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Design and Optimization of an Aerosol Optical Cell for Spectroscopy Analysis for Molten Salt Reactor Safeguards_AvilaJuan_Summer Intern Poster Sessions

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Changing the World's Energy Future

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Introduction

With the world's population anticipated to increase by two billion in the coming decades, a consequent ever-growing demand for energy needed to sustain communities, and a global landscape looking to shift away from fossil fuels and adopting net-zero carbon emission policies, we can look to nuclear power as a solution for our country's energy needs in the future. With an anticipated shift to nuclear energy, there must be an investment in domestic and international safeguards to monitor and account for special nuclear materials to ensure their safe use.

Objective

The purpose of this project is to design a viable method for online real-time monitoring of the concentration of molten salt. Recent approaches utilize a batch nebulizer system coupled with an optical cell for laser-induced breakdown spectroscopy (LIBS). In this work, Idaho National Laboratory (INL) has focused on the development of an aerosol spectroscopy approach for online molten salt analysis for safeguards purposes that incorporates LIBS, ultraviolet-visible spectroscopy (UV-VIS) and other spectroscopy approaches into a single flowing system.

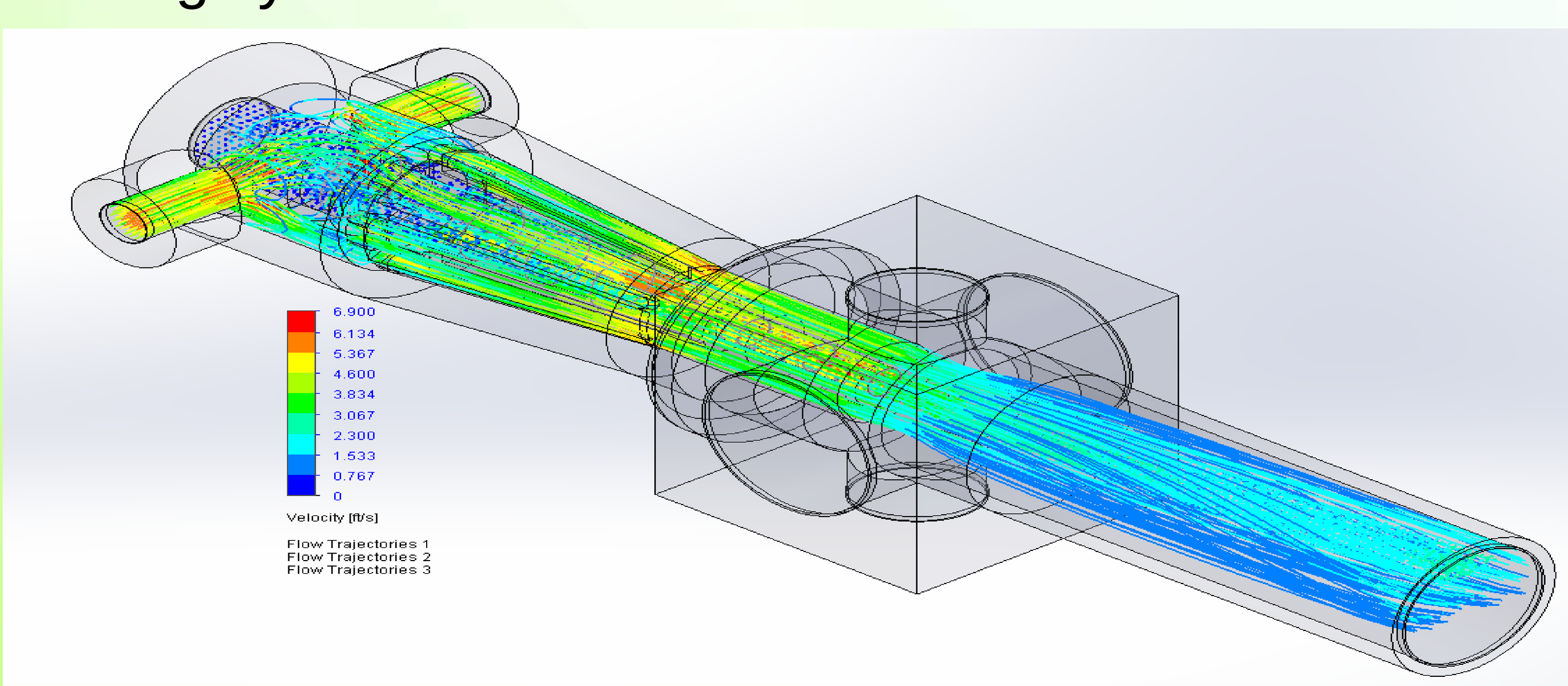

Figure 1: Computational fluid dynamics applied to sheathed nozzle-optical cell assembly to demonstrate the flow trajectory of the aerosol and compressed gases for LIBS testing

Procedure

The approach to this project was to meant to examine the issues that could arise from using the two different forms of spectroscopy:

- A sheathed nozzle was designed on SolidWorks to have concentric outlets for the molten salt aerosol in the center outlet and compressed gas in the peripheral outlet to prevent the aerosol from dispersing within the optical cell and developing salt films which could interfere with the concentration readings from LIBS. The model was constantly modified and reiterated upon when examining the distribution of aerosol and flow trajectories using computational fluid dynamics (CFD). For visual purposes, a transient study of five seconds was conducted using air and water vapor as the sheath and aerosol gases, respectively.
- A spectrophotometer was used to record the light absorbance of different concentrations of neodymium chloride ($NdCl_3$) and praseodymium chloride ($PrCl_3$) in 2% nitric acid (HNO_3) solutions. Data was gathered in a basic flow cell configuration and compared against data that is gathered from 1cm cuvette trials.

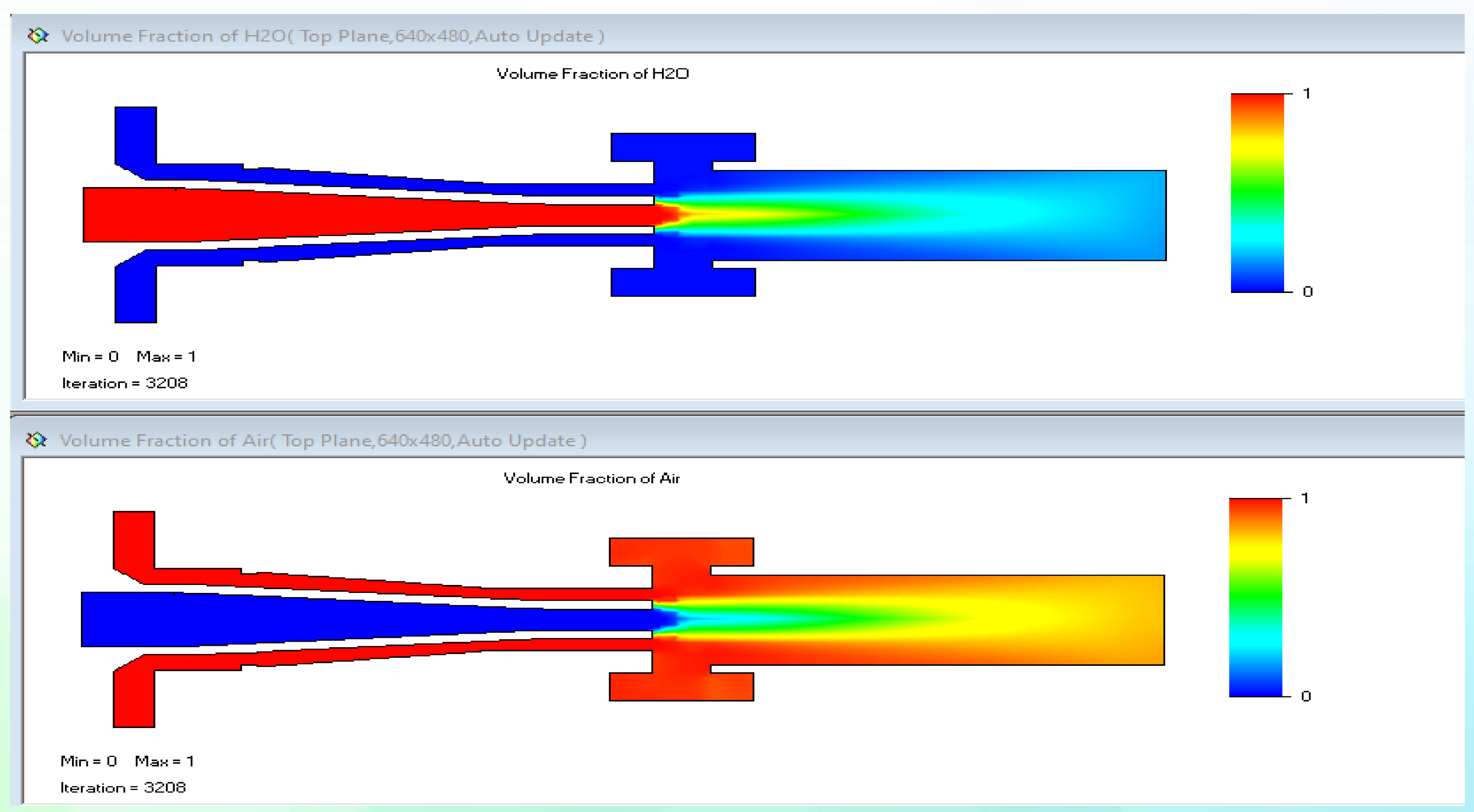

Figure 2: A transient study of 5 seconds was conducted using CFD to observe the distribution of aerosol (water vapor) to compressed gas (air)

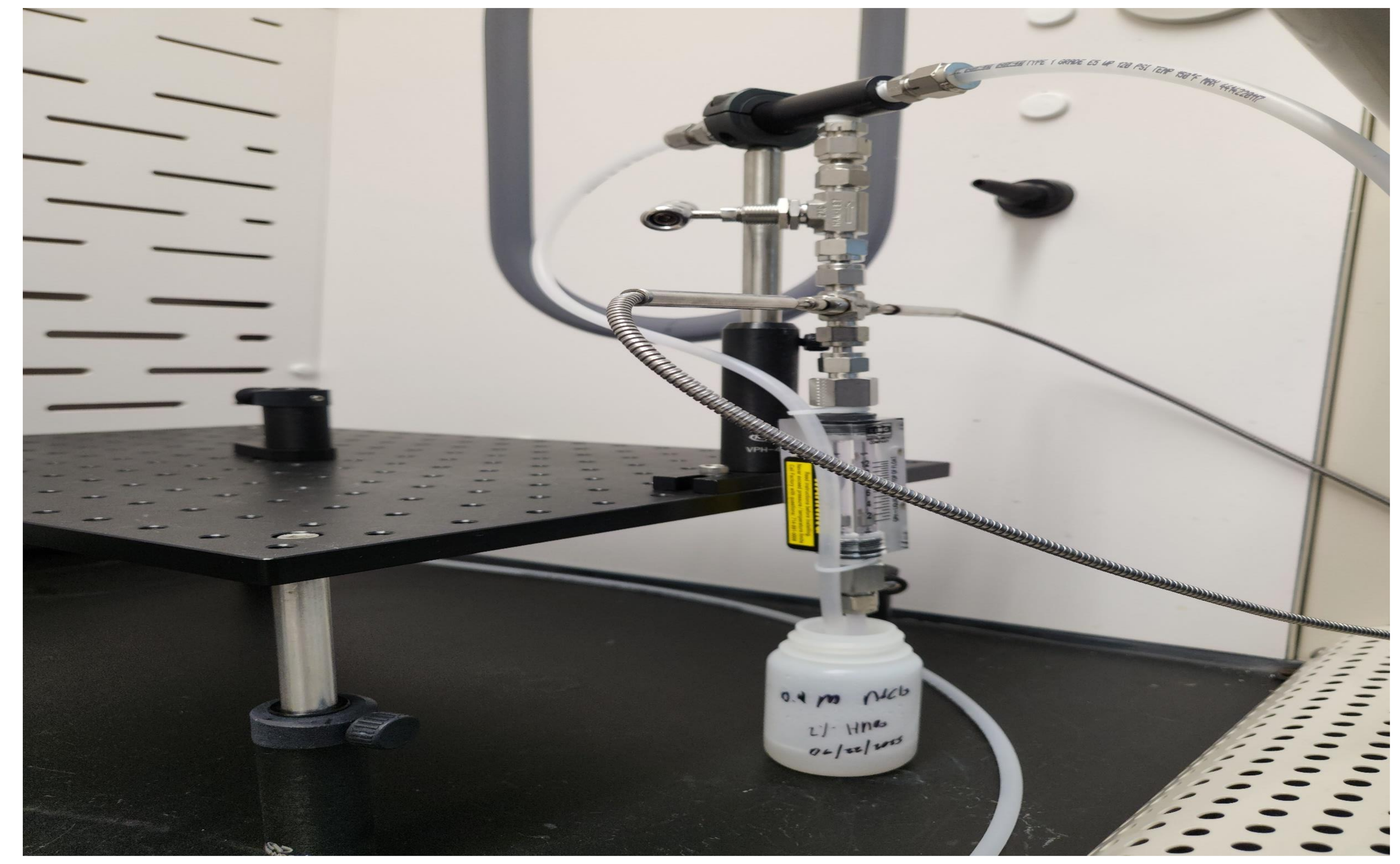

Figure 3: Basic assembly of the flow cell. Fiber optic cables are connected to the apparatus to record the absorbance of different concentrations of $NdCl_3$ and $PrCl_3$ respectively

Results

A final design for the concentric nozzle to be used in LIBS showed promising results in CFD testing and is currently being 3D printed to conduct physical trials for aerosol testing of solutions prepared from UV-Vis testing. The data gathered from UV-Vis spectroscopy samples was showed expected absorbance values for their respective solutions at certain wavelengths and calibration curves were constructed using a select number of peaks within the data.

Future Goals

The immediate future goal of this project is to construct a fluid system capable of operating LIBS and UV-Vis spectroscopy at the same time. Eventually this project will transition to live testing with molten salt aerosols with the anticipation that this design will be used in domestic and international safeguards for live reporting and accounting for special nuclear materials used in molten salt reactors. The results of this project will be presented at the November 2023 American Nuclear Society (ANS) conference.

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