Developing Python Interface and Autonomous Scanning for FTMW Spectrometer

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Research Investigations & Objectives

- Developing overarching Python software controlling Tektronix oscilloscope, Zaber actuator, Stanford Research delay generator, Valon synthesizer, and other components
- Autonomous scanning capabilities for positioning actuator based on Fourier transform of obtained waveforms in Python
- Synchronous and simultaneous control and operation of novel FTMW spectrometer via GUI

Background

- FTMW (Fourier transform microwave) spectroscopy measures molecular transitions between quantized rotational energy levels.
- FTMW spectroscopy, when combined with supersonic molecular beams, offers a near collision-free environment to investigate fundamental properties and dynamics of Van der Waal complexes, short-lived intermediates, radicals, combustion/pyrolysis products, etc.
- Diluted analyte is pulsed into a vacuum and excited by short (<1 us) microwave pulses to record rotational spectra
- FTMW spectrometer designed by Dr. Gurusinghe research lab combines Cavity and Chirped pulse FTMW setups in a novel L-shaped design (**Figure 1**) with integrated instruments described in **Table 1**/**Figure 2**
- Implementation of Python overarching software allows for the development of a multitude of tools through simultaneous instrumentation control on top of ease of spectrometer use

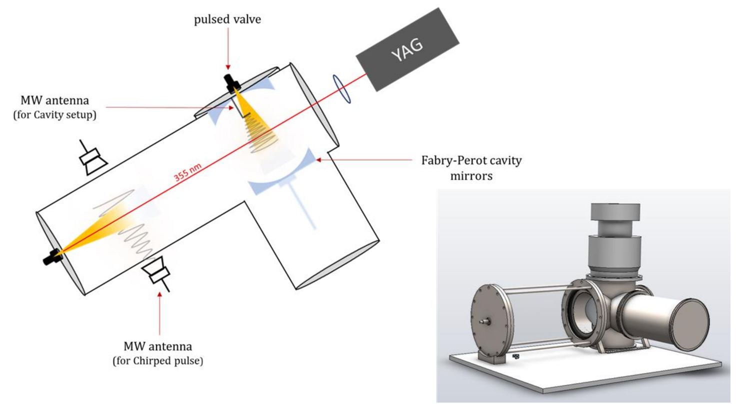

Figure 1: L-Shaped FTMW Spectrometer Design

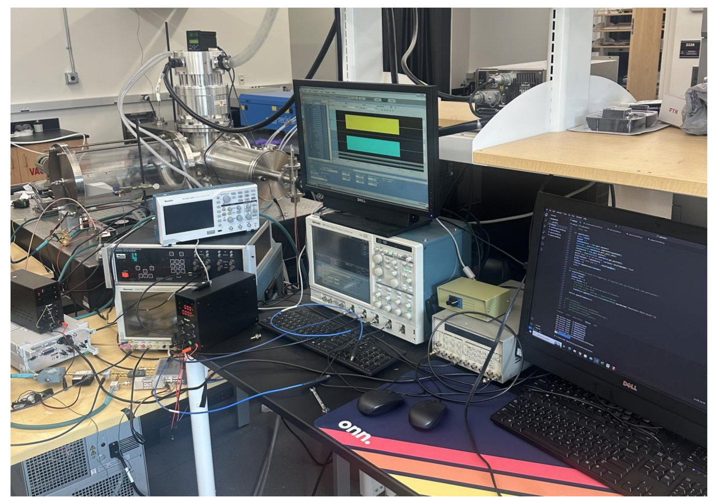

Image 1: Laboratory/Scope Setup

Instrument	Type	Purpose
Tektronix DPO7354	Oscilloscope	Data acquisition
Zaber XNA08A25-E09	Actuator	Fabry-Perot cavity tuning
SRS DG535	Delay generator	Triggering
Valon 5019	Synthesizer	Generate signal
Tektronix AWG7102	Waveform Generator	Generate Signal

Table 1: Main Instruments (red controlled by software)

Instrument Control & Design

- Microwave pulses are generated using AWG and Valon synthesizers and sent to the MW cavity
- Pulse rate dictated by the delay generator
- Cavity length is dictated by the mirror that Zaber actuator positions
- Collected free induction decay signals are routed to the oscilloscope for signal averaging and Fourier transformation

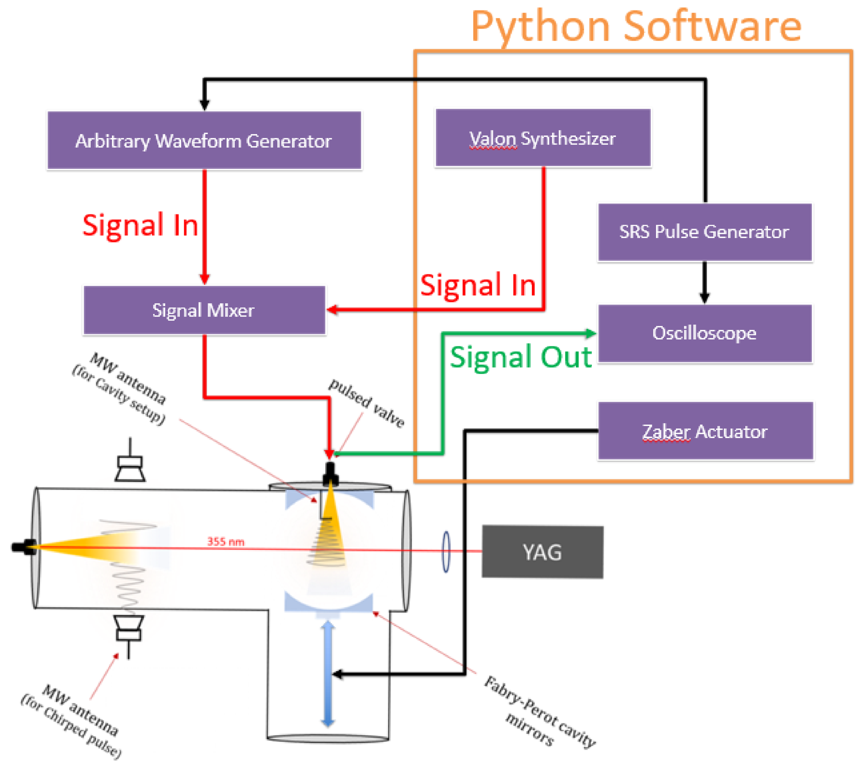

Figure 2: Spectrometer and Software Control Design

Software Design

Code Repo

API/Libraries Utilized

time | threading | pyvisa | tkinter | pyqt5 | pandas | numpy | inquirer | zaber.serial | serial | matplotlib

- GPIB connected oscilloscope handled as pyVISA resource
- USB connected actuator handled as AsciiSerial device
- USB connected synthesizer handled as serial class
- GPIB connected pulse generator handled as pyVISA resource
- Binary/Ascii commands issued to initialize, program settings, and receive real time data
- GUI shell established via Tkinter and PyQt5 while live plotting done via matplotlib
- Threading initialized to receive oscilloscope data (~450 data pt. per second) while handling GUI shell and controlling other instruments according to data output, such as actuator position during calibration
- Ensuring synchronization of position data vs. intensity data handled via time modules to within ~ ±0.007 seconds accuracy as well as optimization via perf_counter()
- Numpy for N-dimensional arrays, Pandas for ease of data analysis
- Scanning handled via Python script coordinating instruments

Scanning Results/Conclusions

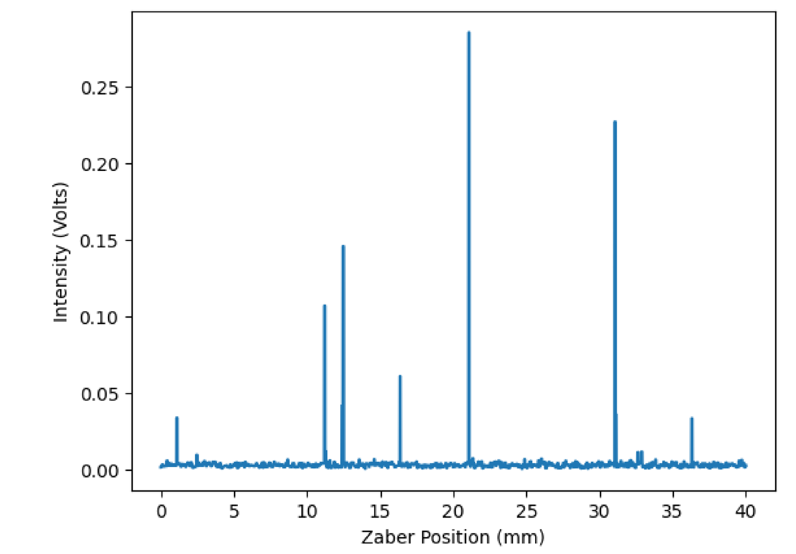

Figure 3: Calibration at 15,491.6451 MHz from 0 – 40mm

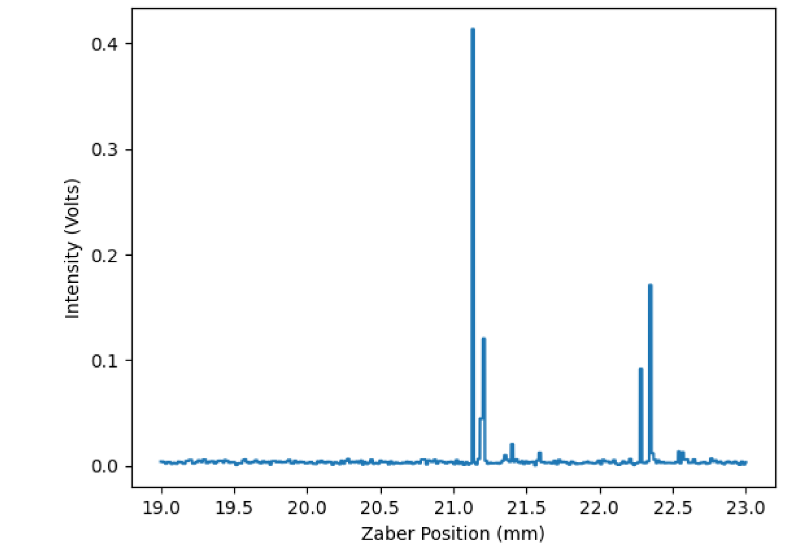

Figure 4: Calibration at 15,491.6451 MHz from 19 – 23mm

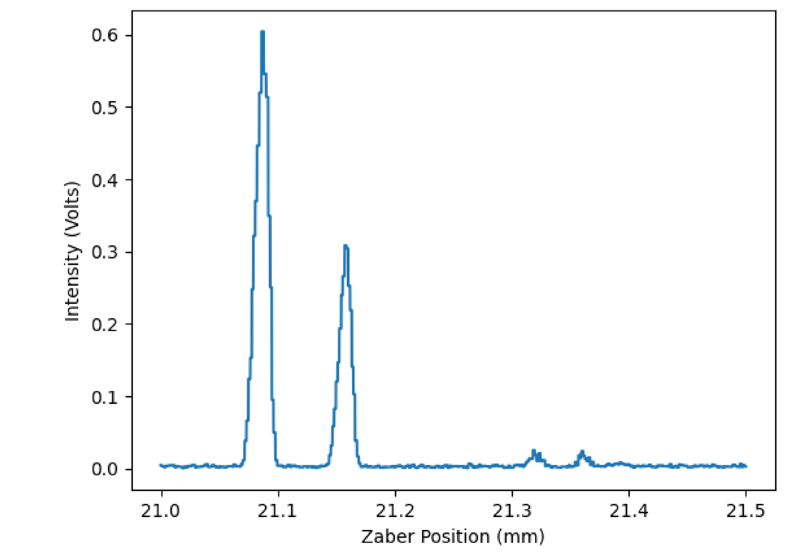

Figure 5: Calibration at 15,491.6451 MHz from 21.0 – 21.5mm

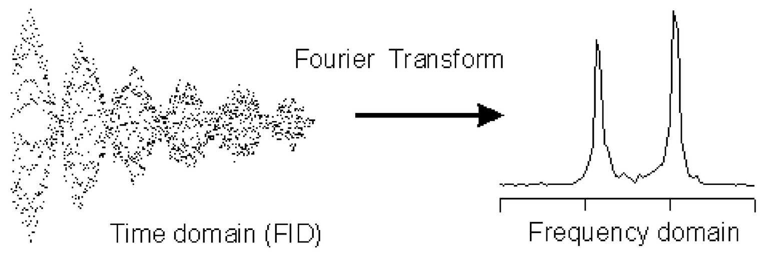

Figure 6: Fourier Transform of a Waveform

- Cavity tuning is fully handled by Python software
- For autonomous tuning, waveforms are generated via AWG/synthesizer on initialization of internal trigger by delay generator
- Determines ideal cavity length for a particular frequency for MW experiments
- Maximum is found with ±0.001 mm accuracy by continuing to refine actuator scan range limits and max actuator velocity
- Mirror actuator position is then fixed in the optimal position for experimentation
- Synthesizer frequency increased for the next run

Future Work & References

- Chirped pulse implementation, improving Big O notation/optimization/settings, and finalizing GUI
- Integrating Tektronix Arbitrary Waveform Generator and generating waveforms via Python

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6: Instrumentation Manuals and API documentation.

CHEMISTRY

GRU LAB

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