Towards Spectroscopy of TaO^+

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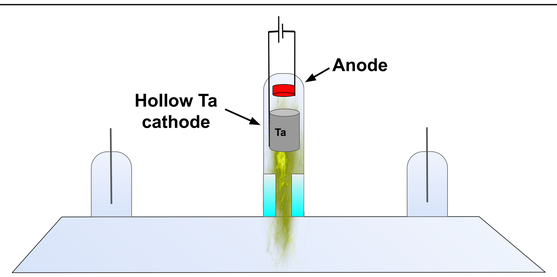
Tantalum Monoxide (TaO^+)

Heavy molecular ions are promising candidates for probing new physics beyond the standard model, but the spectroscopic information for designing experiments is extremely limited. We are pursuing cavity-enhanced velocity modulation spectroscopy to enable first-ever precision measurement experiments with TaO^+ and other molecular ions.

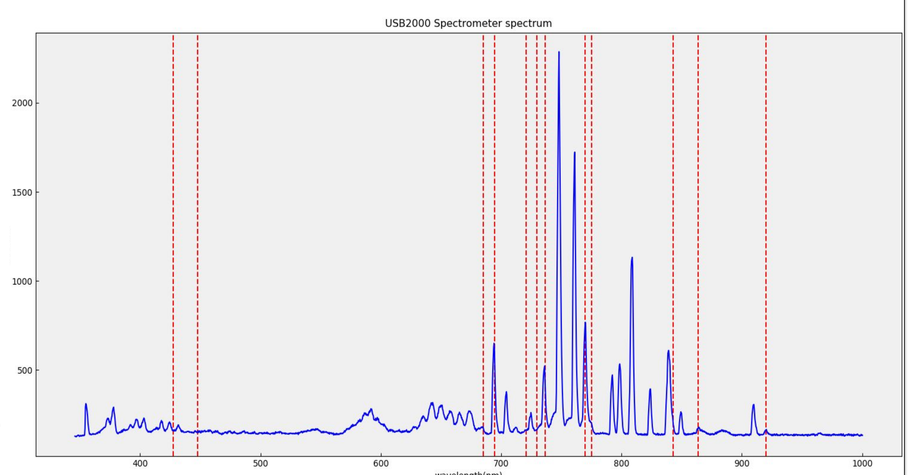
- Nuclear magnetic quadrupole moment measurement candidate
- Highly polar leading to strong intramolecular electric fields
- $^3\Delta_1$ ground electronic state

Cairncross et al. *Phys. Rev. Lett* **119**, 2 (2017).
Fleig. *Phys. Rev. A* **95**, 2 (2017).

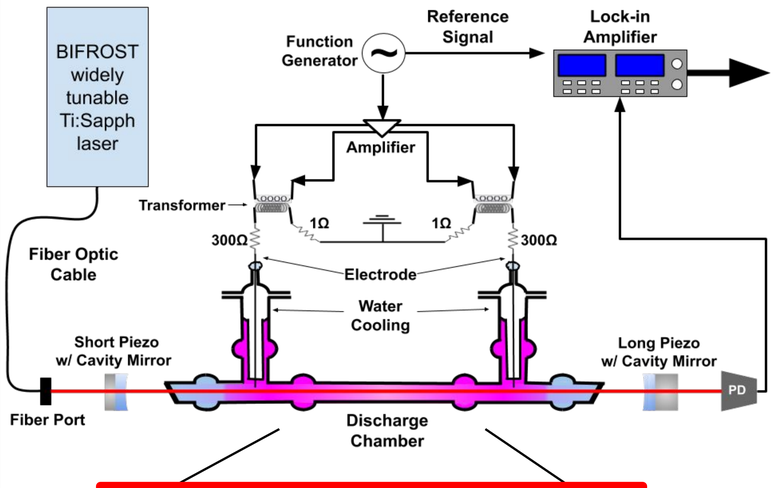
Tantalum Sputtering and Detection



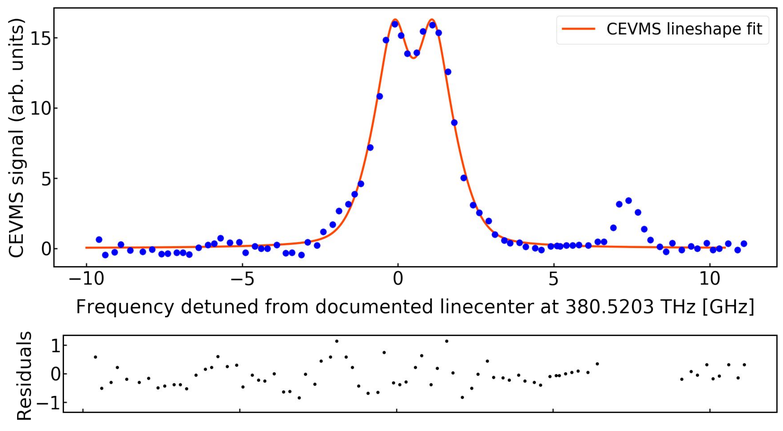
A new source of Ta sputtering, a DC discharge using a hollow Ta cathode, was designed and placed between the RF electrodes. Direct detection of Ta was performed using a spectrometer with the placement of Ta lines labeled red.



Apparatus for Cavity Enhancement + VMS



A water-cooled, radio frequency glow discharge



The RF glow discharge is generated by applying a 15-kHz AC voltage between the electrodes. At low pressures ~100 mTorr, the fluctuating electric field ionizes molecules in the gas phase and modulates the velocity of charged species. This results in the above lineshape which was fit to a numerically integrated pseudo-Voigt absorption profile.

The principle of cavity-enhanced velocity modulation spectroscopy (CEVMS) is demodulation of the spectroscopic signal at the twice the frequency of the glow discharge. This allows discrimination between ionic and neutral species.

The Pound-Drever-Hall technique is used to lock a piezo-actuated, low-finesse optical cavity surrounding the discharge tube to a Ti:Sapph laser. The cavity makes for ~1000-fold increase in signal, allowing us to observe very weak transitions. Scanning of the laser frequency is done using the widely-tunable UCSB BIFROST laser.

Next steps for CEVMS:

- Optimize signal to noise ratio of data
- Search for TaO & TaO^+ electronic transitions by flowing in oxygen gas and studying changes in line intensities
- Consider new sources of TaO, such as baking Ta_2Cl_5
- Potential systematic enhancements using the recently developed NICE-OHVMS technique

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