State of Substances in Diamond Anvil

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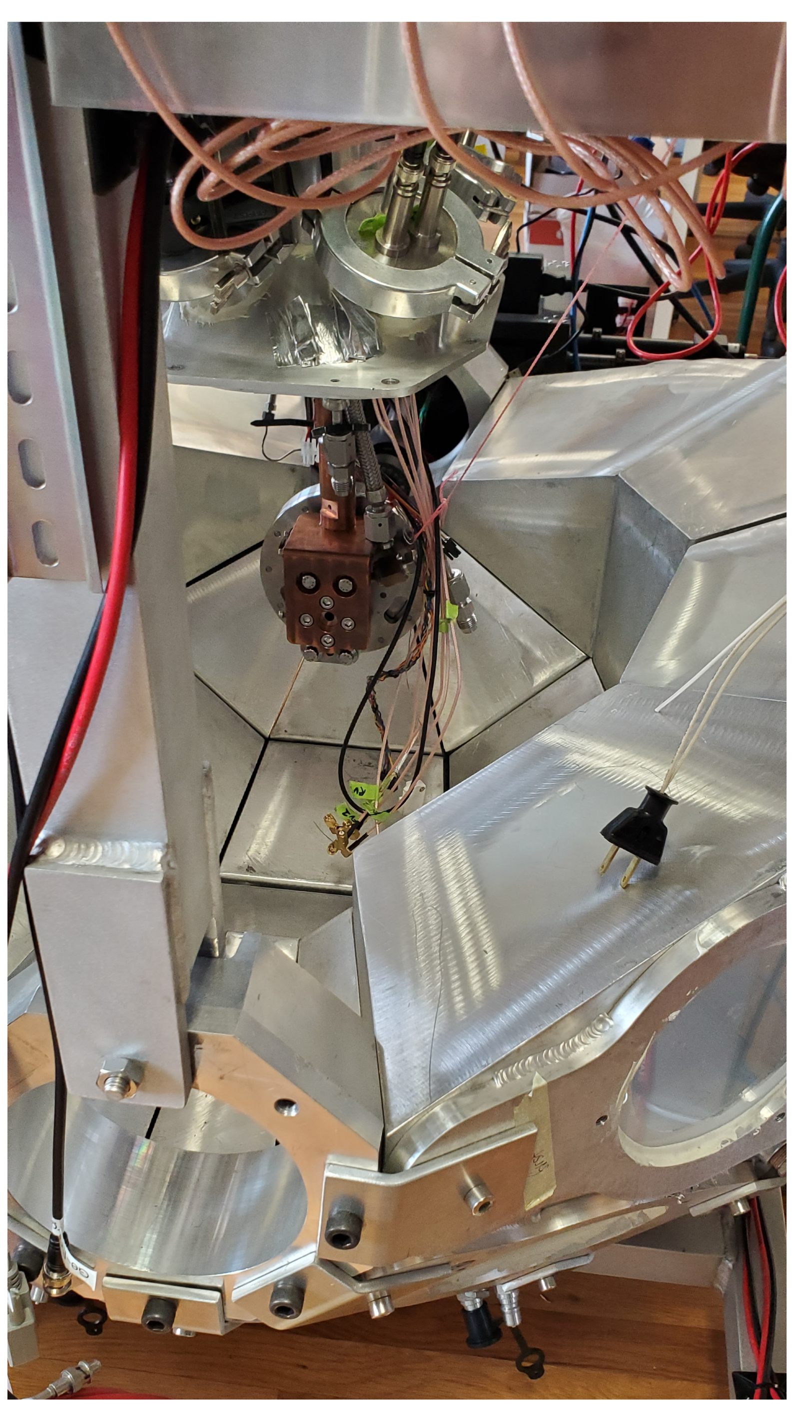
Introduction:

NK Labs, an engineering firm based out of Massachusets has designed a diamond anvil cell for testing muon catalyzed fusion. Fermilab has proposed granting them access to use a new muon beam, located in the MTA hall, for this experiment. As such, to assist in this effort, a review was conducted on previous research to create a series of scripts capable of automatically determining the phase state of Argon, Hydrogen, and Deuterium across a wide range of pressures and temperatures in pursuit of a determination of the density of said substances across the same range.



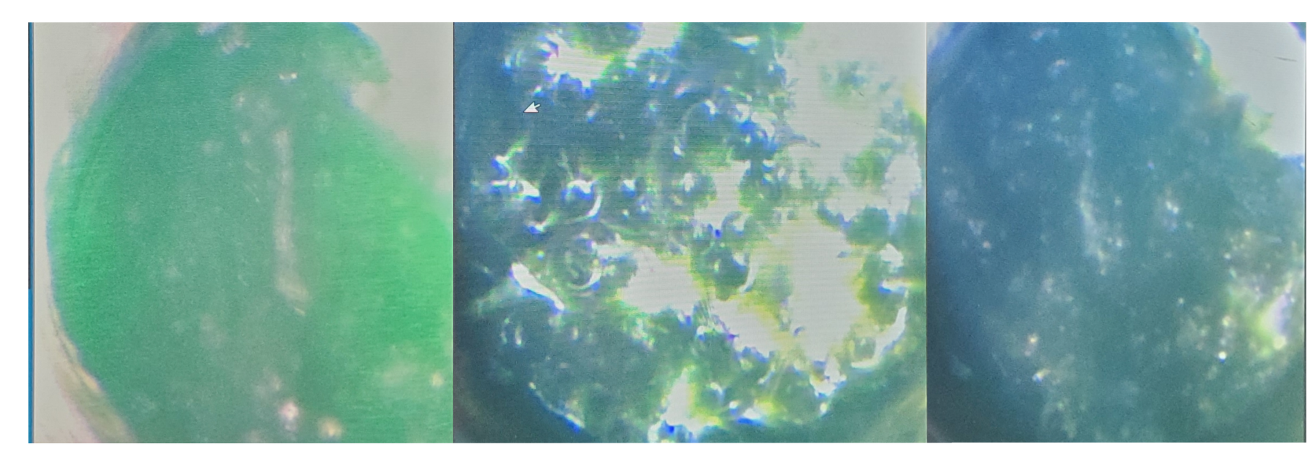
Unshielded diamond anvil cell in partially assembled sensor assembly.

Methods:

Utilizing Fermilab's subscriptions to various scientific journals, a search was conducted to collate data from various relevant studies to create an accurate determination of phase from 5K to 500K and 0.1GPa to 1GPa. The results were then implemented in Python, creating functions that took in temperature in Kelvin (measured by thermocouples) and pressure in Mpa (measured by the spectrometry of ruby dust in the anvil), outputting the phase state of the substances accordingly. A goal of an error range with a maximum of 2% was aimed for. The scripts were compared to experimental studies to ensure their accuracy.

Purpose:

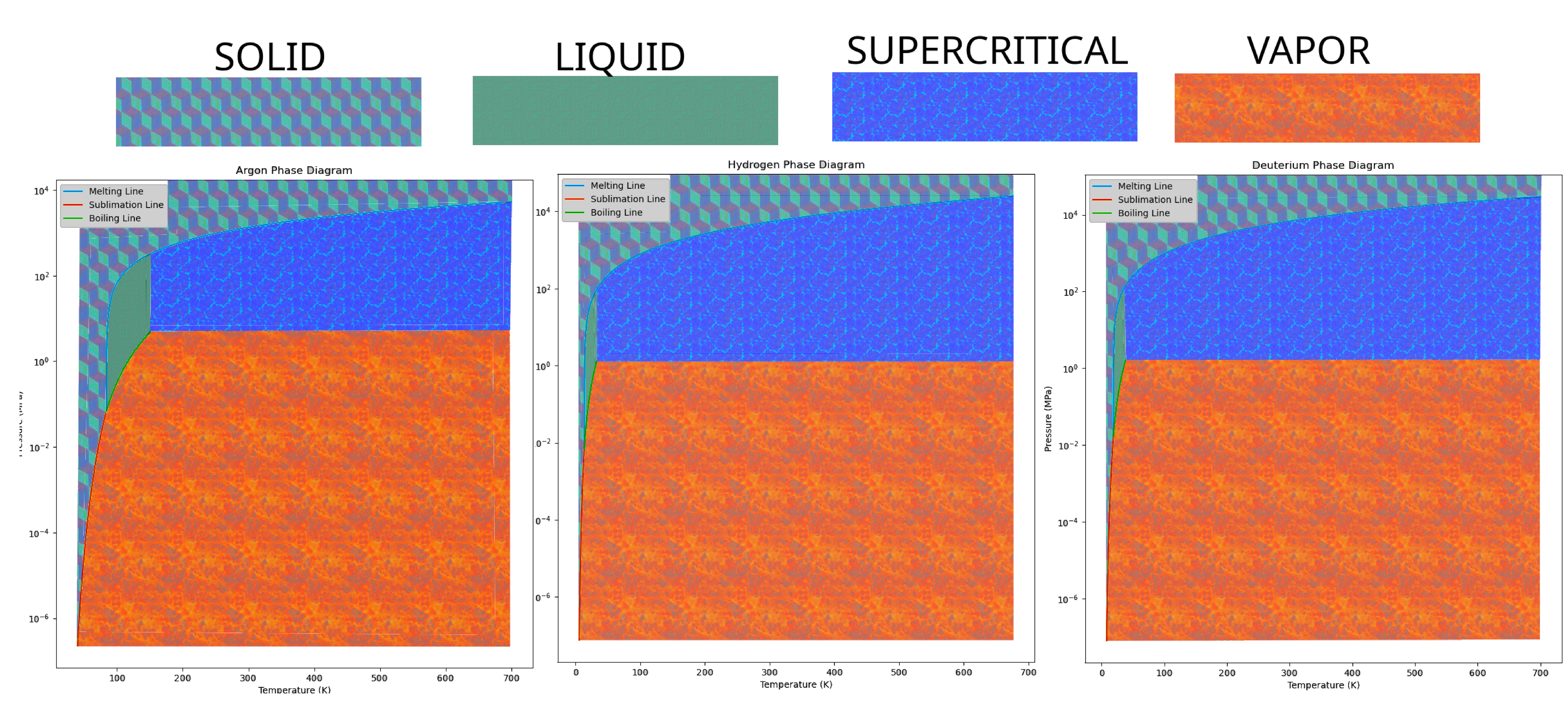
The precise determination of phase is essential for accurate calculations of the conditions of the substances under compression. Density, the factor of greatest importance, was the primary motivation for this work being done. It is believed that the density of the mixture will be strongly correlated to various observed fusion phenomena. Argon, being used for testing; hydrogen, being used as a control substance; and deuterium, being a part of the fusion experiment itself; were chosen as the most relevant substances requiring phase determination.



In order from left to right, vapor, liquid, and solid argon as observed within the diamond anvil under compression.

Results and Conclusion:

Three scripts were created that successfully calculated the phase states of Argon, Hydrogen, and Deuterium across the desired ranges with an acceptable level of error. An attempt was made to continue on with the determination of density, but the extreme rarity and complexity of the relevant density equations meant that as of this conclusion, only an acceptably accurate and wide-reaching Argon density script has been created, and only for the fluid phases. As such, it can be concluded that the next item of focus should be the completion of scripts to determine the density of the relevant substances.



Graphs produced by the phase state Python scripts. From left to right: Argon, Hydrogen, Deuterium.

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Abstract

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NK Labs, an engineering firm based out of Massachusets has designed a diamond anvil cell for testing muon catalyzed fusion. Fermilab has proposed granting them access to use a new muon beam, located in the MTA hall, for this experiment. As such, to assist in this effort, a review was conducted on previous research to create a series of scripts capable of automatically determining the phase state of Argon, Hydrogen, and Deuterium across a wide range of pressures and temperatures in pursuit of a determination of the density of said substances across the same range. Ultimately, the priority ranges of 0.1-1GPa and 20-500K for hydrogen and .1-1GPa and 90-500K for argon were covered adequetly in all cases but that of the determination of the density of solid Argon. As an addition, there remains a desire for extensions of the created scripts to cover out to 1500K and 5GPa.