

FREQUENCY COMPARISON (H_MASER 40 3818) - (SU-CsFO2) For the period MJD 57049 to MJD 57079.

The primary frequency standard SU-CsFO2 has been compared to the hydrogen Maser 40 3818 of the laboratory, during a measurement campaign between MJD 57049 and 57079 (27th January 2015 - 26th February 2015). The fountain operation covers ~ 70 % of the total measurement duration for the period MJD 57049-57079. The mean frequency difference at the middle date of the each period is given in the following table:

| Period (MJD) | Date of the estimation | y(HMaser40 3818 – CsFO2) | u_B | u_A | u_{Link_Maser} |
|--------------------|------------------------|--------------------------|------------|------------|-------------------|
| 57049-57079 | 57064 | -246.4 | 2.5 | 2.4 | 1.3 |

Table 1: Results of the comparison in 1×10^{-16} .

For the uncertainty due to the clock link $u_{Link_Lab} = 0.1 \times 10^{-15}$ is obtained by taking into account the actual measurement time.

The CsFO2 standard uncertainty u_B is estimated as 0.25×10^{-16} (1σ) for the relevant periods.

Accuracy

The following table summarizes the budget of systematic effects and their associated uncertainties. The accuracy is the quadratic sum of all the systematic uncertainties.

| Physical Effect | Shifts (10^{-16}) | Uncertainty (10^{-16}) |
|----------------------------|-----------------------|----------------------------|
| Second-order Zeeman effect | 1069 | 0.10 |

| | | |
|--|---------------|------------|
| Black-body radiation | -165.5 | 1.0 |
| Gravitational shift | 244.3 | 0.5 |
| Resonator pulling | 0.014 | 0.1 |
| Purity of probe signal spectrum | 0 | 0.1 |
| Light shift | 0 | 0.1 |
| Tilting(DCP) | 0.37 | 0.75 |
| Microwave leakage | 0 | 0.1 |
| Collisions with residual gas | 0 | 1 |
| Microwave power dependence | 0.1 | 1.8 |
| Spin exchange shift (low density)* | 0.4* | 0.3* |
| Total(not including spin exchange) | 1148.1 | 2.5 |

Table 2: Budget of systematic effects and uncertainties for VNIIFTRI- CsFO2 fountain for the MJD 57049 – 57079 period

$$u_B = 2.5 \times 10^{-16}.$$

Uncertainty due to the dead times

During the evaluation period there were gaps in the data collection (dead time) due to both intentional and unintentional breaks. Most of the unintentional breaks were caused by failures of the laser locking systems(due to rapid change barometric pressure).

The standard deviation of the fluctuations of frequency due to the dead times in measurements is estimated by the ratio

$$\frac{\sqrt{\sum_i \sigma_{x_i}^2}}{T} = \sigma_{Dead_Time}$$

| Period | σ_{Dead_Time} |
|---------------|---|
| 56049 - 56079 | 8.4E-17 |

The uncertainty on the link Maser is obtained by the quadratic sum of the link lab uncertainty and the uncertainty due to the dead times calculated above:

$$u_{Link_Lab} = 1 \times 10^{-16},$$

$$u_{Link_Maser} = \sqrt{(\sigma_{Dead_Time})^2 + (\sigma_{Link_Lab})^2}$$

| Period | u_{Link_Maser} |
|---------------|-------------------------------------|
| 57049-57079 | 1.3E-16 |

References

[1] Domnin, Yu.; Baryshev, V.; Boyko, A.; Elkin, G.; Novoselov, A.; Kopylov, L.; Kupalov, D., "The MTsR-F2 fountain-type cesium frequency standard", Measurement Techniques, Volume 55, Number 10, January 2013, pp. 1155-1162(8)