

## Progress on cadmium-ion and ytterbium-ion Microwave Frequency Standards at Tsinghua University

The laser-cooled cadmium-ion microwave frequency standard has been developed at Tsinghua University for thirteen years. Recently, the ground-state hyperfine splitting frequency of  $^{113}\text{Cd}^+$  was determined to be 15199862855.02799(27) Hz, and the fractional frequency instability was measured to be  $4.2 \times 10^{-13}/\sqrt{\tau}$ . The result was consistent with previously reported values, but the measurement precision was four times better than the best result obtained to date. In addition, using sympathetic cooling technology, we have developed a high-performance cadmium-ion microwave frequency standard with  $^{40}\text{Ca}^+$  as coolant ions. The short-term frequency instability reached  $3.48 \times 10^{-13}/\sqrt{\tau}$ , which is comparable to that of the mercury ion frequency standard. It is worth mentioning that a microwave frequency standard based on laser-cooled  $^{171}\text{Yb}^+$  ions has also been developed in our laboratory since 2021. Recently, the short-term frequency instability was measured to be  $8.5 \times 10^{-13}/\sqrt{\tau}$ . The ground-state hyperfine splitting frequency of  $^{171}\text{Yb}^+$  was determined to be 12642812118.4674(8) Hz.

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