liquid iron which is very slowing cooling. For billions of years, Earth's liquid core has been cooling and solidifying slowing, gradually increasing the solid core.
- RRR Values vs. Growth Methods

Growth	RRR	References
Flux	900	Canfield (ref. 3)
Flux	1250	Cava 2015 (ref. 1)
CVT	370	Cava (ref. 4)

Target Materials

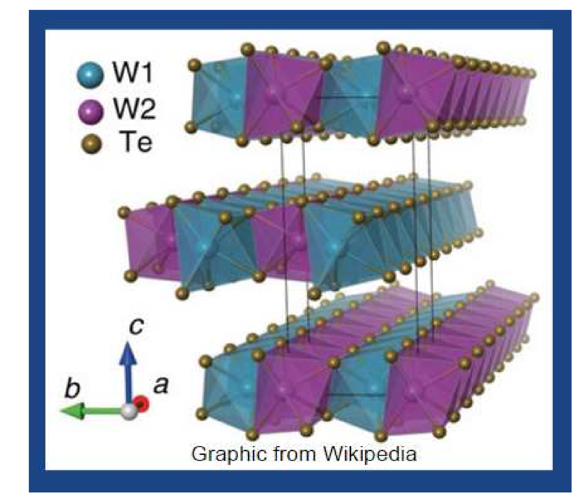
WTe2 has gained much interest for being a suspect holder of Weyl fermions

- Recipe: 10g Te and 200mg WTe_2 powder cooled from 825^oC to 525^oC at 2^oC/hr (ref. 1)

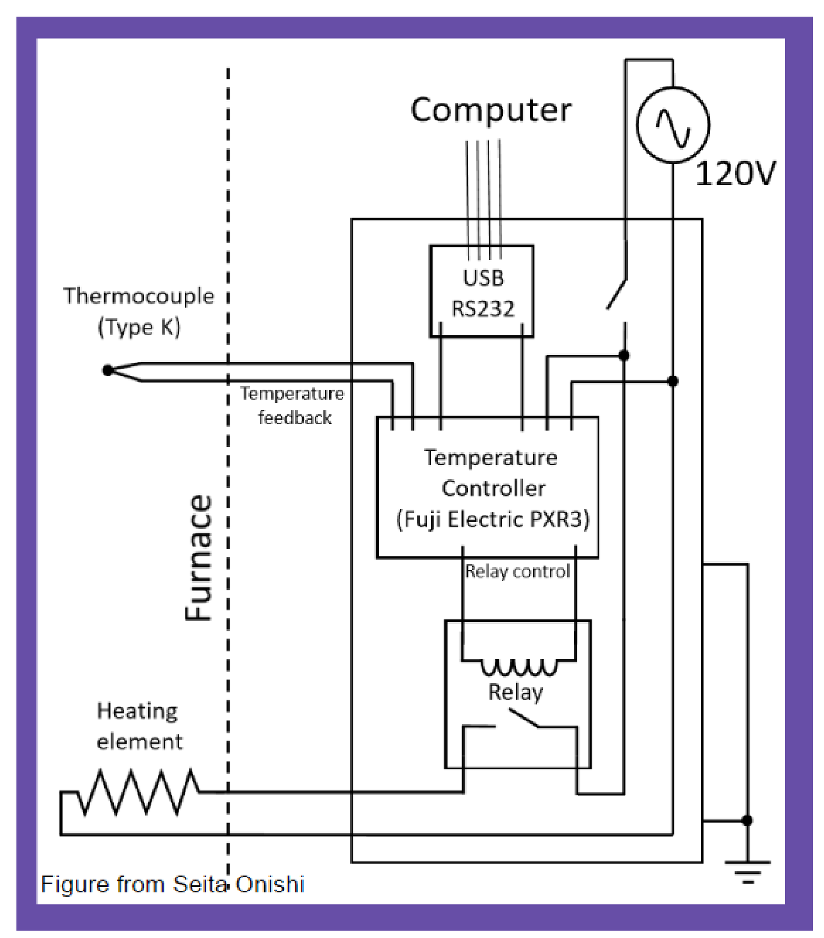
FeSe monolayer has seen lots of attention recently for being an iron based superconductor at high temperatures

- Recipe: 1:0.82 mole ratio of Fe and Se powders in Na/Cl (1/1 mole ratio) flux cooled from 850^oC to 600^oC at 3^oC/hr (ref. 2)

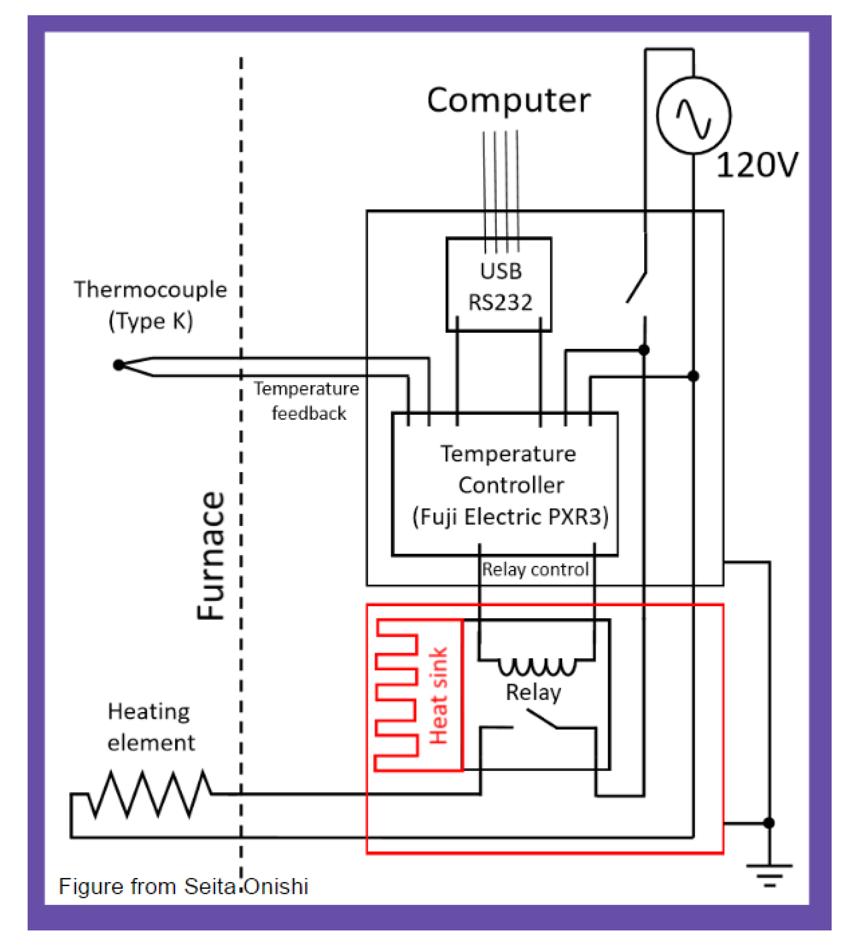
WTe_2



1st Design

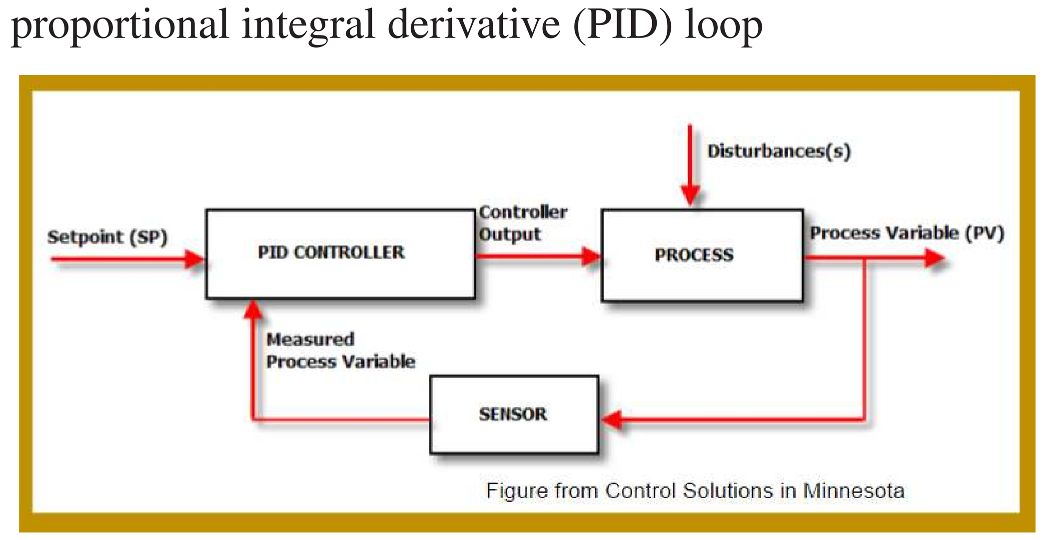


2nd Design

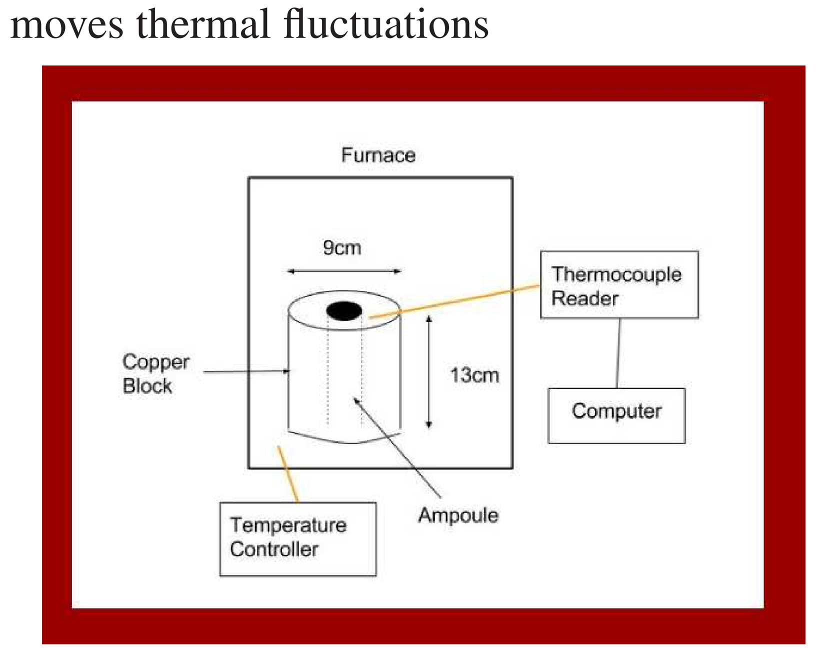


How it works

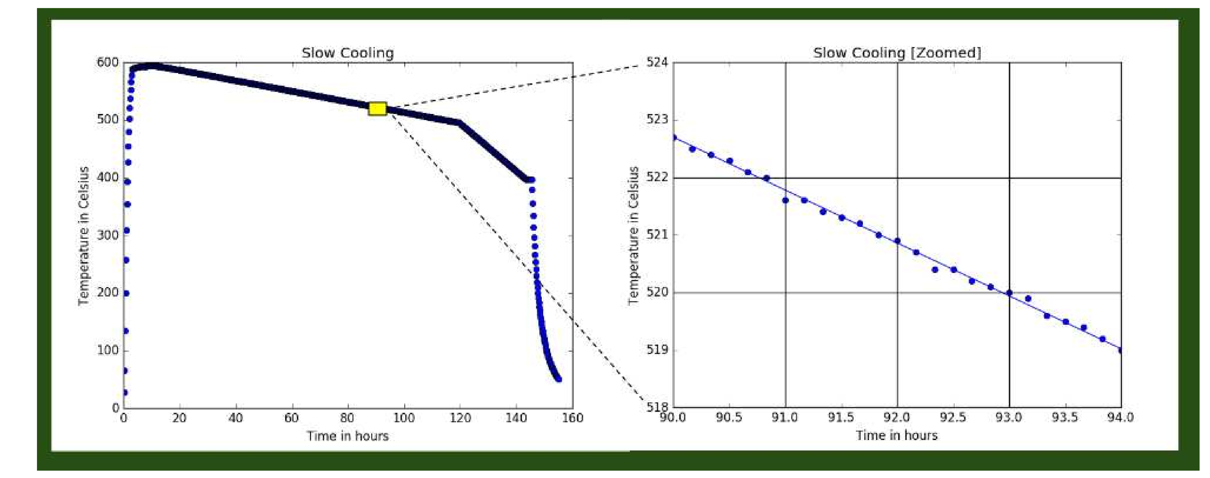
The temperature controller regulates the furnace through a proportional integral derivative (PID) loop



The copper block surrounding the ampoule removes thermal fluctuations

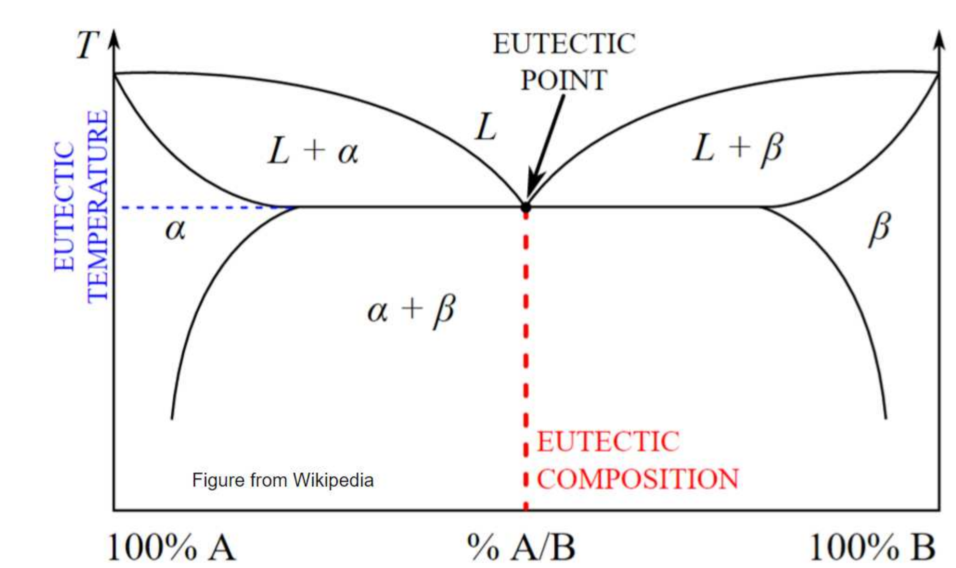


Synthesis Parameters



$\pm$0.1^oC stability over 100hrs (measurement accuracy limited)

The solubility and melting point of the eutectic (flux), is highly dependent on the mixing ratios



Next Steps

- Greater compatibility to three phase power
- Higher temperatures and thus greater solubility ranges and eutectic options
- FeSe and WTe2 growths at very slow cooling rates

References

(1) Ali, Mazhar N., Leslie Schoop, Jun Xiong, Steven Flynn, Quinn Gibson, Max Hirschberger, N. P. Ong, and R. J. Cava. "Correlation of Crystal Quality and Extreme Magnetoresistance of WTe2." IOP Science. N.p., 29 June 2015. Web. 7 Sept. 2016.

(2) Zhang, S. B., Y. P. Sun, X. D. Zhu, X. B. Zhu, B. S. Wang, G. Li, H. C. Lei, X. Luo, Z. R. Yang, W. H. Song, and J. M. Dai. "Crystal Growth and Superconductivity of FeSex." IOP Science. N.p., 28 Nov. 2008. Web. 7 Sept. 2016.

(3) Wu, Yun, Na Hyun Jo, Masayuki Ochi, Lunan Huang, Daixiang Mou, Sergey L. Bud'ko, P. C. Canfield, Nandini Trivedi, Ryotaro Arita, and Adam Kaminski. "Temperature-Induced Lifshitz Transition in WTe2." Physical Review Letters (2015): n. pag. ArXiv. Cornell University Library, 12 Oct. 2015. Web. 5 Apr. 2017.

(4) Ali, Mazhar N., Jun Xiong, Steven Flynn, Quinn Gibson, Leslie Schoop, Neel Haldolaarachchige, N. P. Ong, Jing Tao, and R. J. Cava. "Titanic Magnetoresistance in WTe2." ArXiv (n.d.): n. pag. 23 Sept. 2014. Web. 5 Apr. 2017.

Contact information: Patrick C. Stetz, 105 Birge Hall, Department of Physics, University of California, Berkeley, Berkeley, CA 94720 – Phone: 408–823–8417 – Email: *pstetz@berkeley.edu*;
Acknowledgments: This work received assistance from Seita Onishi in Professor Alex Zettl's lab in UC Berkeley. In addition I would like to thank the other undergraduates who have helped me along the way: Jacob Bryon, Joey Barreto, Kevin Nuckolls, and Xiyue Wang