Towards semi-automatic, broadband, kHz-precision, astro-atmospheric molecular spectroscopy

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Experimental Design

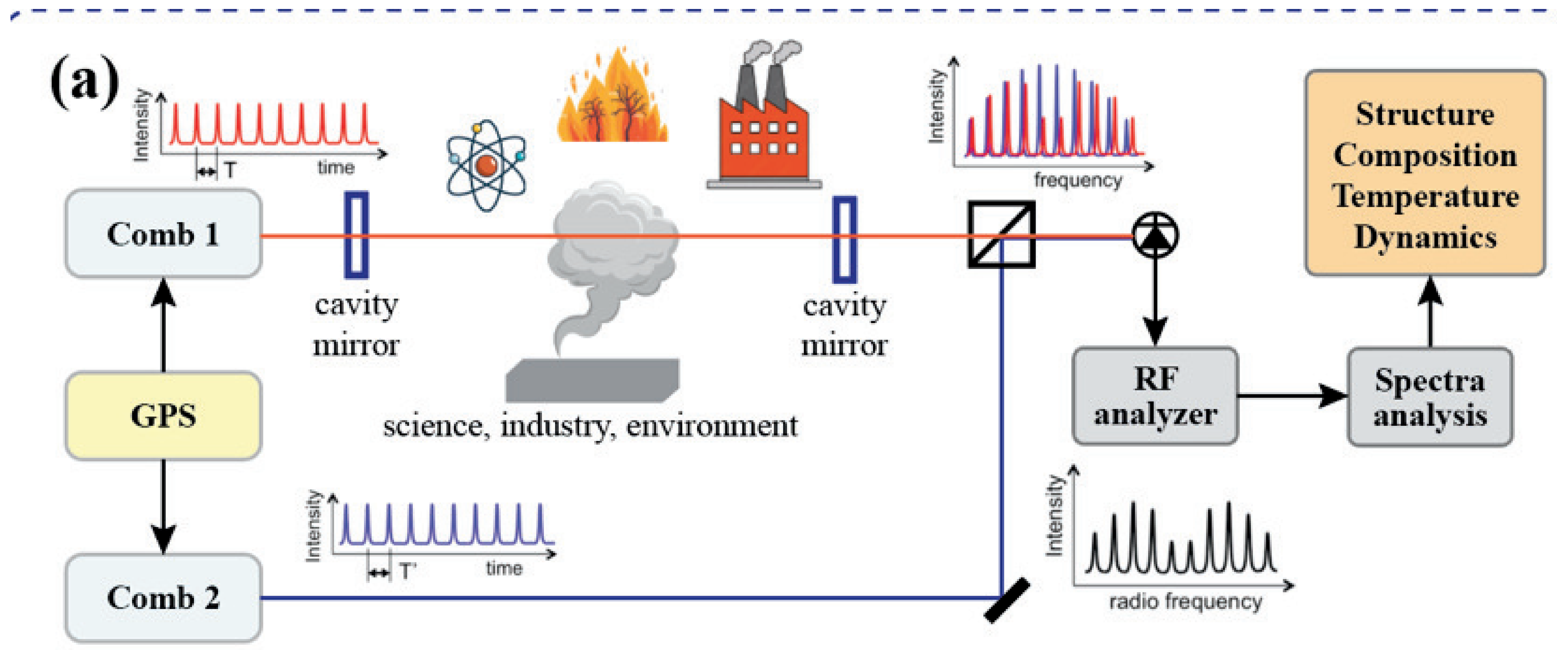

Figure 1- Schematic of dual OFC setup for atmospheric broadband spectroscopy

A schematic of a possible dual optical frequency comb (OFC) spectroscopy setup is shown in Figure 1. Comb 1 captures the molecular spectra while Comb 2, being slightly de-tuned from Comb 1, interacts with Comb 1 to down-convert the optical frequencies to RF frequencies. This dual OFC technique will be used to get automatic broadband molecular spectroscopy. From here, to obtain kHz frequency precision from the broadband spectroscopy, a Doppler-free method will be employed as in Figure 2(a). In this method, a counter-propagating pump-probe configuration is used to saturate the desired molecular transitions while the probe beam detects the doppler-broadened transitions, leaving a peak in the resulting spectroscopy at precisely the transition energy of the pump-saturated molecules, thus allowing for Doppler-free spectroscopy. To ensure the kHz linewidth precision of these transition frequencies, the DFB laser used for the Doppler-free spectroscopy will be referenced to an OFC as shown in Figure 2(b).The OFC will be phase-locked to a GPS reference to obtain kHz level precision, and in addition, will be referenced to a Ca atomic clock tranisition through an ECDL that will ultimately provide kHz frequency precision.

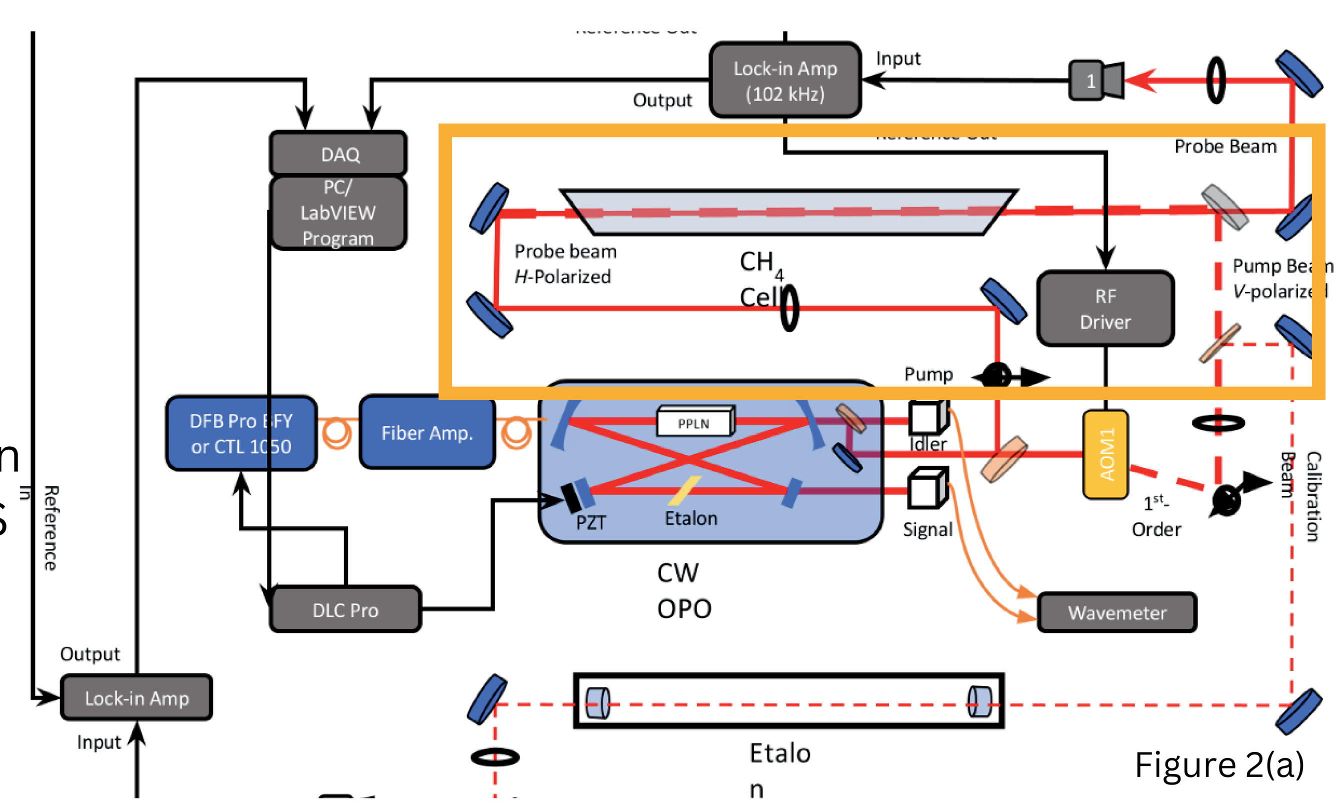

Figure 2(a)

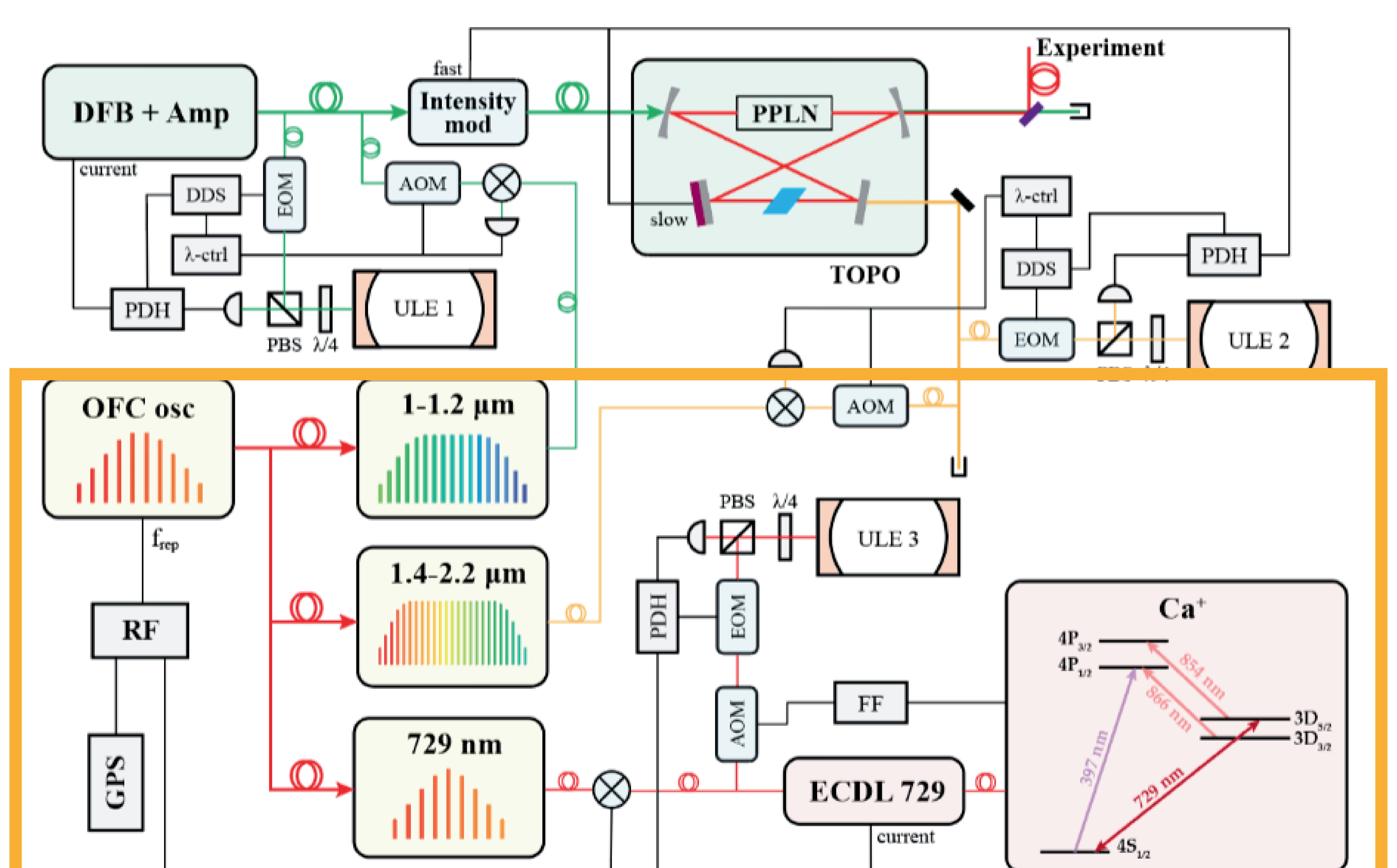

Figure 2(b)

Figure 2 (a) Credit: S. M. Shah Riyadh, Ian W. Jones, Hamzeh Telfah, & Dr. Jinjun Lui. Figure 2(b) Credit: Dr. JinJun Lui

Comparing the methods for this experiment to traditional frequency-scanning spectroscopy with single-frequency lasers, OFC spectroscopy leverages the broadband nature of the comb's modes, allowing for the simultaneous probing of numerous transitions. This capability enables the generation of absorption spectra containing thousands of spectral lines, significantly enhancing molecular identification.

Instrument Setup

Currently, Dr. Yan Zhou's lab at UNLV houses two TOPTICA Difference Frequency Combs (DFC +) as well as three wavelength extension modules as shown in Figure 3. The DFC + is an erbium based comb oscillator that runs at a center wavelength of 1550nm with the extensions allowing for wavelengths from 0.7- 2.2μm. This allows for molecular ion spectra in the visible and IR spectrum.


Figure 3- Two DFC+ Cores and wavelength extension modules at UNLV

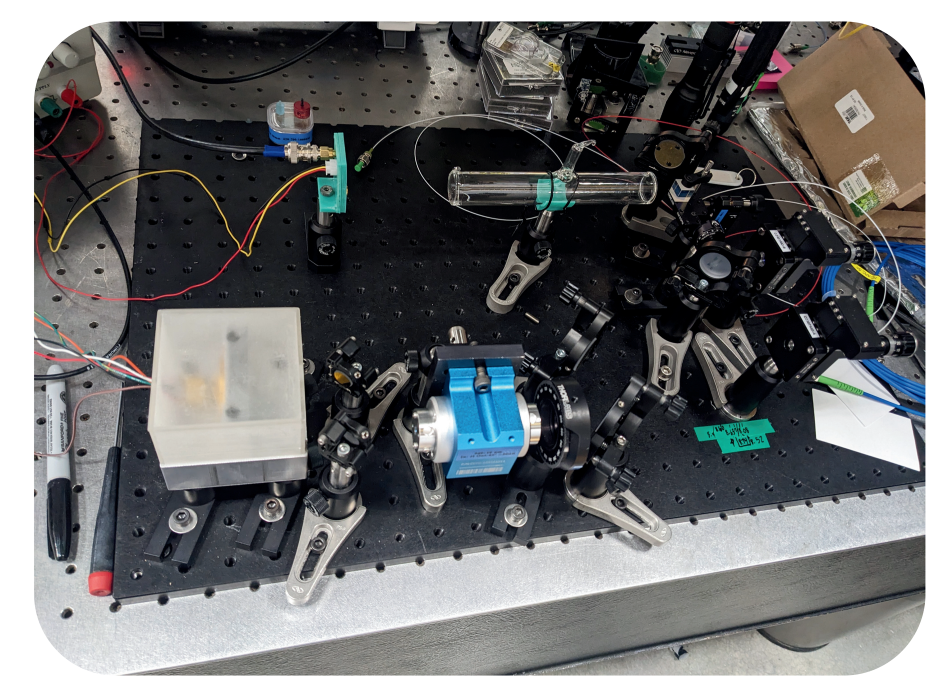
Figure 4- DFB laser setup in Dr. Yan Zhou's lab at UNLV, in preparation for water vapor cell spectroscopy

As well as the DFC + setup, Figure 4 shows a setup of the DFB laser system that will take preliminary water vapor spectroscopy. These results will be used to model the DFC+ absorption experiments in the future.

Preliminary Results

Using the DFB setup in Figure 4 and the HITRAN absorbance spectrum in Figure 6, our first goal was to obtain the water vapor spectrum. Figure 5 are plots for 7 different transitions.

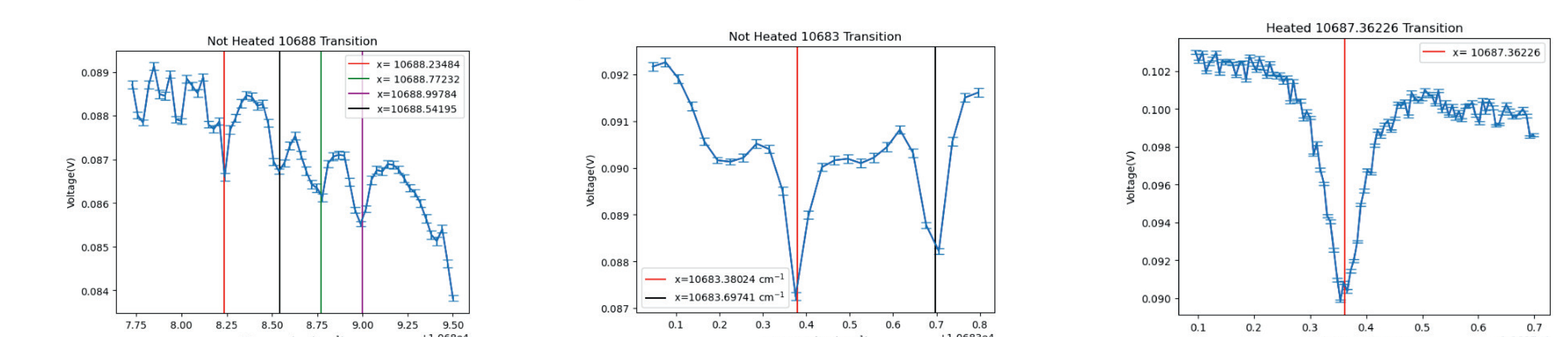

Figure 5(a) Figure 5(b) Figure 5(c)

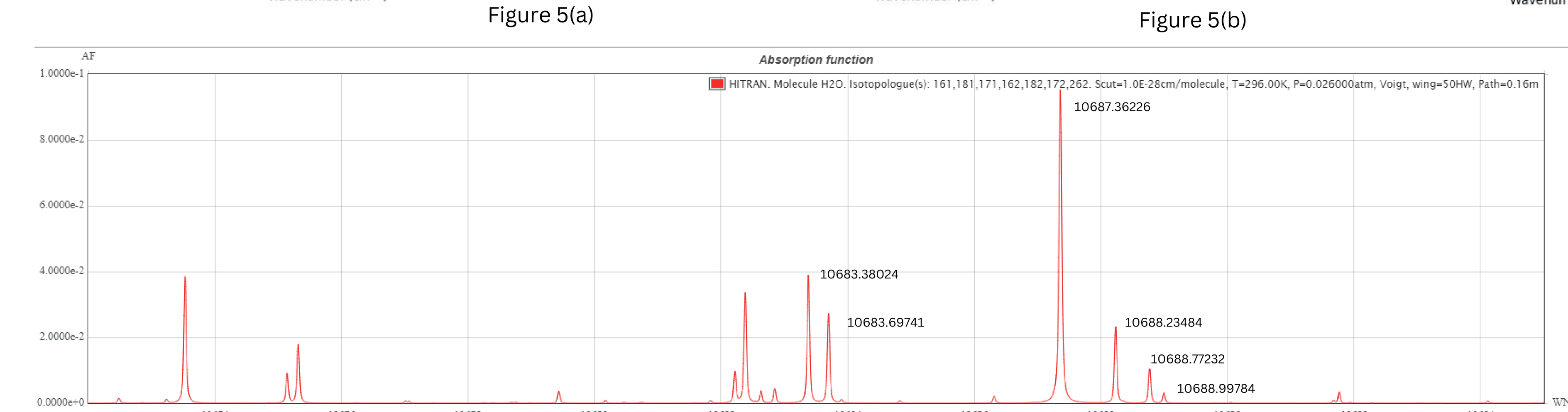

Figure 6- The absorption function of water vapor from HITRAN database

Acknowledgements

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