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Editorial: Quantum precision measurement and cold atom physics

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Editorial on the Research Topic
Quantum precision measurement and cold atom physics

Ever since the invention of the cesium beam atomic clock in 1955, quantum frequency standards have seen considerable development over the decades, as a representative of quantum precision measurement. The progress in frequency measurements achieved in the past allows one to perform measurements of other physical and technical quantities with unprecedented precision, whenever they could be traced back to frequency measurements. Using atomic transitions as frequency references, quantum frequency standards are far less susceptible to external perturbations, and the quantum identity principle of microscopic particles allows easy replication of quantum frequency standards with the same frequency at any time and place. With laser cooling and trapping, cold atomic ensembles eliminate Doppler shift broadening and have become the go-to quantum reference when precision is required.

The advancement of laser cooling and cold atom physics, in addition to novel physical matter states such as Bose-Einstein Condensation, gives rise to new experimental techniques in quantum precision measurement, especially quantum frequency standards, such as cesium fountain clocks dictating the SI second, as well as optical lattice clocks and single-ion optical clocks pushing the *Frontier of Quantum Metrology*. Other areas of quantum metrology, such as gravitometers and magnetometers, also benefit greatly from cold atoms. Challenges still remain, as researchers strive to push forward the limit in quantum precision measurement and search for novel physical phenomena in cold atomic systems.

In this regard, we organized the Research Topic "*Quantum Precision Measurement and Cold Atom Physics*" in Frontiers in Physics.

As a tribute to his 90th birthday on September 20, we dedicate this Research Topic to the venerable Prof. Yiqiu Wang, a pioneering figure in China's development of quantum precision measurement and cold atom physics. Chen et al. chronicled the scientific career and contributions of Prof. Wang in a Review article, including his early research on nuclear magnetic resonance, his later works on microwave atomic clocks, laser cooling, and Bose-Einstein Condensate, as well as his foray into the fields of optical tweezers and optical atomic clocks. Currently, including the aforementioned Review, fifteen contributed articles have been collected on this topic.

The first part of contributions has been made on recent advancements in the field of quantum precision measurement. Utilizing diffuse laser cooling, Meng et al. realized a compact cold atomic clock suitable for satellite-borne operation, with applications in satellite navigation. While cesium fountain clocks have long been used for defining the SI second, rubidium fountain clocks also show great potential for robustness and excellent long-term stability for timekeeping, as demonstrated by Chen et al at the National Institute of Metrology in China. Meanwhile, Wang et al.'s work produced an optical system for a microwave atomic clock based on optical-lattice trapped atoms, with the potential for performance beyond the atomic fountain. Ever seeking innovation, researchers have made various improvements to the cesium beam atomic clock. Chen et al.'s mini-review discusses the optically detected magnetic-state-selected cesium beam clock, which combines the advantages of the magnetic state selecting scheme and fluorescence detecting method. He et al.'s review article records their effort in improving the short- and long-term stability of high-performance portable optically pumped cesium beam atomic clock. Chen et al. designed an optically pumped cesium beam tube with a hexapole magnetic system, achieving a longer lifetime and better signal-to-noise ratio. Chen et al. also analyze the characteristics of a compact magnetic state-selection cesium atomic clock called LIP Cs-3000 in their article. Moving on to hydrogen masers, we have Que et al. designing a vacuum system for an active hydrogen maser in space, and Dai et al. reviewing the development of the hydrogen maser, as well as its space applications. In the field of optical frequency standards, Wang et al. recount how they were able to trace the optical frequency to the SI second, applying the frequency comparison link from UTC(NIM) to International Atomic Time. Shi et al.'s research on active-optical-clock lasing on the Cs 7S 1/2-6P3/2 transition under a weak magnetic field shed new light on the active optical clock concept.

The second part of the contributions focuses on works on laser cooling and various aspects of cold atom physics. Li et al. demonstrate a deep cooling scheme of quantum degenerate gas for the Chinese Space Station and verified the scheme with a ground experiment. The manipulation of ultracold atoms of high orbitals in optical lattices under nonadiabatic holonomic quantum control is also discussed in Jin et al.'s Review. Tong et al.'s article recounts their effort in detecting the pH-dependent liquid-liquid phase separation of single levitated aerosol microdroplets using a laser tweezers Raman spectroscopy system.

We conclude our Editorial with our most sincere thanks to all the authors of the articles published on this Research Topic for their valuable contributions, and the Frontiers in Physics team for their assistance with publishing.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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