Construction and Operation of a Rubidium-Vapor Atomic Clock

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Introduction

Here we report on the completion and operation of a Rubidium-Vapor clock. Measuring changes in transparency of an Rb87-vapor bathed in 6.834 Ghz microwaves allows us to find the clock resonance. To isolate the F=2 transition for this purpose, we had to cancel the local magnetic field generated by the earth. This was done by stepping current in two Helmholtz coils and observing low points in the resulting Zeeman splitting parabola. We then embarked on a strict precision-based measurement of the clock's performance, taking thousands of resonance scans to understand the ability of the apparatus as a clock and thus its capability as a timekeeper.

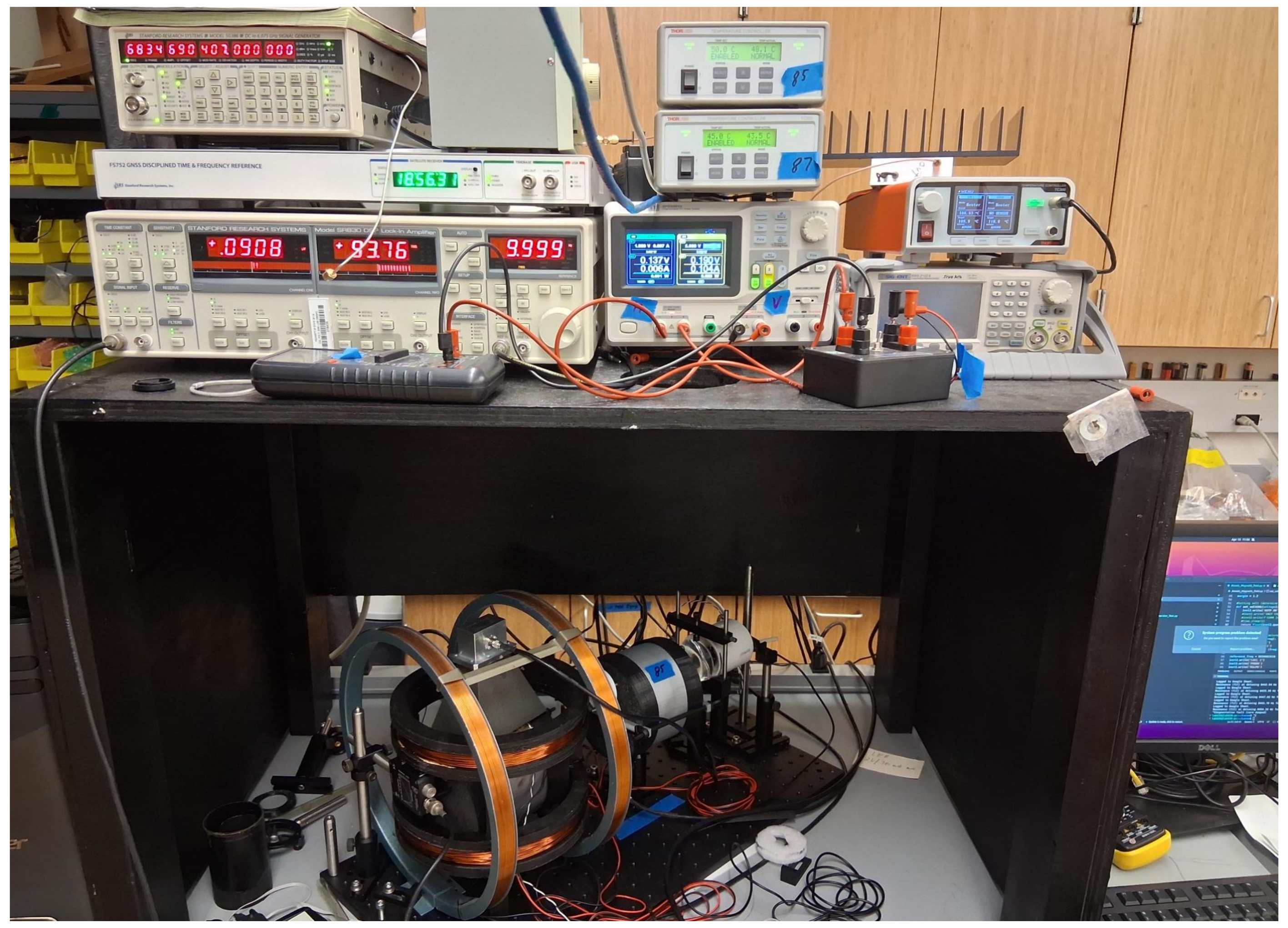
Methods

IN THE LAB:

- Stepping current through Helmholz coils and graphing
- Taking microwave resonance scans over several months
- Histogramming, curve fitting, and finding the full width at half maximum (FWHM)

ANALYSIS:

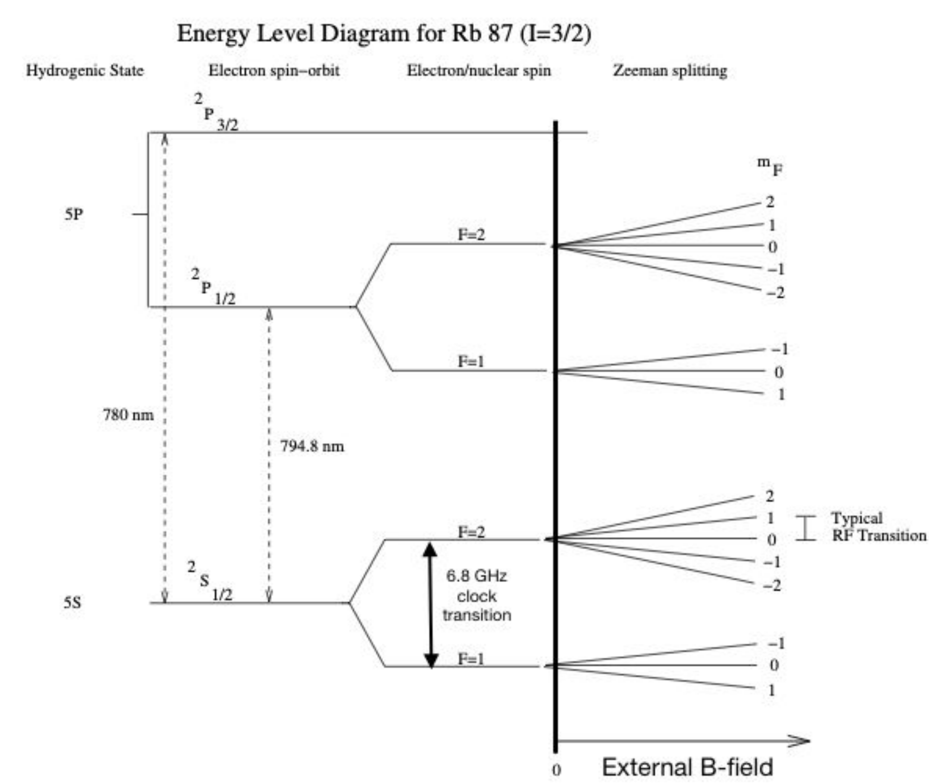
- FWHM determined to be 12.512 from histogram
- $Q=\Delta t/t$ and $Q=f_0/\Delta f$
- $t=\Delta t/(f_0/\Delta f)$

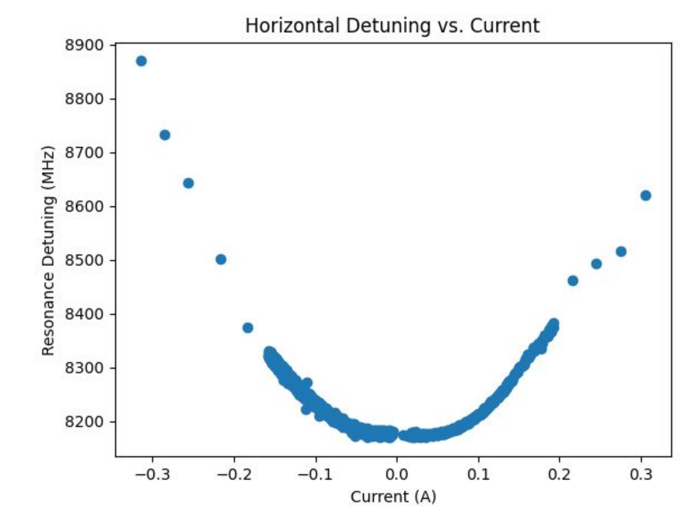


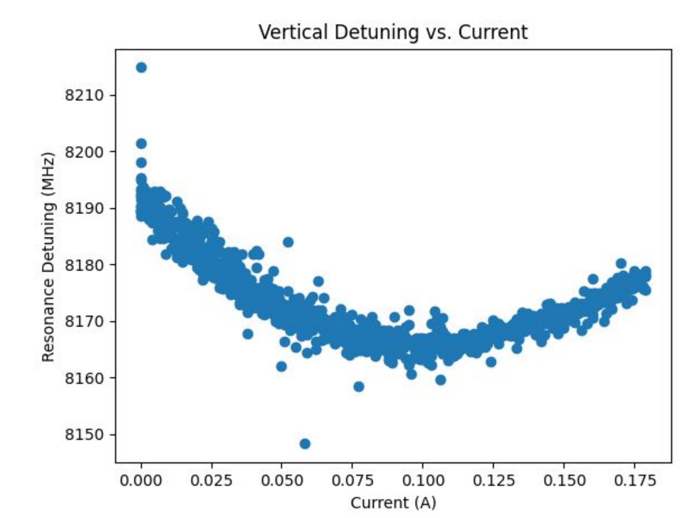
The atomic used to collect data for this project housed in 180-630.

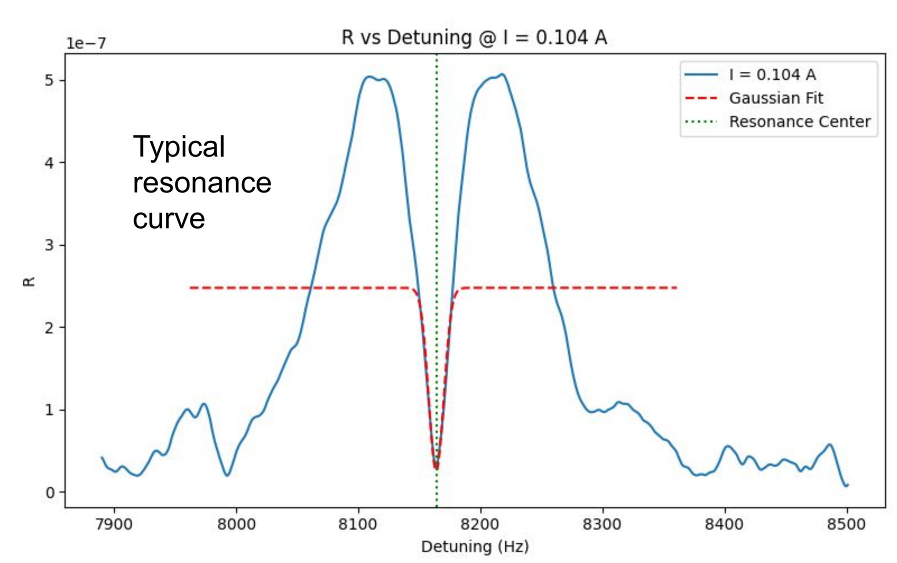
Results

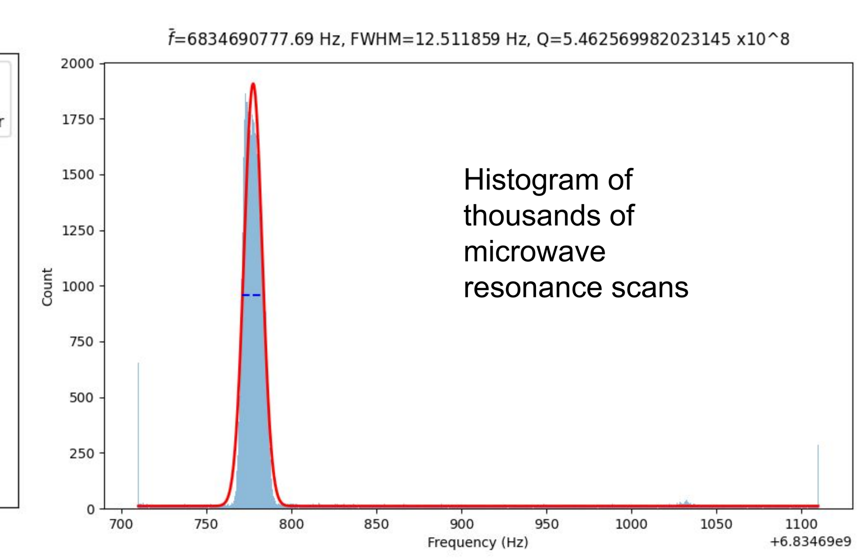
From the parabolic nature of resonance detunings against current, 0.006A horizontal and 0.104A vertical were the optimal currents. 6,834,690,777Hz seemed to be the most stable frequency, which holds steady to ±100 Hz.

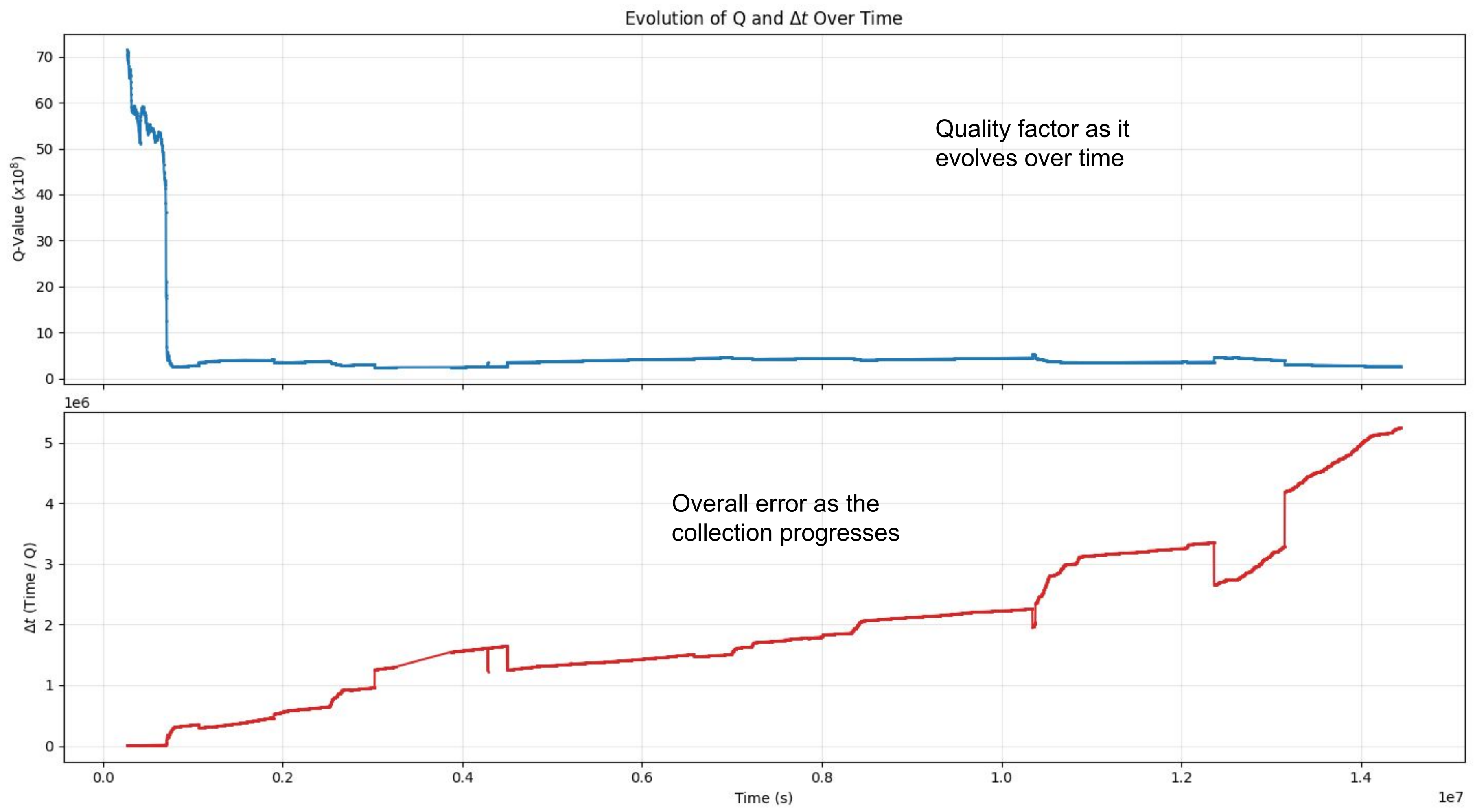












Conclusions / Discussion

Over a continuous sampling for around 170 days the clock has a $Q=5\times10^8$, meaning if used in timekeeping applications, the clock would allow for timekeeping to within 175μseconds/day or 1s every 15 years. This is over 3,000 times more accurate than a previously tested quartz timekeeper and 300,000 times more accurate than an average mechanical clock.

Overall, this is consistent with other work on for a rubidium-vapor clocks. We are working on improving this performance, by re-examining our lock-in techniques, which currently fails regularly, preventing us from completing long-term assessments of the clock.

Future Directions / Next Steps

We wish to continue optimizing the clock, take these findings to compare to other timekeepers, and publish a journal article detailing construction and operation of the clock as a component for advanced lab curriculums in physics departments.

References

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- Qiang Hao, Wenbing Li, Shengguo He, Jianfeng Lv, Pengfei Wang, Ganghua Mei; A physics package for rubidium atomic frequency standard with a short-term stability of 2.4×10^{-13} $\tau^{-1/2}$. *Rev. Sci. Instrum.* 1 December 2016; 87 (12): 123111. https://doi.org/10.1063/1.4972567

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