Micro mercury ion clock with frequency stability performance comparable to that of rack mount Cs frequency standards

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As communication and navigation systems increasingly rely on precise timing signals from atomic clocks, the interest for smaller and more power-efficient clocks has grown in recent years. However, achieving high performance in clock frequency stabilities while reducing size, weight, and power (SWaP) has proven to be a challenge. Surveying existing atomic clocks in use clearly shows stubborn trade-off [1]. Improving clock stability means higher number of atoms, better vacuum conditions, higher laser powers, and more complex system control, all of which inevitably result in larger size and higher power consumption. In this paper, we will present the development of micro mercury trapped ion clocks (M2TIC) that clearly broke away from the typical trend as shown in Figure 1 [2].

M2TIC adopts the traditional trapped mercury ion microwave clock approach as it was demonstrated NASA Deep Space Atomic Clock [3]. To significantly reduce SWaP while maintain its high frequency stability capability, we have developed miniature vacuum trap tubes with field-emitter-arrays electron sources, 194-nm micro plasma lamps, and 40.5-GHz CMOS-based microwave synthesizers. We integrated these new technologies into the M2TIC clock prototypes, which demonstrated stability at the 10^{-14} level within a day, while packaged in a 1.1-liter standalone box and consuming less than 6 watts of DC power. This stability level is comparable to the widely used Microchip 5071A cesium frequency standard, which is much larger and consumes more power. The prototypes have also been shipped across North America intact to a government laboratory where they were independently tested and verified. One of the prototypes were able to run over 40 days with a drift less than any vapor-cell based atomic clocks in use. The successful demonstration of the M2TIC opens possibilities for high-performance clocks in terrestrial and space applications.

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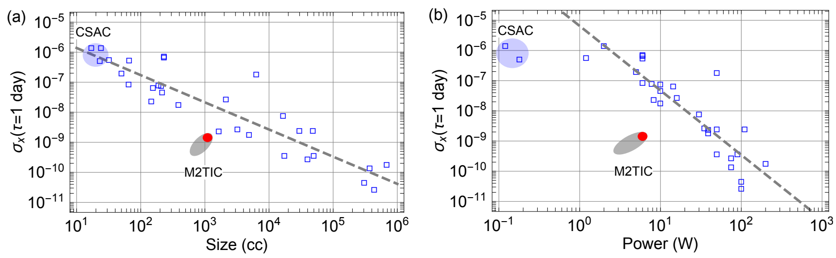

Fig.1. Time deviation after a day vs. size (a) and power (b) of some of the state-of-the-art compact atomic clocks. Existing compact atomic clock data (blue markers) are taken from Ref.1. The solid red dot indicates the current M2TIC prototypes, and the gray shaded area indicates possible further improvements. Figure from Ref. [2].

References

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