Introduction: Isotopic compositional measurements of lunar ice would provide insight into the origin and potentially the age of the reservoir. Multiple sources have been proposed as the source of lunar volatiles (e.g., comets, interplanetary dust particles, meteorites, production on the surface via solar wind, and volcanic outgassing). An instrument that can measure isotopes in situ lies in the critical path for determining the delivery and trapping process for lunar volatiles: e.g., source(s), transport to the polar regions, and ultimate storage. Hence, we are beginning to develop a flight-ready instrument, which will include extraction and analysis, for the purpose of measuring H, O and C isotopes of polar volatiles. Our prototype development plan is to miniaturize an existing experimental apparatus that has been designed to carry-out isotopic measurements of water formed or processed in astrophysical conditions.

Historically, the method of choice for determining the stable isotopic composition of samples has been Isotope Ratio Mass Spectrometry (IRMS) utilizing the null method developed in the 1940s [1]. A promising (and field-portable) alternative to IRMS is tunable infrared laser-based Cavity Ringdown (CRD) absorption spectroscopy. The isotopic resolution of this technique may compete and, in some cases, surpass that of traditional IRMS systems, offering “per meg” resolutions and allowing for the continuous measurement of atmospheric gases such as CO$_2$ and H$_2$O with ~1 Hz time resolution or better.

To demonstrate CRD data robustness, we report results from a suite of laboratory experiments, which includes the extraction and analysis of small (~52 μmol) water samples, carried out by commercially available off-the-shelf instrument that has been integrated into a laboratory apparatus that in many way mimics the sample flow that could be expected in a lunar sample analysis mission.

ICE Apparatus: The Astrophysical Isotopic Characterization Experimental apparatus at California State University, San Marcos (CSUSM) was developed with the goal of measuring the isotopic composition of water samples synthesized or altered in astrophysical conditions [2]. Briefly, it consists of a 12-inch diameter UHV chamber that is pumped by a magnetically levitated turbo pump and is attached to a stainless steel vacuum line equipped with various gas-introduction ports, including a septum for injecting small liquid water samples and standards. Two U-shaped sections serve as cold-traps that can be used to concentrate or isolate water samples. Finally, the vacuum line is connected to a Picarro L2120-i that has been customized for measurements of δ$^{17}$O in addition to the advertised δ$^{18}$O and dD measurements (See Figure 1). Ultra-high purity N$_2$ is used as a carrier gas for making isotopic determinations of H$_2$O samples. For technical details on CRD isotopic determination, see [3].

![Figure 1. ICE apparatus for studies of the isotopic composition of water samples using a Picarro CRD spectrometer for D/H and $^{18}$O/$^{16}$O and $^{17}$O/$^{16}$O measurements](image)

Isotopic Determinations of Meteorite Water: We have successfully extracted and isolated liquid water samples from the Zag meteorite using a solenoid driven vacuum sample cruser [4]. Our preliminary results for D/H and δ$^{18}$O are shown below. Future work will focus on determining the systematic fractionation associated with the vacuum line.

![Figure 2. Preliminary multi-oxygen isotopic composition of water found in Zag using CRD.](image)