RESULTS ON LIMITATIONS IN PRIMARY CESIUM STANDARD OPERATION

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ABSTRACT

We report on the most recent design changes in our primary cesium standards, their current operational use, results obtained and limitations. NBS-4, the shorter device with an interaction length of L = 0.5 m has been extensively used for many months as an operating clock. After improvements in the magnetic shielding and the microwave feed, stabilities in the 10^{-15} region were obtained. NBS-6, the longer, more accurate device (L = 3.7 m) features a linewidth of only $\sim$ 30 Hz which is believed to be the narrowest line ever reported for a cesium device. NBS-6 offers a short-term stability in the 10^{-13} region at 1 s sampling time and easy beam reversal. The effects on signal intensity and frequency bias corrections of modulation frequencies high enough to approach the linewidth of the atomic resonance are discussed. The current and past rates of the international atomic time (TAI) in terms of our primary cesium standards are reported and compared with the results of other laboratories. An assessment of current and possible absolute accuracies is given.

SUMMARY

Recent design changes and results are reported for the two NBS primary cesium standards, NBS-4 and NBS-6. Particular attention has been paid to improving the long-term stability of NBS-4 and in evaluating the limitations of an absolute frequency determination using NBS-6.

NBS-4 [1] has been modified slightly to improve long-term stability. We have recently installed an additional moly-permalloy magnetic shield (external to the vacuum chamber) and have also installed a new microwave feed with the idea of improving mechanical stability. In addition, the entire beam apparatus has been physically relocated to reduce the effects of spurious external perturbations (e.g., visitors, technicians, physicists). Finally, with the idea of prolonging running time, the oven temperature was reduced (signal current = 1.65 pA, Bkg current = 0.20 pA). This reduction was effected to make the short-term ferquency stability ($\tau \simeq 1$ s) comparable to that of the commercial cesium tubes used in the NBS clock ensemble. With these changes, we have obtained $\sigma_y(1\ \text{wk}<\tau<2\ \text{wks}) = 7 \times 10^{-15}$ for the fractional frequency stability of NBS-4.

NBS-6 [2] is a modified version of NBS-5 [1] and has been in operation since March 1975. The modifications included larger capacity vacuum pumping ($p \simeq 10^{-8}$ Torr presently), and improved beam reversal capability. Present operating linewidths are 25 to 30 Hz (L = 3.75 m) and short-term stabilities σ_y (1s)= 7×10^{-13} have been obtained (τ_{oven} = 88° C, signal current = 9 pA, Bkg = 13.5 pA). An 18.75 Hz sinusoidal phase modulation is used and improvements are expected for a squarewave FM system. Particular attention has been paid to limitations of an accuracy evaluation. It appears that the largest and most difficult to obtain uncertainty is that due to the cavity phase shift. For example, residual cavity mistuning, magnetic field inhomogeneities, and second harmonic content in the phase modulation all give effects which mimic cavity phase shift in a power shift determination [3]. A summary of the errors associated with an accuracy evaluation including power shift and beam reversal will be given.

The small uncertainties attributed to primary standards and the relatively large dispersion of measured rates of TAI by the various standards laboratories would seem to indicate that increased attention should be paid to systematic errors in cesium devices.

REFERENCES

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[3] S. Jarvis, Jr., "Determination of Velocity Distributions in Molecular Beam Frequency Standards from Measured Resonance Curves," *Metrologia,* Vol. 10, 1974.