Measurement of the ratio of scalar to vector transition polarizabilities for the 6s→7s transition in atomic cesium

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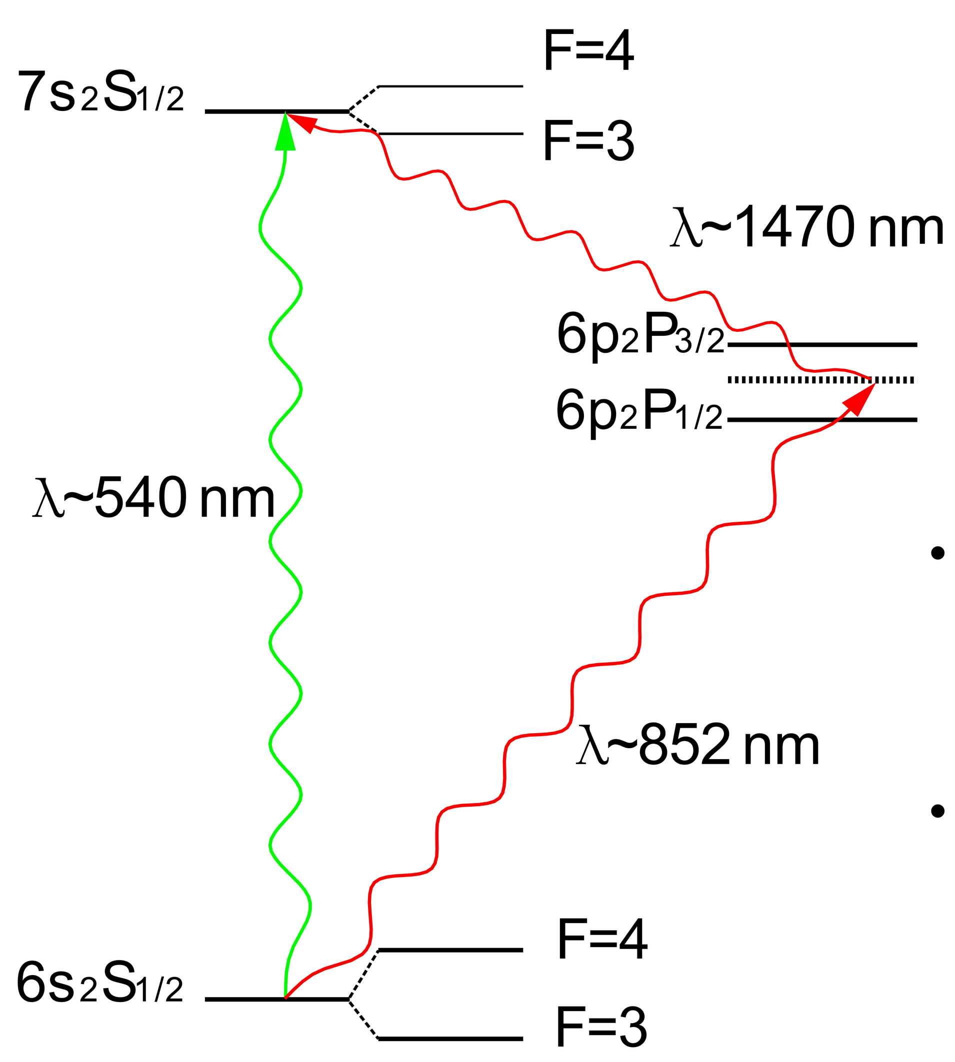
Background

Precision measurements of weak optical interactions in atoms can provide a sensitive means of probing the weak force between nucleons and electrons at low momentum transfer.

The extent to which atomic parity non-conservation (PNC) measurements agree with standard model predictions can provide constraints on conjectures of `beyond standard model' physics.

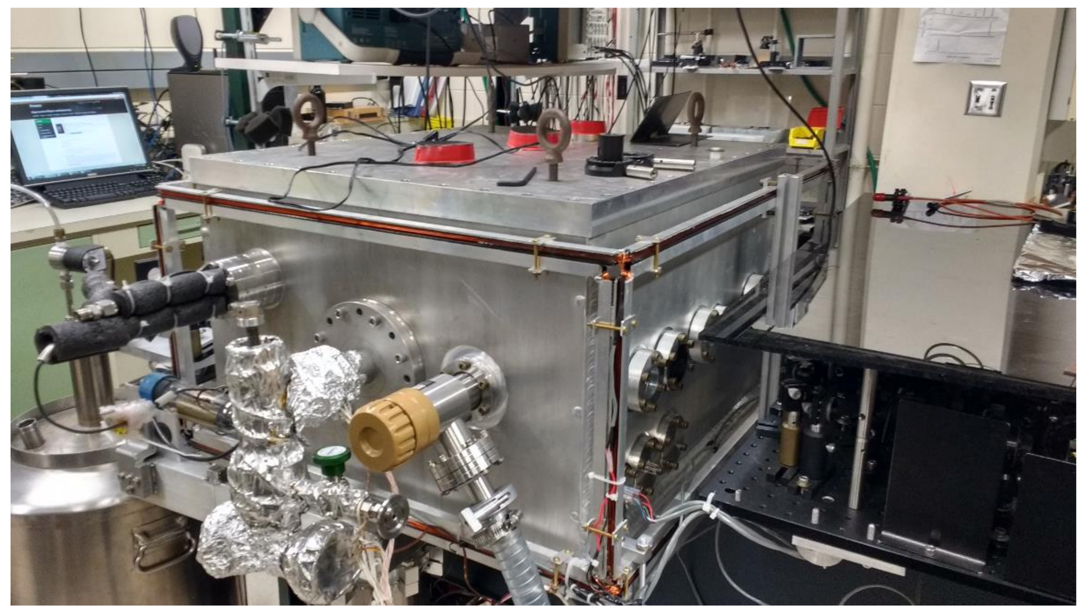
A precise measurement of the ratio of the scalar to vector transition polarizability in the 6s→7s transition in atomic cesium is a crucial step towards a more precise measurement of the parity non-conserving weak interaction

6s→7s Transition



- Using a coherent control technique, we will excite the $7s^2S_{1/2}$ state of atomic cesium through two interfering optical pathways; these transitions are Stark-induced one photon (green arrow) and two photon excitation (red arrows).
- By varying the relative phase between these two transitions, the resulting signal will be modulated.
- The depth of the modulated signal will be twice the product of the 2-photon amplitude and Stark amplitude.

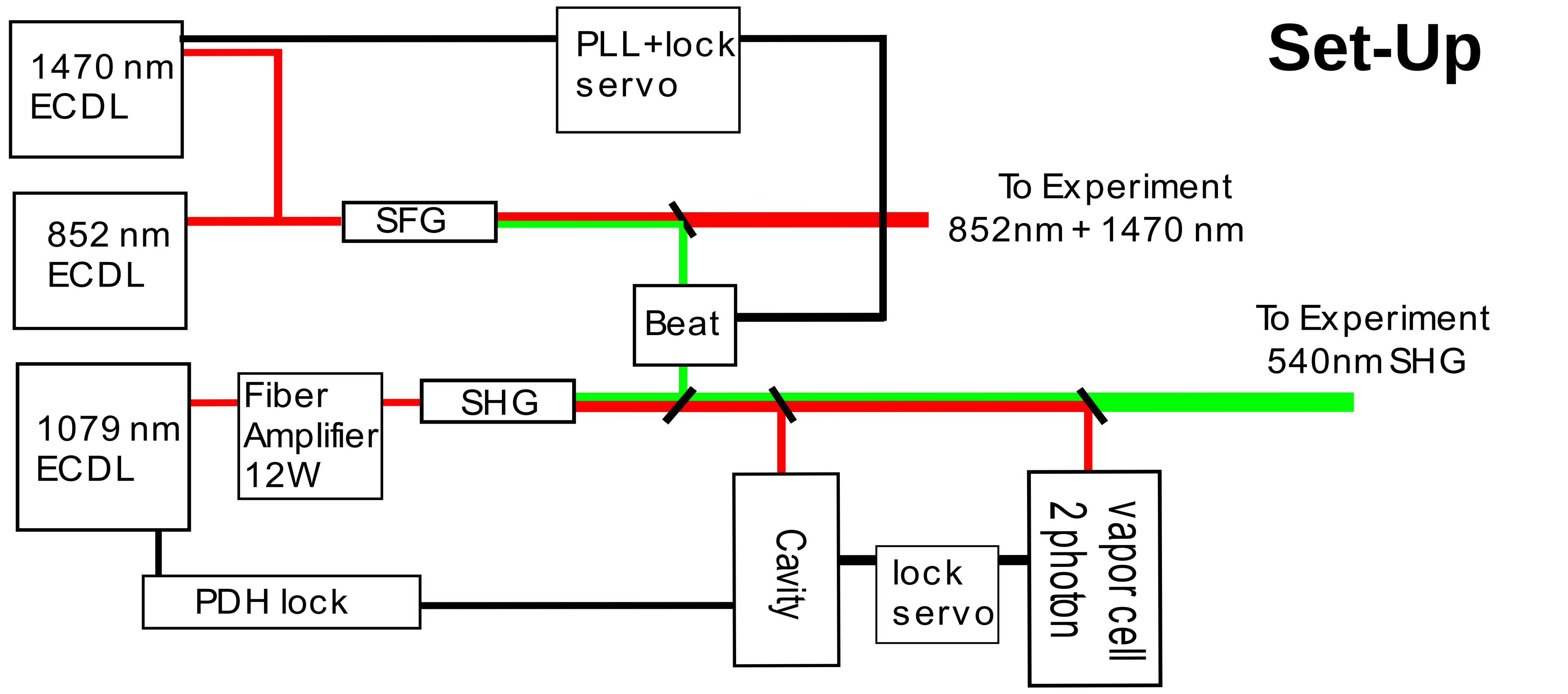
Vacuum Chamber



Our vacuum chamber used for measurements of weak transitions (above)

- A cesium beam travels along the length of the chamber.
- Ports on either side allow us to interrogate the cesium beam
- Plenty of room within to place B field coils and E field plates .
- Modest Vacuum and a turbo molecular pump allow us to have a quick turnaround between openings (~1 day).

Set-Up



For this measurement, we require an intense beam at a wavelength of 540 nm to drive the Stark-induced transition, and two beams of moderate power (852 nm and 1470 nm) to drive the two-photon transition. We require phase coherence between these beams in order to allow for interference between the transitions.

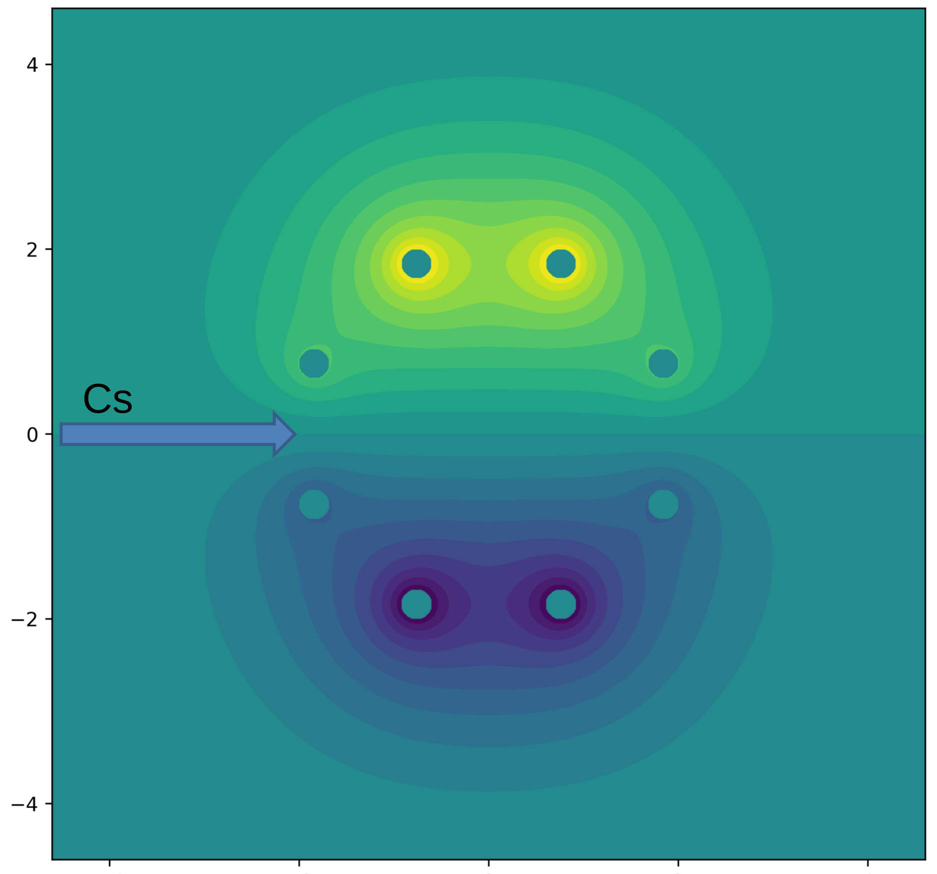
We generate 1079 nm light via a tunable cw ECDL. This light is phase modulated, amplified, and frequency doubled via second harmonic generation (SHG). This laser is locked using Pound-Drever-Hall to a cavity which is locked to the 6s→7s two-photon resonance. The 540 nm light produced here is used in the experiment (~600 mW).

We generate 852 nm and 1470 nm light via two tunable cw ECDLs. These two beams are then used in sum frequency generation (SFG) to produce 540 nm light which will be beat against the 540 nm light generated through SHG. We then lock the 1470 nm light to the beat signal to phase lock the two optical transitions.

Field Configuration

- We will measure the ratio of the scalar to vector transition polarizability by alternating the electric field between parallel and perpendicular to the 540 nm polarization.
- Using 8 electric field rods in the configuration to the right, we will be able to quickly alternate fields without moving our field rods.
- In the figure to the right, the cesium beam would be traveling from left to right and the optical beam would be going into and out of the figure.

Electric potential around the electric field rods



Stark transition amplitude: **E** Applied electric field, **ϵ** polarization

$$A(F', m_{F'}; F, m_F) = \alpha \mathbf{E}\cdot\boldsymbol{\epsilon}\, \delta_{F'F}\delta_{m_{F'}m_F} + i\beta(\mathbf{E}\times\boldsymbol{\epsilon})\cdot\langle F', m_{F'}|\boldsymbol{\sigma}|F, m_F\rangle$$ [1]

Motivation

- Measurements of the weak moment E_{PNC} must be carried out relative to another larger moment, such as the transition polarizability (vector β or scalar α) or magnetic dipole moment M_1.
- We are currently working towards a new, precision measurement of E_{PNC}/β on the 6s→7s transition of atomic cesium in our laboratory.
- There are currently two precise determinations of the vector polarizability β.
  - One uses a theoretical value of the hyperfine-changing magnetic dipole moment $M_{1,hf}$, combined with a precision laboratory measurement of $M_{1,hf}/\beta$.
  - The other uses precise E1 matrix elements to calculate the scalar polarizability α, combined with a precise laboratory measurement of α/β.
  - These two methods produce values of β that differ by ~0.6%, greater than their combined uncertainties.
- This new determination of α/β is intended to help resolve this discrepancy.

[1] D. Cho, C. S. Wood, S. C. Bennett, J. L. Roberts, and C. E. Wieman, Phys. Rev. A 55, 1007(1997).