Progress towards measuring parity non conservation in francium

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Parity violation in atoms

- Atomic physics experiment ⇒ Studying electronic transitions.
- Z-boson exchange between atomic electrons and the quarks in the nucleus.
- Short range ⇒ Depends on probability of the electron to be in the nucleus
- Special ⇒ Same finale state.

Nuclear spin independent:

Coherent over all nucleons.

Nuclear spin dependent :

Interactions with valance nucleons.

Main Contribution from anapole moment of heavy nuclei.

Optical experiment

Microwave experiment

Parity violation in francium

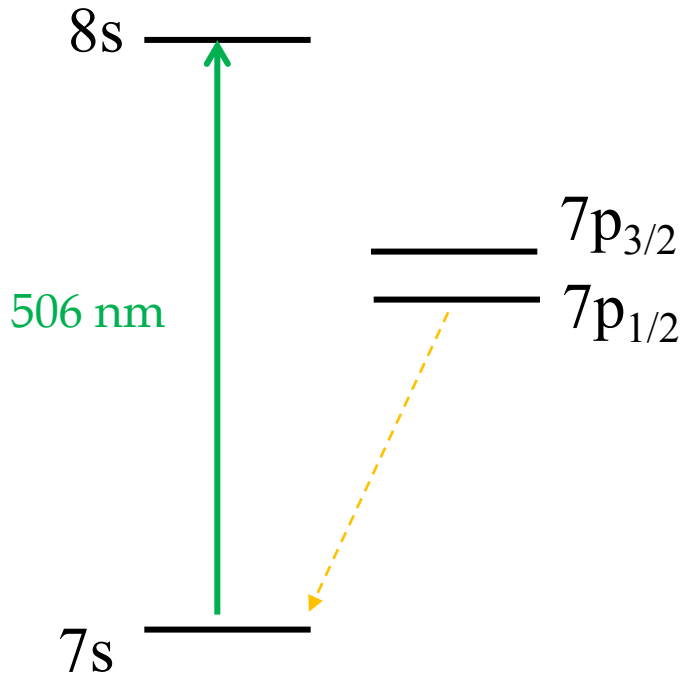
Electric dipole transition from l=0 to l=0 is not allowed

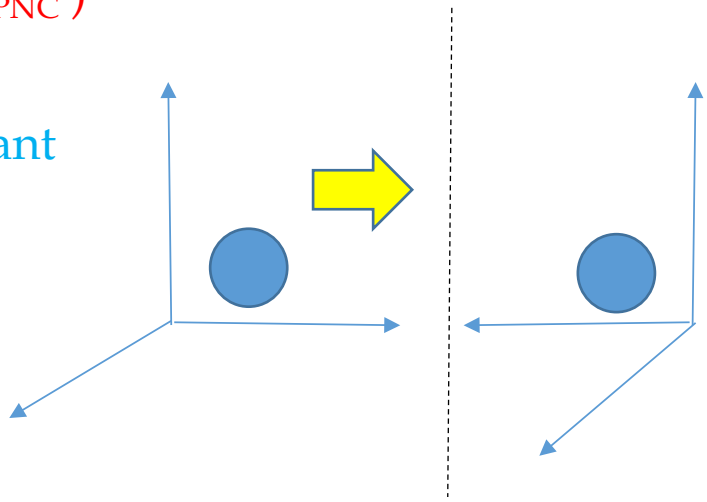
H_{PNC} mixes s & p electronic states,
$\langle n's' | H_{PNC} | np \rangle \propto Z^3$

Mixing too small to probe the effects directly, the mixing of p states is at the $\sim 10^{-11}$ level.

Interference technique
$R \propto |A_{stark}+A_{PNC}|^2 \approx (A_{stark})^2 \pm 2Re(A_{stark}A_{PNC}^*)$

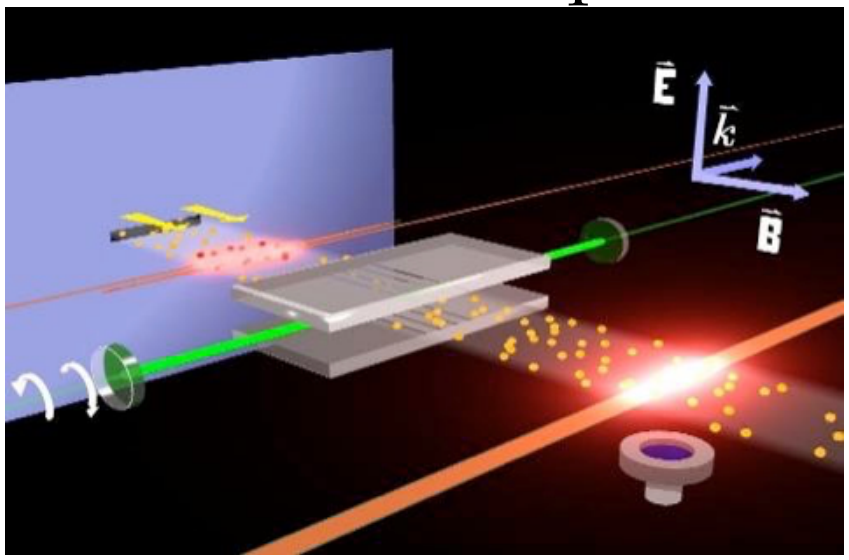
→ Observe a modulation signal on a constant background

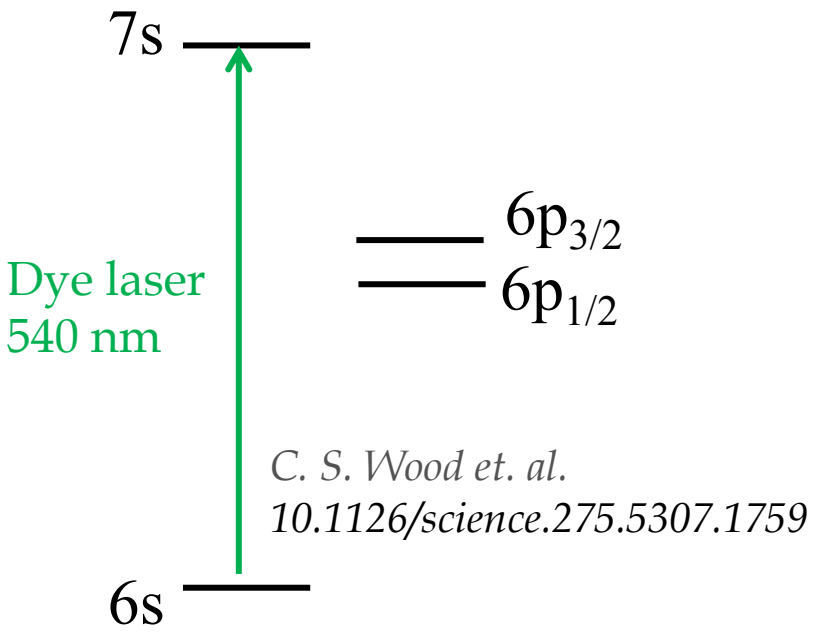




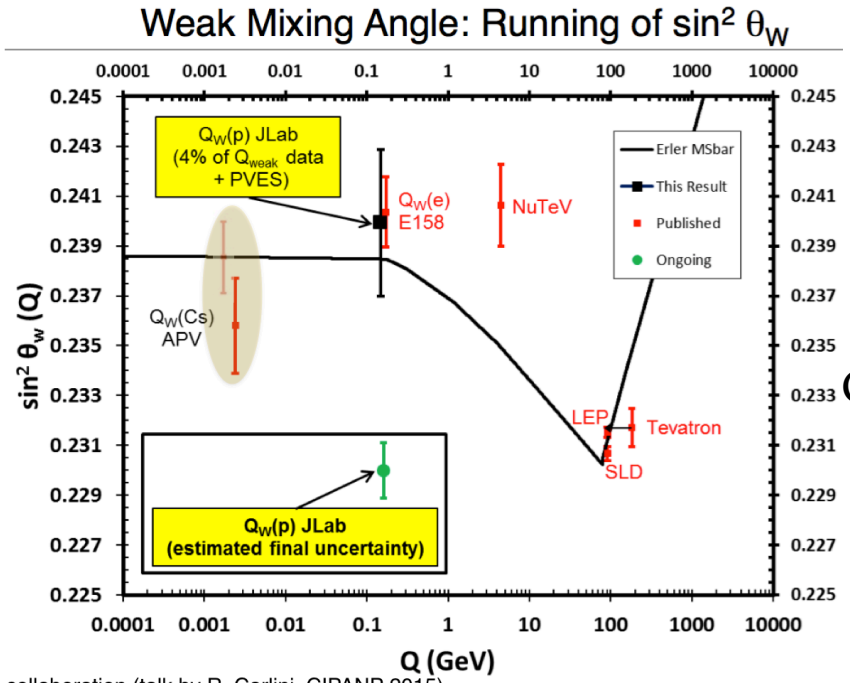
Optical experiment *Bouchiats, 1974*

The cesium experiment





C. S. Wood et. al.
10.1126/science.275.5307.1759



Qweak collaboration (talk by R. Carlini, CIPANP 2015)

Tl, Pb, Bi, Yb

Good experiment + Good theory ⇒ Good test

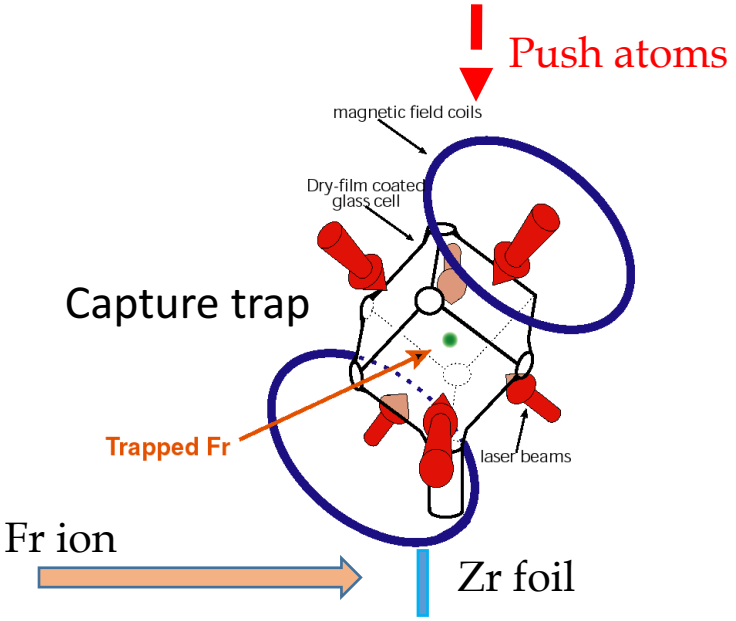
Parity violation in francium

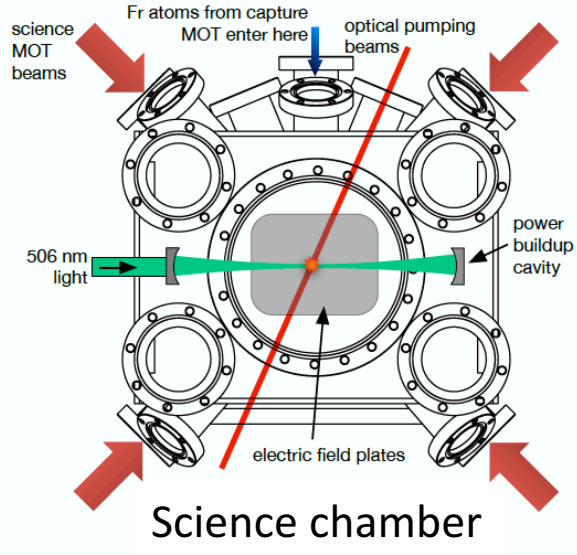
- Francium Z=87 (Heaviest alkali)
- APNC effect 18 times larger than Cs
- Atomic structure theory same level as Cs

- No stable isotope

- Francium trapping facility at TRIUMF/ISAC
  - ➢ Neutralize francium ions
  - ➢ Collect in dry film coated cell
  - ➢ Transfer using resonant push beam
  - ➢ Measurements in science chamber

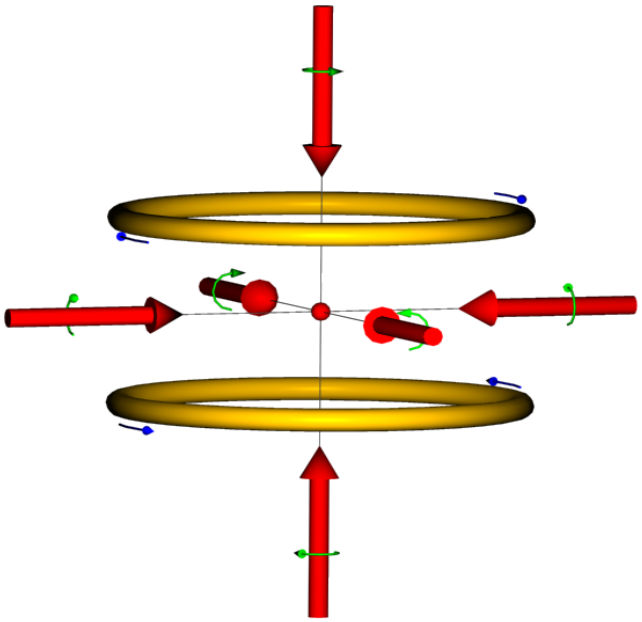
System is tuned with Rb





Laser cooling and trapping

Magneto Optical Trap (MOT):



Trapping

F = -kx

Cooling

F = -av

- Quadrupole magnetic field
- Red detuned laser
- Opposite circular polarization

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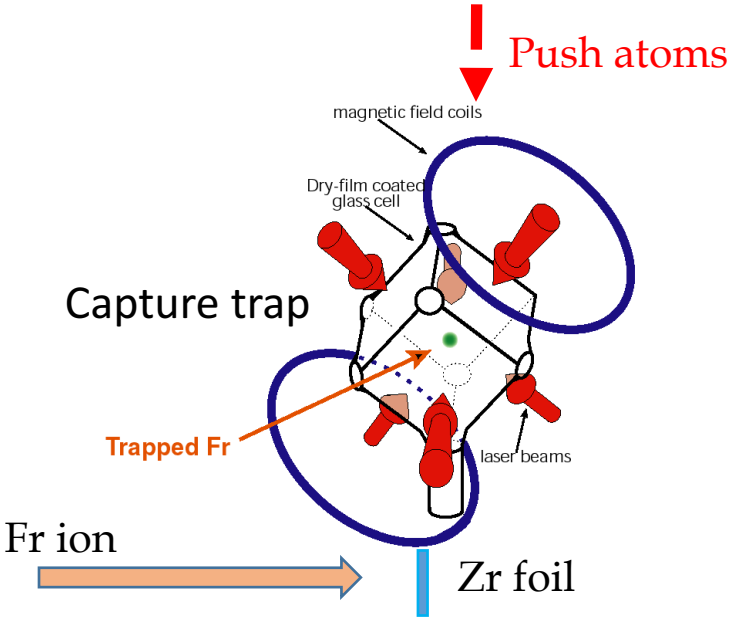
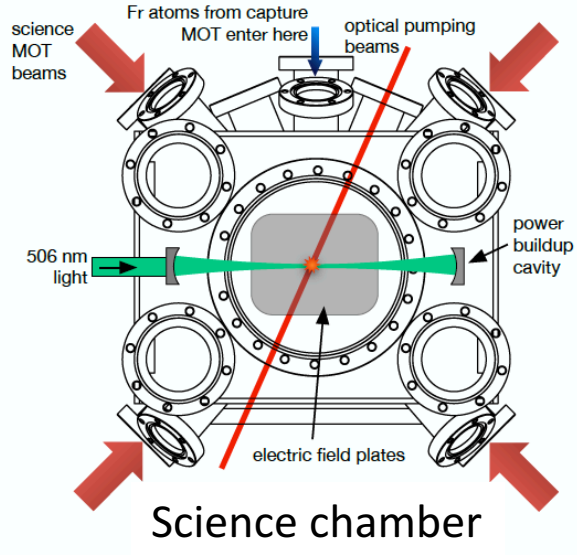
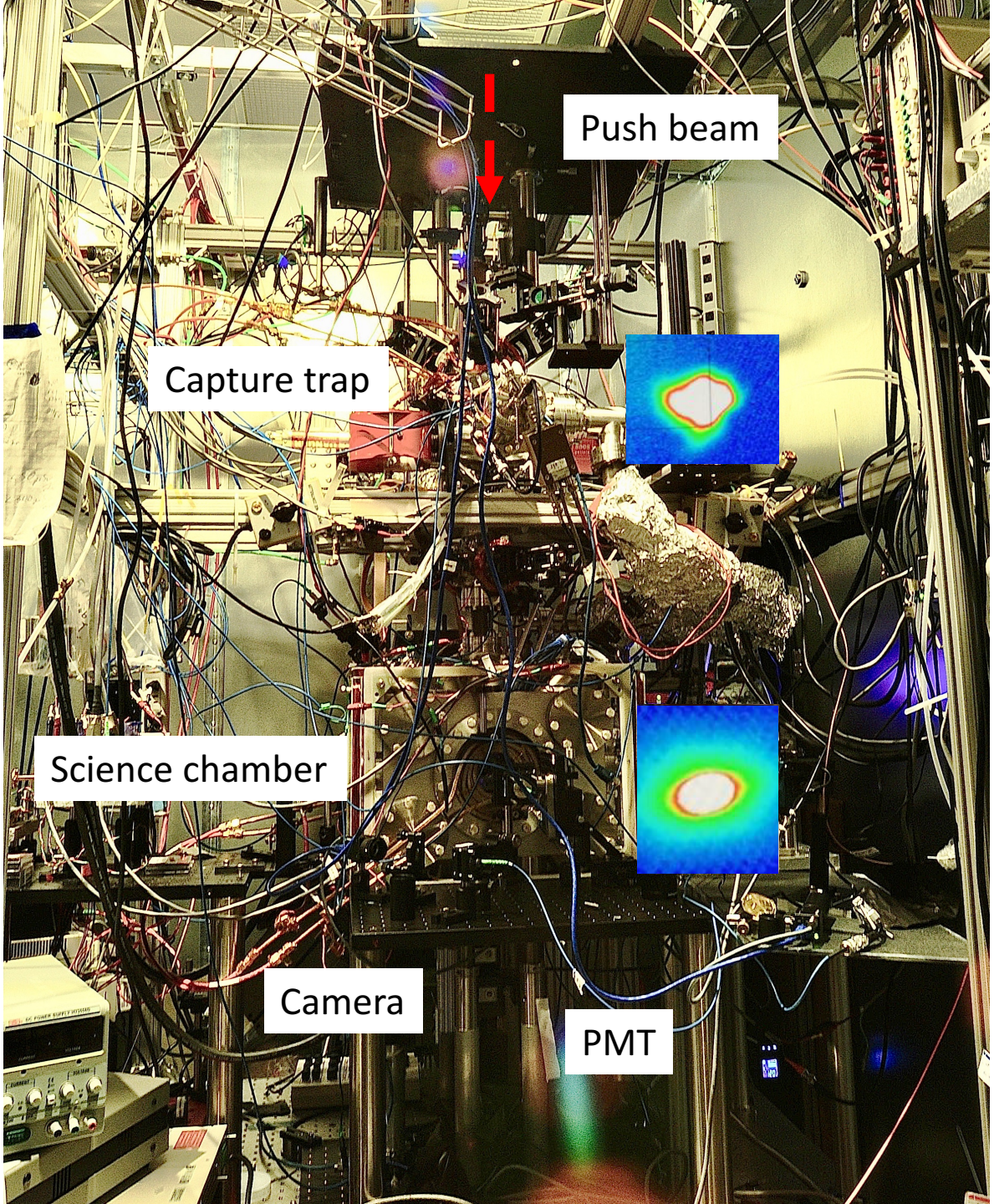
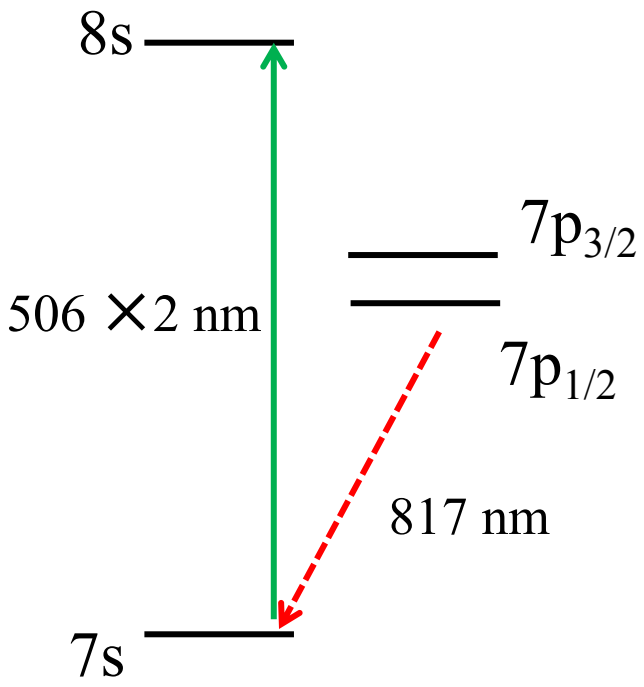


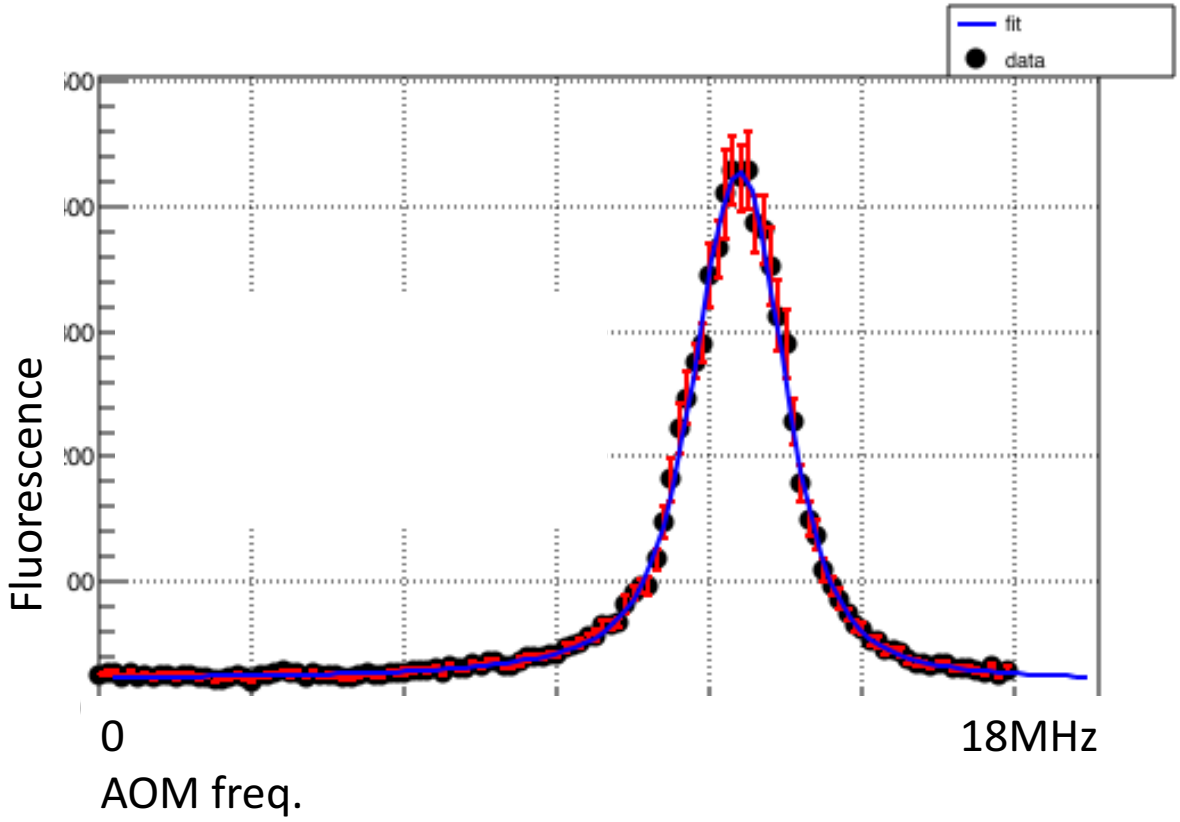



Push beam
Capture trap
Science chamber
Camera
PMT

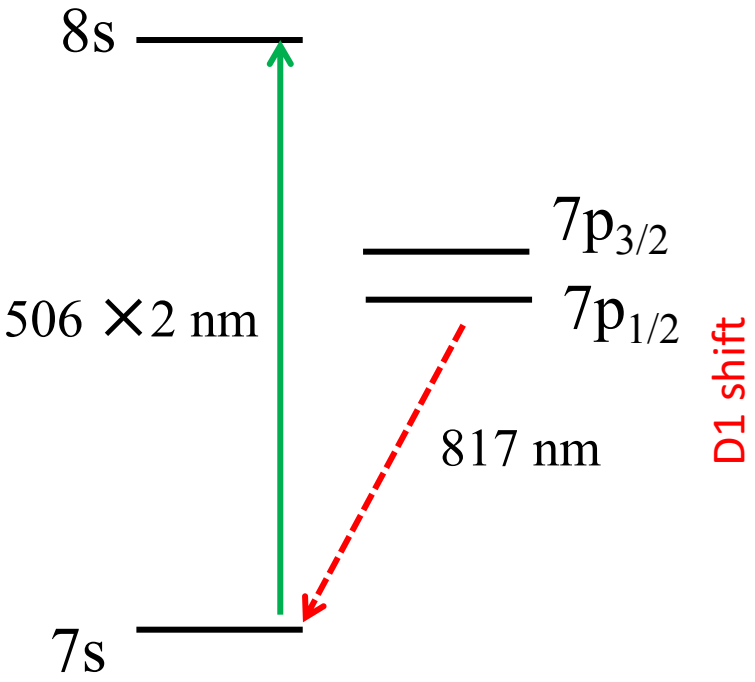
Progress so far

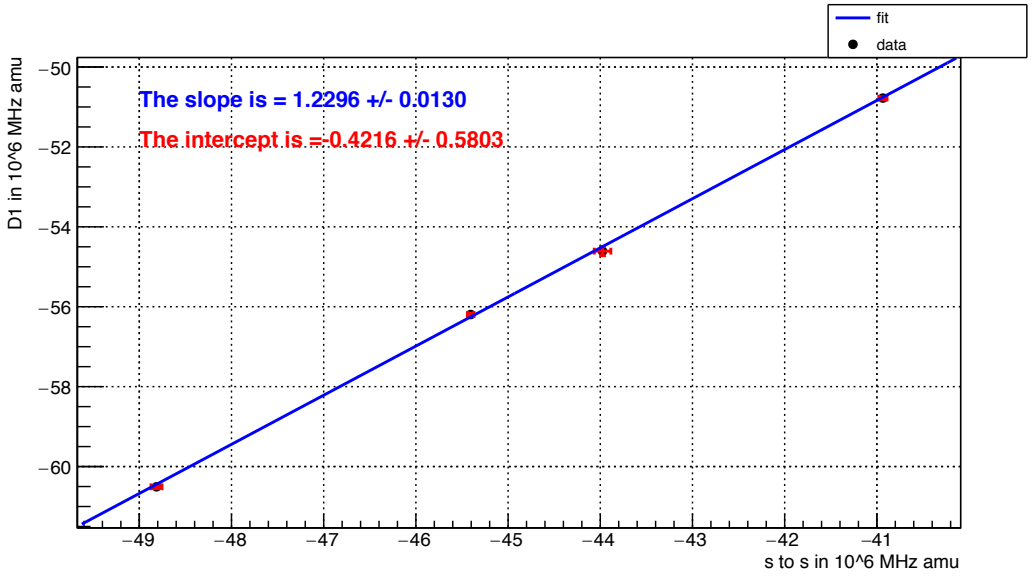
- Observed for the first time 7s-8s transition using two photon spectroscopy in ^{208}Fr, ^{209}Fr, ^{210}Fr, ^{211}Fr, ^{213}Fr.
- Isotope shifts.





Progress so far





7S →8S shift

$$\left(\frac{M_A M_{A'}}{M_A - M_{A'}}\right)\delta\vartheta_{IS,D1} = (N_{D1} + S_{D1}) - (N_{SS} + S_{SS})\frac{F_{D1}}{F_{SS}} + \frac{F_{D1}}{F_{SS}}\left(\frac{M_A M_{A'}}{M_A - M_{A'}}\right)\delta\vartheta_{IS,SS}$$

Preliminary results

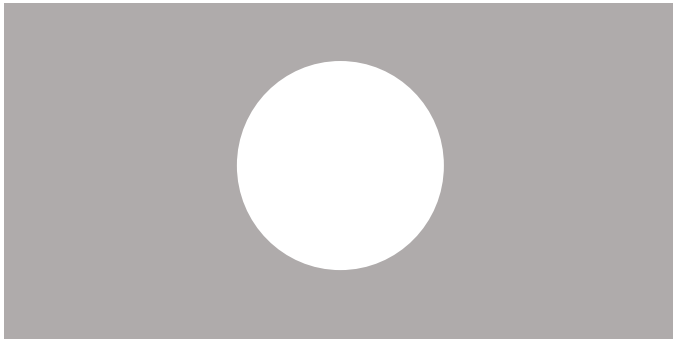
Slope=

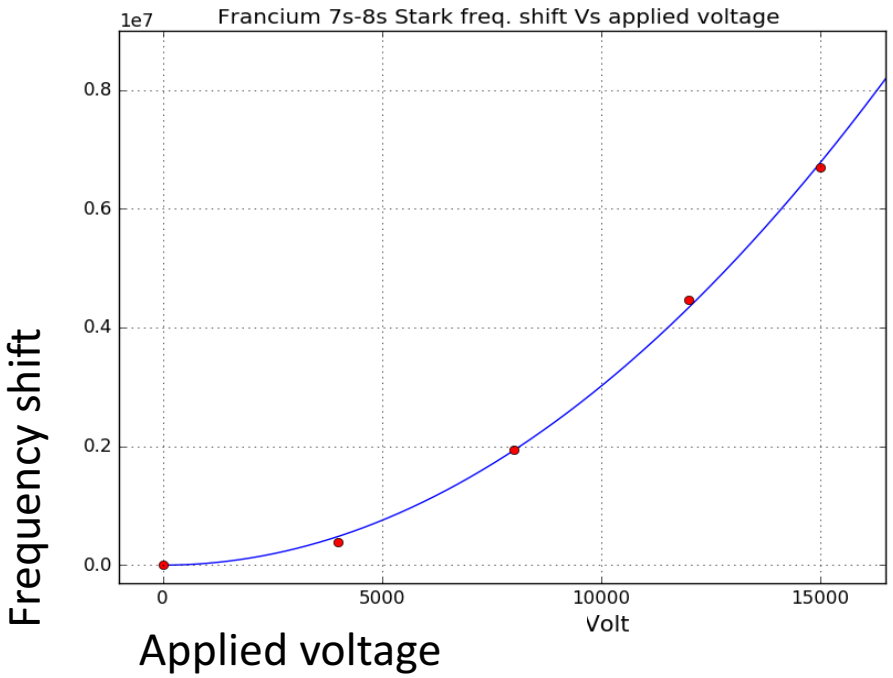
1.2296 ± 0.0130 (experiment)

1.2342 ± 0.0124 (theory by V. Dzuba, V. Flambaum, M. Safronova)

Progress so far

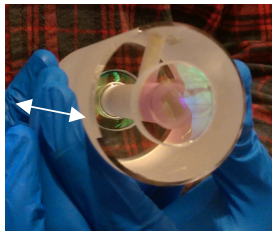
- DC Stark shift of the 7s-8s transition.
- Electrodes with holes

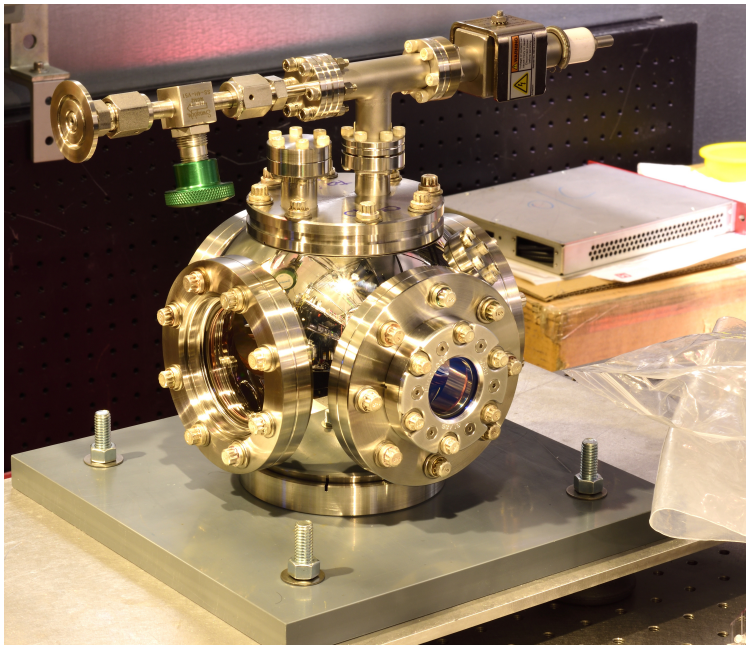




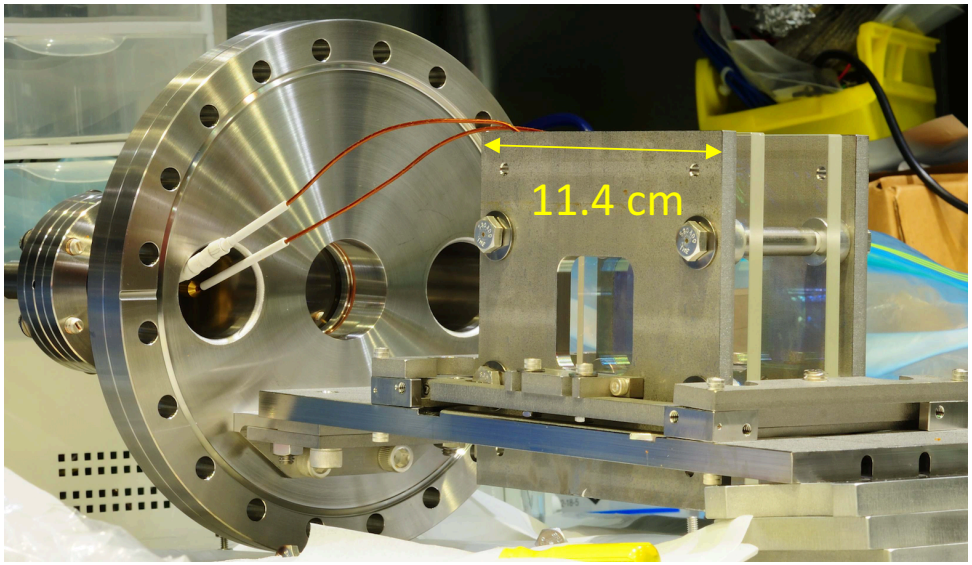
Current work

- New Laser lock for 506 nm based on ULE cavity and PDH method.
- ✓ Error signal observed.
- ✓ Temperature control is being developed.

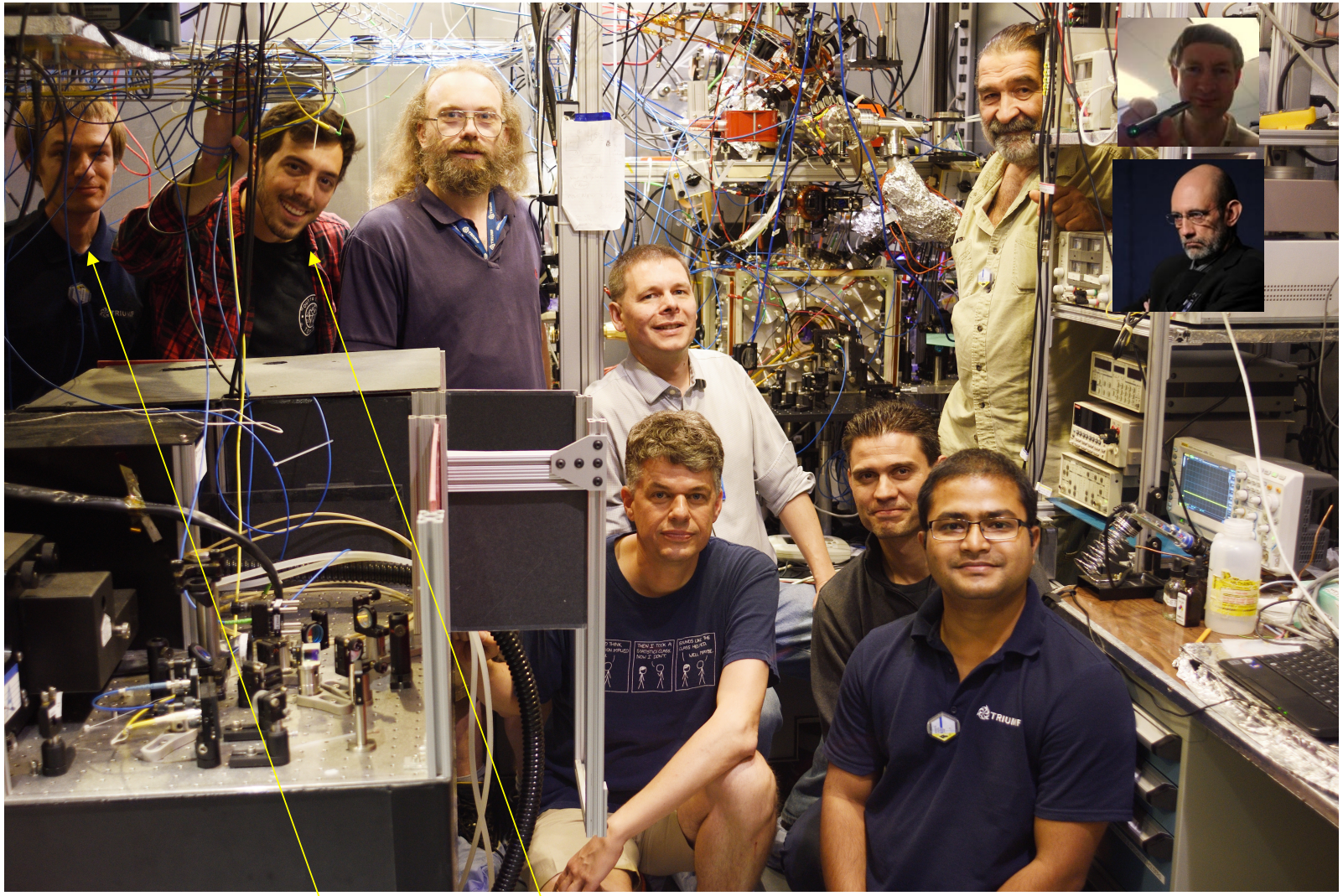




- Transparent Electric field plates with ITO coating.
- ✓ Installed.



- Power build up cavity in vacuum for 506 nm.
- ✓ Early summer.



From Left to right: Michael Kossin, Austin deHart, Matt Pearson, Seth Aubin, Gerald Gwinner, Eduardo Gomez, Mukut Kalita, Alexandre Gorelov, John Behr, Luis Orozco.
Not in the picture: Andrew Senchuk

Conclusion

- Several francium isotopes have been trapped at the Francium Trapping Facility at TRIUMF using laser cooling and trapping techniques.
- We have started to perform atomic physics measurements to benchmark theoretical calculations.
- **The 7s-8s transition that we plan to use for PNC studies has been observed.**
- DC Stark shift of the 7s-8s transition has been observed.
- Lasers, laser locks, electric field generating system with transparent field plates and power build up cavity are in development.

Thank You