Agreement between two $^{88}Sr^{+}$ optical clocks to 4 parts in 10^{17}

Geoffrey Barwood, Guilong Huang, Hugh Klein, Luke Johnson, Steven King, Helen Margolis, Krzysztof Szymaniec and Patrick Gill

National Physical Laboratory, Teddington, UK, TW11 0LW

Email: gpb@npl.co.uk

The frequencies of two nominally identical $^{88}Sr^{+}$ trapped single ion optical clocks, based on the 674 nm 5s $^{2}S_{1/2}$ – 4d $^{2}D_{5/2}$ electric quadrupole clock transition, have been compared over a period of 9 months. The frequency of the two clocks was found to agree within a total fractional uncertainty of 4×10^{-17}, demonstrating that the individual $^{88}Sr^{+}$ optical clocks are reproducible at the 3×10^{-17} level.

Two-trap frequency comparison data were taken over continuous periods of up to 38 hours. A total of about 1.7 x 10^{6} s of results were taken in 2012 and 2013 with weighted frequency differences of –10(12) mHz and +38(32) mHz respectively for these two periods (figure 1). Combining these figures and weighting according to the two uncertainties gives a mean difference of 4 mHz with a statistical (type A) standard error of the mean of 11 mHz (2.4×10^{-17}). When combined with systematic uncertainties for the comparison, estimated to be 3.2 x 10^{-17}, this gives a total comparison uncertainty of 4 parts in 10^{17}, corresponding to 3 parts in 10^{17} for a single trap.

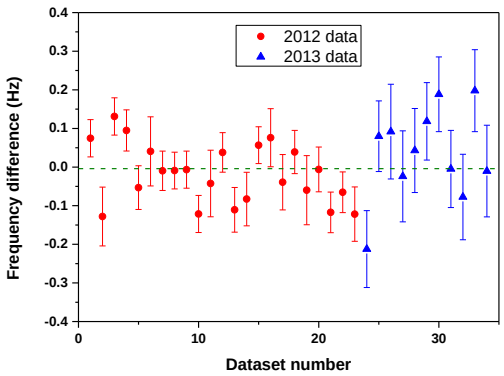

Fig. 1: Two-trap frequency comparison data from October 2012 to July 2013 (~19 days of measurements). The mean frequency difference between the traps is shown as a dashed line and is consistent with zero to within the measurement uncertainty.

The absolute frequency of the clock transition was measured using two combs to be f = 444 779 044 095 486.71(24) Hz, referenced to a caesium fountain primary frequency standard. The standard uncertainty of 0.24 Hz (5.3×10^{-16} of the optical frequency) is dominated by measurement statistics and caesium fountain systematics and is around four times lower than previously published[1].

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[1] A.A Madej et al: "$^{88}Sr^{+}$ 445-THz Single-Ion Reference at the 10^{-17} Level via Control and Cancellation of Systematic Uncertainties and Its Measurement against the SI Second", Phys Rev Lett vol 109, 203002 (2012).