Preface

In the past decades, the ability of observing and manipulating quantum phenomena has been tremendously improved. It has advanced the thriving of quantum technologies with atomic, optical and solid-state systems. In practice, various control problems of quantum dynamics can be found when the high-precision and robust quantum operations are desired, which has attracted a large amount of cross-disciplinary researches from physics, chemistry, information science, mathematics, electrical engineering and system control communities. Much progress has been made on developing theory of modeling, analysis and design of quantum systems, as well as the large amount of their laboratory applications to controlling ultrafast dynamics, nuclear magnetic resonance (NMR) spectroscopy, optical networks and atomic systems. All successes have exhibited an elegant landscape for researchers to explore. In China, the long-term development strategy of science and technology for future decades, the quantum control has been set as a key direction. With this background, we organized this special topic for introducing the frontier of quantum control theory and its applications.

The aim of quantum control theory is to introduce the engineering control methodologies into the practical manipulation of quantum dynamics and synthesis of quantum devices. From a mathematical point of view, many results in control theory can be readily transferred when treating quantum objects as a dynamical system. However, the analysis and performance evaluation of quantum control require a deeper understanding of quantum mechanics. In addition, the quantum nature brings up many interesting issues, which lead to essential difficulties that distinguish quantum control from classical control theory. For example, the concept of feedback has to be seriously reconsidered due to the famous Heisenberg uncertainty principle and inevitable disturbances by quantum measurements. These distinctions have attracted studies from both engineering and science communities, and the different thoughts thereof need to be fused in order to resolve practical quantum control problems.

The main focus of this special topic is on quantum control theory and its applications to quantum physics and technologies. Nine research and review articles are included with invited contributions of authors from China, Australia and United States. The state-of-art of quantum control theory is outlined, with several fundamental control problems highlighted and discussed. In particular, the rapidly growing area of coherent feedback control is systematically reviewed by leading researchers in this field. The research articles address various important control problems in closed and open quantum systems, with applications to quantum computation, quantum communication and laser spectroscopy. This special topic will provide a comprehensive introduction to quantum control theory, with which we wish to reduce the gap between science and engineering communities and push more high-level interdisciplinary collaborations.

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