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EDITORIAL

Quantum coherence, correlations and dynamics of ultracold atoms: From fundamental research to future technology

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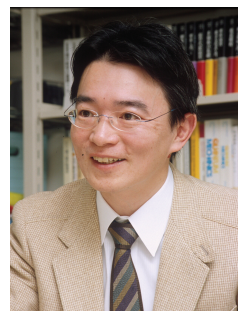

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Coherence and correlation are at the heart of all quantum sciences. The emerging quantum technologies crucially depend on exotic coherence and correlations that cannot be found in classical systems. To realize quantum technologies, one has to use dynamical processes to control and exploit quantum coherence and correlations. Instead of being satisfied with what nature hands us, by applying experimental techniques for quantum manipulation it is possible to explore what new things can be done with quantum systems. The emergence of quantum technology is not just a way to understand what already exists, but also a way to engineer our surroundings for our own needs from science to technology.

In recent years, several seminal discoveries have appeared in both experimental and theoretical studies of ultracold atoms. The controllability and robust quantum coherence of ultracold atoms provides new opportunities for testing the fundamentals of quantum theory, and offers us an excellent platform for exploring many-body quantum dynamics. Furthermore, understanding quantum correlations and dynamical phenomena in ultracold atomic systems will advance quantum technologies in simulation, high-precision measurement and information processing.

In order to discuss the latest achievements in the quantum dynamics and quantum technologies of ultracold atoms, the International Symposium on Quantum Dynamics of Ultracold Atoms and Quantum Technologies was held at Sun Yat-Sen University, Guangzhou, on 7–10 December 2010. Contributed by some invited speakers of this symposium, who are international experts from Australia, China, France, Germany, New Zealand, Russia and USA, this special issue "Recent Progresses on Quantum Dynamics of Ultracold Atoms" includes two research articles and eight review articles. X.-W. Guan discussed polaron-like effects and pairing in a one-dimensional two-component attractive Fermi gas; A. R. Kolovsky suggested how to simulate cyclotron-Bloch dynamics of a charged particle in a two-dimensional lattice with cold atoms in a driven one-dimensional optical lattice; Q. Y. He, M. D. Reid, B. Opanchuk, R. Polkinghorne, L. E. C. Rosales-Zárate, and P. D. Drummond reviewed recent developments in the theory of quantum dynamics in ultracold atomic physics; D.-W. Zhang, Z. D. Wang and S.-L. Zhu presented ideas on simulating relativistic quantum effects of Dirac particles with ultracold atoms; A. Yu. Cherny, J.-S. Caux and J. Brand reviewed theoretical approaches to superfluidity and drag forces in a one-dimensional Bose gas; M. D. Reid, Q. Y. He and P. D. Drummond discussed entanglement and nonlocality in multi-particle systems; A. Sinatra, J.-C. Dornstetter and Y. Castin reported on particle loss and non-zero temperature effects in spin squeezing of Bose condensed atoms; H. Hu reviewed some new theoretical techniques for exploring the density response of a strongly correlated atomic Fermi gas; C. Lee, J. Huang, H. Deng, H. Dai and J. Xu reviewed recent progress in nonlinear quantum interferometry with Bose condensed atoms; and finally, M. A. Garcia-March, D. R. Dounas-Frazer and L. D. Carr presented a multi-mode description for ultracold atoms in a double-well potential and discussed the macroscopic superposition states in such a system.

As more and more experimental achievements with ultracold atoms appear, the field of quantum dynamics of ultracold atoms is expanding into ever more exciting areas. Beyond the issues of fundamental research, it is now

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becoming possible to engineer ultracold atoms for practical technological applications. There are many important questions that need to be answered, and the beginnings of these answers can be found in this special issue:

- How will ultracold atoms enable better quantum metrology and other measurements?
- How will ultracold atoms test the fundamental principles of many-body physics?
- Will new quantum phases be found?
- Can ultracold atomic systems resolve the quantum paradoxes of macroscopic systems?
- What theoretical approaches can treat open systems of interacting ultracold atoms?
- How can we overcome imperfections from dynamical excitations and the environment?

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