The USNO Rubidium Fountain

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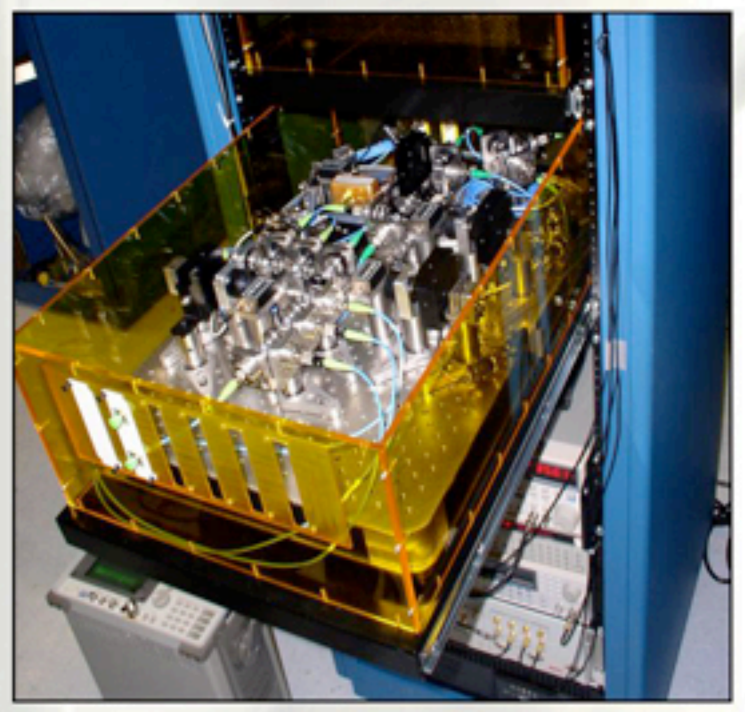
http://tycho.usno.navy.mil/clockdev/CDpapers.html

Abstract

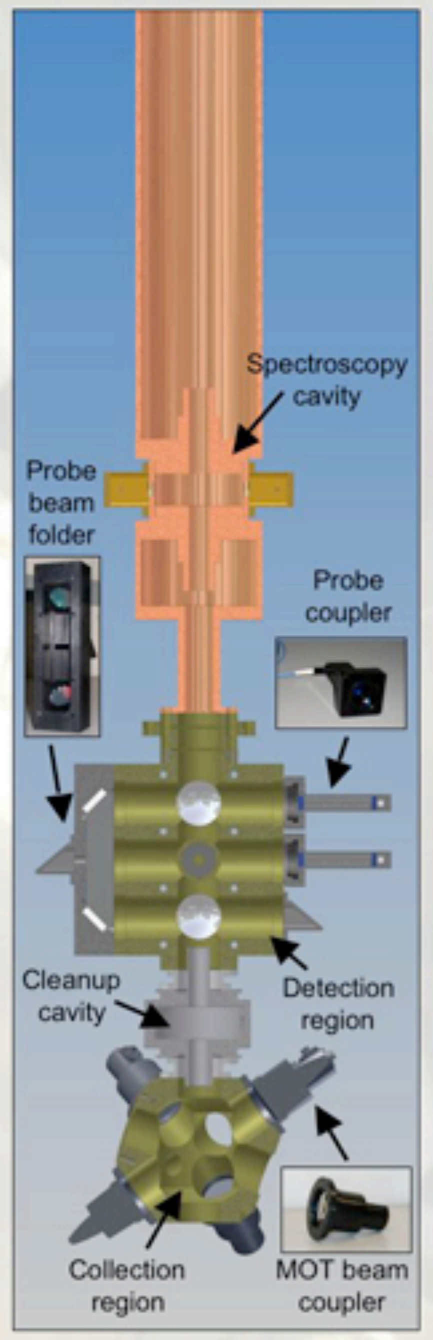
We present initial evaluations of our rubidium atomic fountain - the first of six that are designed for continuous operation and for inclusion into the USNO timescale. We have demonstrated short-term performance in weak-gradient, MOT-loaded operation at $1.3\times10^{-13}/\tau^{1/2}$ using a Ti:Sapphire laser system and recently demonstrated comparable performance with a fiber-amp laser system.

We have made a comparison between our rubidium fountain (NRF1) and cesium fountain (NCF), demonstrating a relative stability characterized by white-frequency noise down to an Allan deviation of 1.5×10^{-15}. Assuming that each fountain exhibits the same noise type, the data are consistent with an Allan deviation for our rubidium fountain of 7×10^{-16} at 11 hours. Further upgrades to our cesium fountain should enable more precise comparisons.

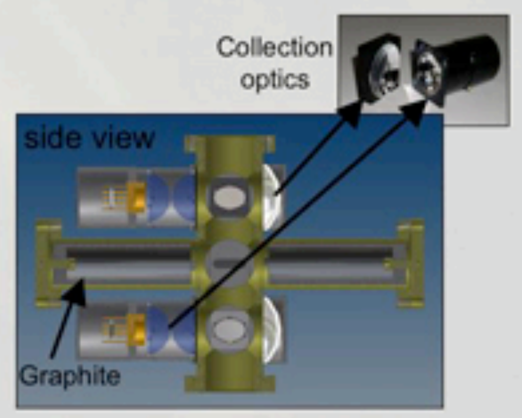
NRF1 Fountain Design

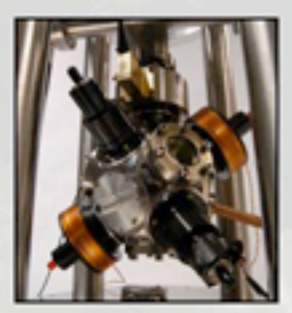


Our rubidium fountains are required to run in an operational environment without user intervention. Toward this end we have developed a compact, robust system that is contained in three equipment racks. Shown here is our rack-mounted miniature optical table with which all of the laser beam-splitting and frequency-shifting is carried out. Optical fibers transmit laser light from this table to monolithic couplers at the physics package.



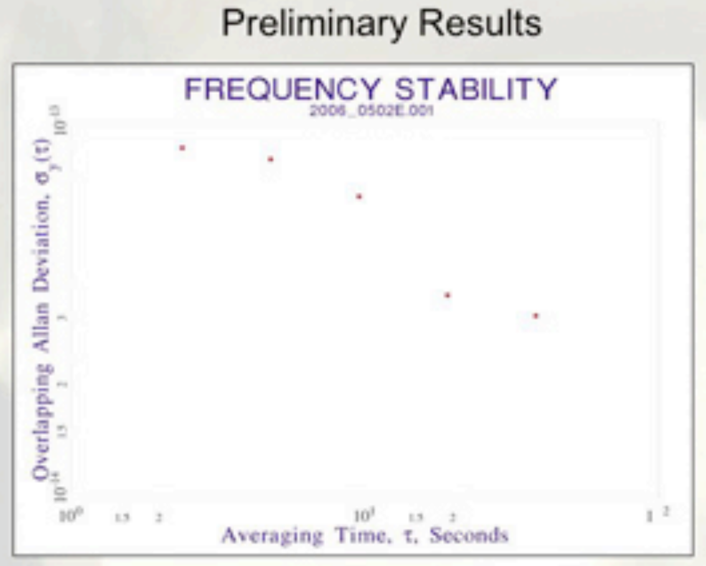
The physics package consists of machined titanium vacuum chambers with weld-in windows. Monolithic couplers which bolt directly to the vacuum chamber deliver the required collection/launching, detection and probe laser beams. All components are nonmagnetic.



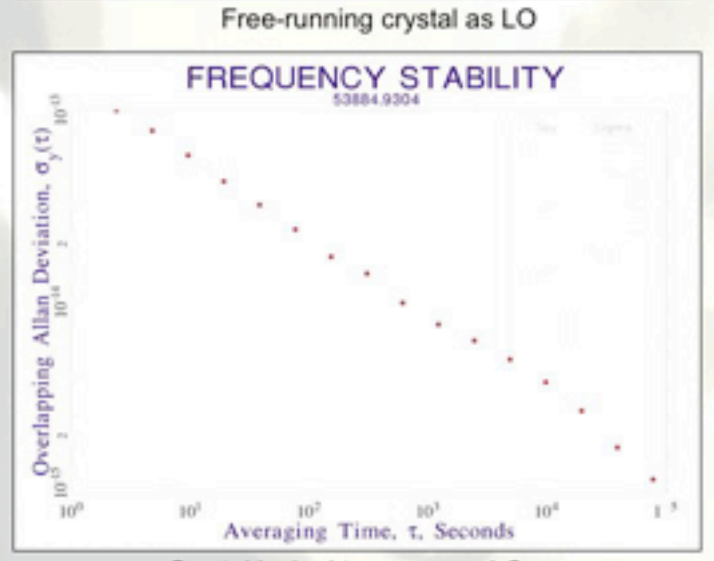


Fiber-Amp Laser System

Preliminary Results



Free-running crystal as LO



Crystal locked to maser as LO

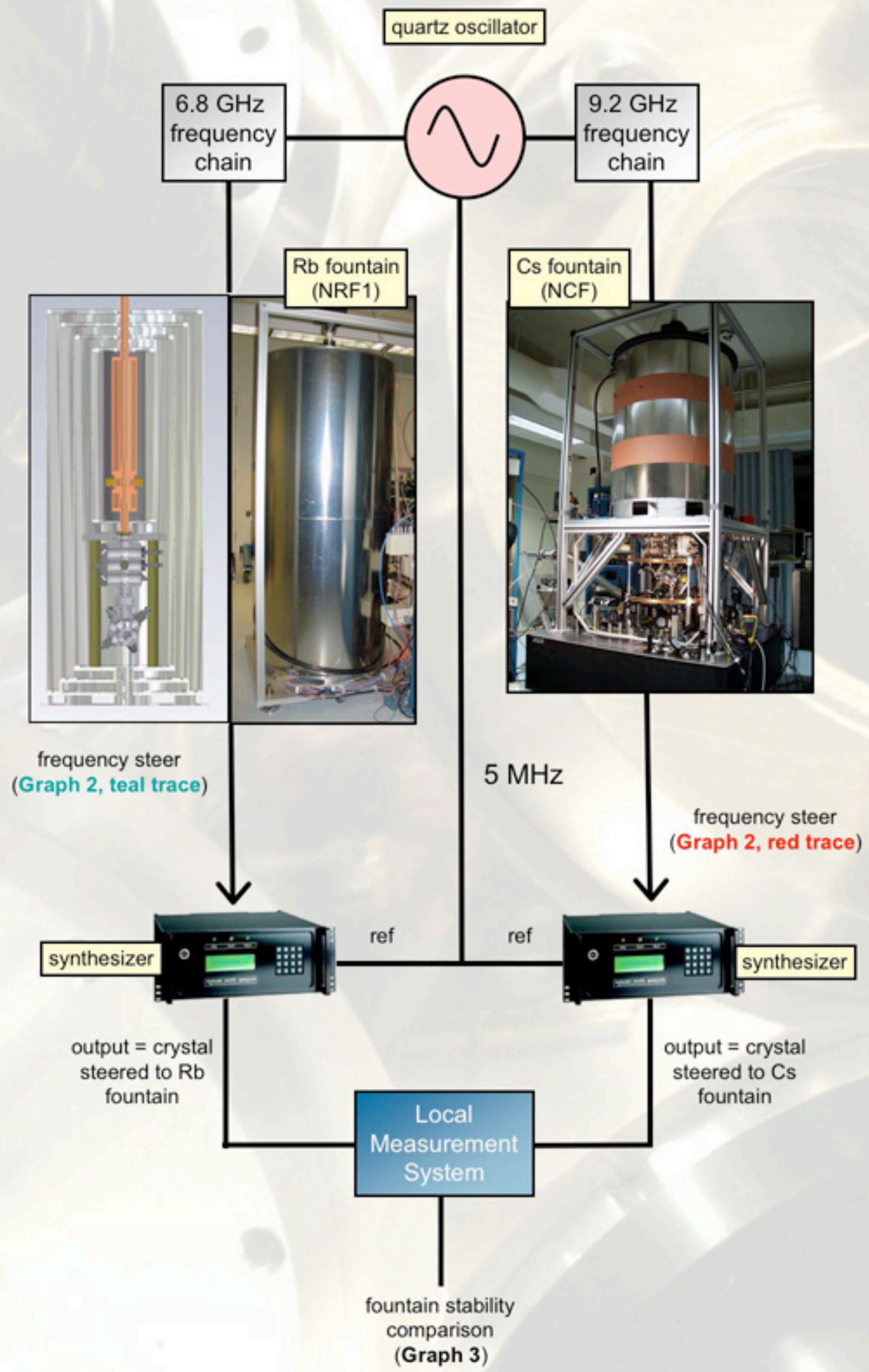
We have recently been operating NRF1 with a commercial fiber amplifier and doubler system which takes a 1560nm telecom seed laser input and provides more than 1.5W of 780nm light from a fiber that feeds directly into the optical table. Our initial data uses an ECDL as a seed and we plan to replace with a DFB fiber laser seed.

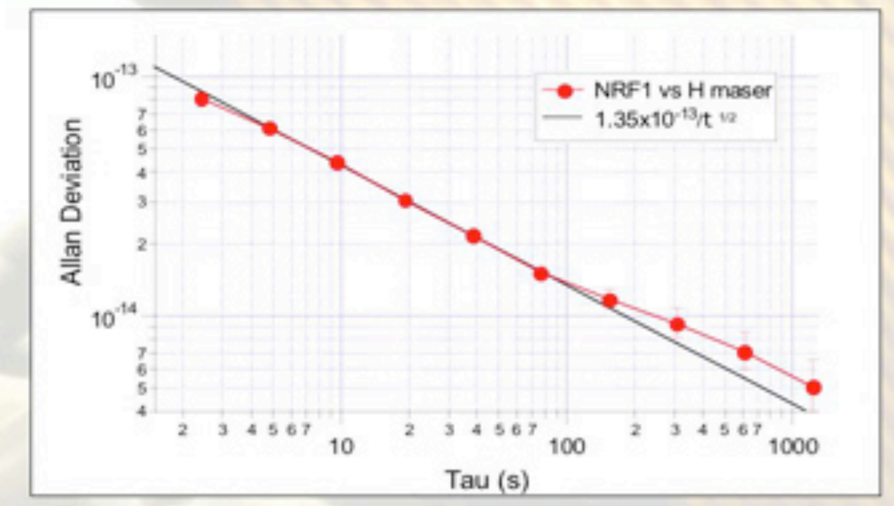
Preliminary results show a short-term performance that is on-par with operation when using our Ti:Sapphire laser. Mid- and long-term operation is now being investigated and showing good results so far with three continuous weeks of operation.

Characterization

Our fountain versus maser comparisons are typically limited by maser frequency fluctuations in the mid to low 10^{-15}'s (Graph 1). In order to get a better characterization of NRF1 at these levels of stability, we carried out a comparison between NRF1 and our cesium fountain, NCF.

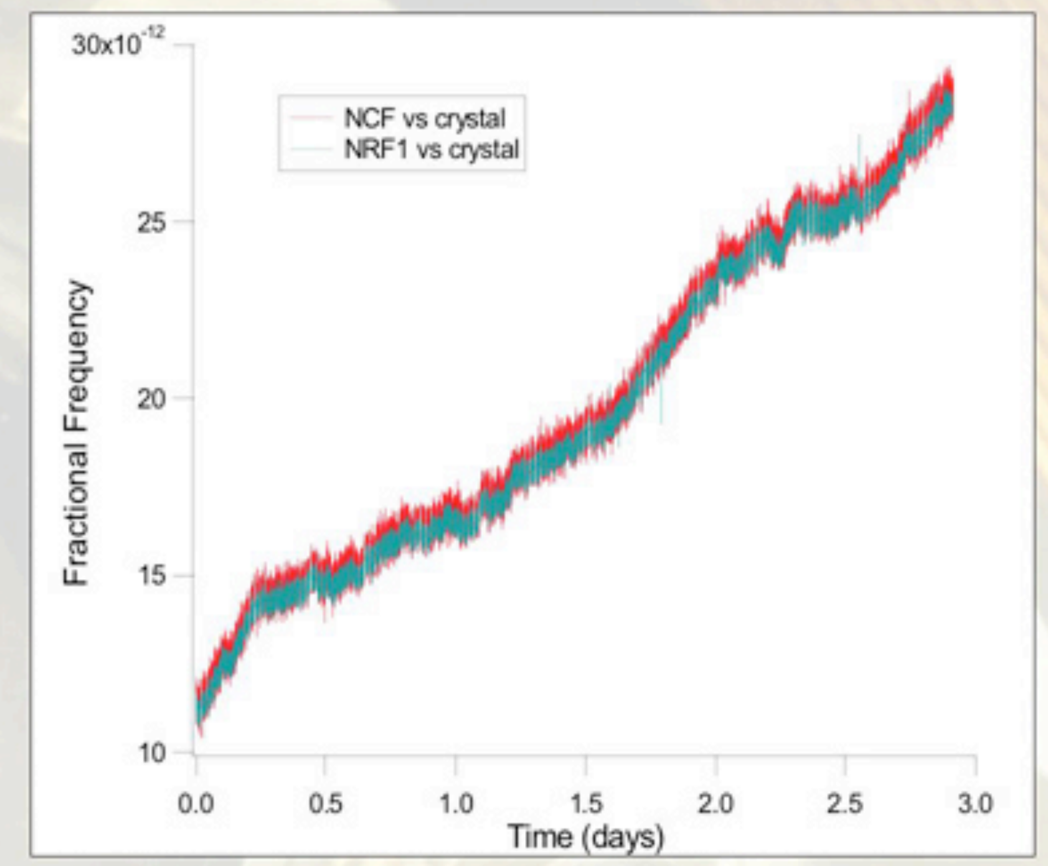
This data was taken with the Ti:Sapphire laser, prior to installation of the fiber-amp laser system.



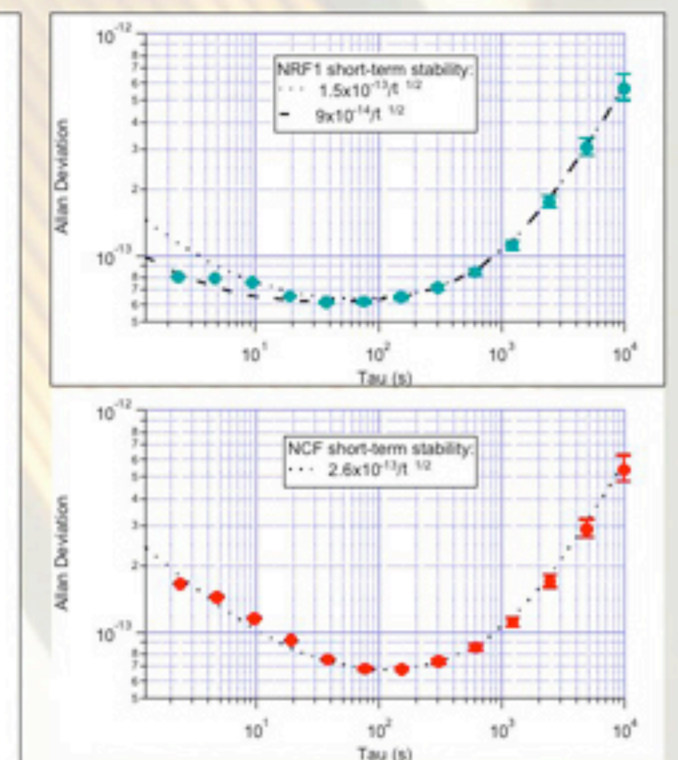


Graph 1

Our standard method for determining the short-term performance has been to compare the fountain to a maser by phase-locking our crystal to the maser. NRF1 shows performance as good as $1.3\times10^{-13}/\tau^{1/2}$. Deviations from white-frequency noise typically arise when the maser fluctuations dominate the frequency stability comparison.

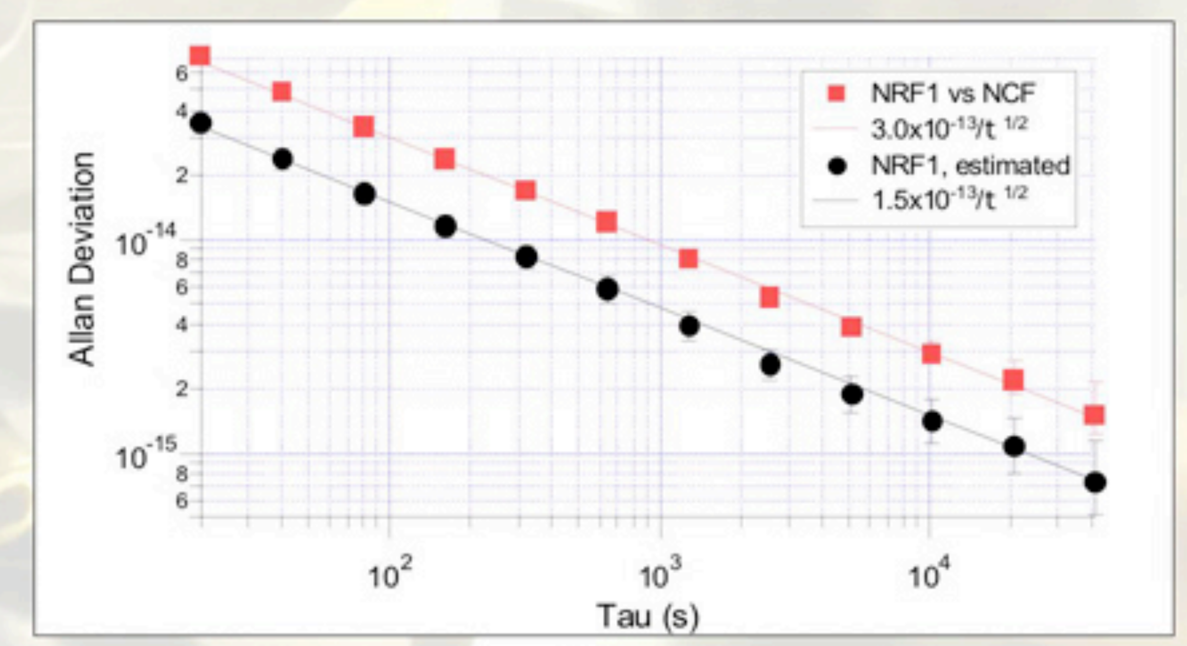


Graph 2



Fitting the Allan deviation plots to the sum of white-frequency (fountain), flicker (crystal), random walk frequency (crystal), and frequency drift (crystal) noise terms enables us to extract short-term fountain stabilities when the crystal is not locked to the maser.

To measure medium-term performance, we compare NRF1 to NCF. Each fountain measures the frequency of the same crystal and produces (via an AOG synthesizer) a steered output. Measuring the relative stability of these steered outputs yeilds a comparison of NRF1 and NCF stabilities.



Graph 3

Measuring the relative stability of the rubidium and cesium fountains indicates $1/\tau^{1/2}$ averaging behavior out to τ = 11 hours (for a 3 day run). Coupled with measured short-term stabilities, this allows us to estimate the Stability of NRF1, which is consistent with an Allan deviation of 7×10^{-16} at 11 hours.