Short-term frequency stability analysis of time-keeping ^{87}Rb fountain clock at NTSC

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Frequency stability is one of the most critical metrics for time-keeping atomic clocks. This paper analyses the effects of various noises on the short-term frequency stability of the time-keeping ^{87}Rb fountain clock developed by the National Time Service Center (NTSC), Chinese Academy of sciences, identifies the main noise sources, and gives suggestions for improvement.

The atomic transition probabilities (ATPs) are measured for different atomic numbers and the respective variances are calculated. The effects of quantum projection noise (QPN), electron detection noise (EDN), and local oscillator (LO) phase noise on atomic transition probability for normal clock operation are obtained by fitting them according to the relevant formulae, respectively. Based on the fitted values, the effects of the above noises on the short-term frequency stability of the clock are estimated as $1.39\times10^{-13}\tau^{-1/2}$, $9.04\times10^{-14}\tau^{-1/2}$, $1.53\times10^{-13}\tau^{-1/2}$. By measuring the relative frequency and intensity noise of the detecting laser, the effect of laser detection noise (LDN) on the clock frequency stability is estimated to be $2.03\times10^{-14}\tau^{-1/2}$.

We estimated the clock frequency stability (1s) for different atomic numbers based on the previous variances and also measured these stabilities, as shown in Figure 1. The current noise sources limiting the short-term frequency stability of our clock (normal operation) are QPN and LO phase noise, which can be suppressed by applying the 2D-MOT[1], a cryogenic sapphire oscillator or a optically stabilization microwave oscillator， respectively[2].

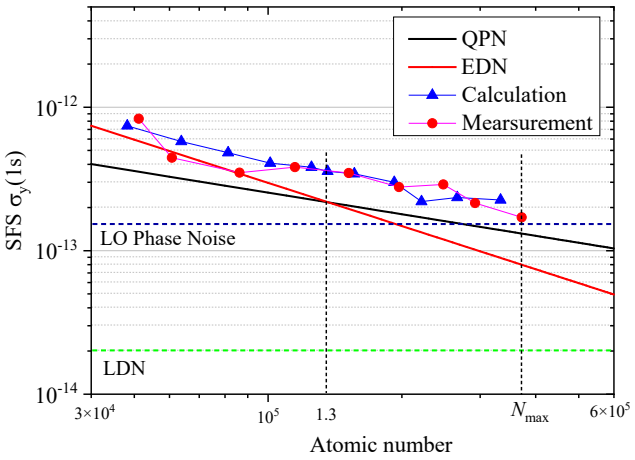

Fig. 1: Variation of clock frequency stability (1s) with atomic numbers. the stability of the clock decreases with the increase of atomic numbers. When the atomic number is less than 1.3×10^5, the noise sources affecting the stability of the clock are QPN and EDN, and when the number of atoms is greater than 1.3×10^5, QPN and LO phase noise gradually dominate as atomic numbers increase.

[1] C. J Wu, "A two-dimensional magneto-optical trap for a cesium fountain clock," Acta Phys. Sin., vol.62， p. 063201, 2013.

[2] C. Fluhr, "Characterization of the individual short –term frequency of Cryogenic Sapphire Oscillators at the 10^{-16}," IEEE Trans. Ultrason. Ferroelectr. Freq. Control, vol. 63, p.915-921, 2016.