

Quantum Optics Team at East China Normal University & Shanghai Jiao Tong University

Location

East China Normal University & Shanghai Jiao Tong University,
Minhang Campus, 500-800 Dongchuan Road, Shanghai, China

Overview

The team focuses on the frontier research in the field of atomic, molecular, and optical physics, including, but not limited to, quantum optics-atom optics and quantum metrology. Several research directions have been developed into quantum control of atoms and light, quantum-correlated interferometry, quantum-enhanced sensing, and precision measurement beyond conventional techniques. The team is building up into a joint one with the East China Normal University and Shanghai Jiao Tong University. Currently, it consists of 5 professors, 3 associate professors, 2 assistant professors, and 4 post-doctors, including one recipient of the National Science Fund for Distinguished Young Scholars, etc.. In addition, a number of prizes are awarded including Yutai Rao Prize in Physics, and the First-prize Shanghai Natural Science Award.

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Research Foci

- **Quantum optics:** Developing and utilizing quantum metrology technologies to manipulating ^{87}Rb vapor cell and generating atom-light interface. These have been demonstrated efficient broadband atom-light quantum conversion, quantum atomic magnetometer, optical quantum interferometer, and atom-light hybrid interferometers.
- **Quantum metrology:** Quantum mechanics sets the ultimate limit on the accuracy of any measurement. Quantum metrology, therefore, uses quantum effects to enhance precision beyond that possible through classical approaches.
- **Quantum optomechanics:** Motivated by the rapid experimental advance of hybrid optomechanical systems to the quantum regime, theories are developed to describe macroscopic quantum



(contents continued from inside back cover)

effects and quantum control and feedback. The developed theories also guide quantum metrology and quantum machines to show unprecedented performance, and to improve fundamental knowledge of the underlying physics.

- **Nanooptics and graphene electron optics:** Developing optical metagratings and generalizing conventional optics or meta-optics theories to graphene to manipulate electron transport. The works focus on the miniaturization of optical and electric devices and the applications in optical and electric integration by exploring novel means of controlling light and electrons and uncovering novel mechanisms.
- **Quantum effect and manipulation of ultra-cold atoms:** Because of the intrinsic quantum character and the unprecedented level of control and precision in the experiments, ultra-cold atoms have become an ideal platform for emulating diverse significant condensed matter models, and exploring new interesting physical phenomena as well.
- **Non-equilibrium quantum many body physics in atomic, molecular and optical (AMO) systems:** We investigate collective quantum phenomena in AMO systems, using the method of numerical simulation of quantum many body system, and focus on generating, characterizing and manipulating these quantum phenomena such as quantum phase transition and entanglement, also study their usage in quantum-enhanced technologies such as quantum sensing.
- **Rydberg physics:** Rydberg atoms with highly-excited valance electrons, can exhibit some exaggerated properties such as a large electric dipole moment, which facilitates strong dipole-dipole interactions between two nearby Rydberg levels. We focus on the optimal control of these interactions by static electric, magnetic, laser or microwave fields, making the exotic systems of Rydberg atoms ideal platforms for implementing quantum computing, quantum simulation, high-resolution imaging and quantum many-body simulators.

Recent Projects

- **Quantum optics:** Developing quantum-enhanced technologies based on atom-light quantum interface to improve the precision of displacement measurement and angular velocity measurement to below standard quantum limit; developing noise reduction technologies to realize quantum conversion with efficiency above 90%.
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- **Quantum metrology:** A new type of quantum interferometer/gyroscope – atom-light interferometer/gyroscope – has been realized and shown to provide a novel route to quantum enhanced

interferometry and measurement.

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- **Quantum optomechanics:** A design of an autonomous quantum heat engine based on optomechanical systems has been produced, verifying a novel route to autonomous quantum control. The theory of quantum nondemolition measurement has been developed to be available for relativistic optomechanical measurement systems.

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- **Nanooptics and graphene electron optics:** Various optical metagratings have been designed to realize negative transmission and retroreflection of light. Metagratings are another single-nanoparticles-layer optical material besides metasurfaces which have the advantages of compactness, light weight, low loss and easy fabrication. The concepts of electron metagratings and electron metasurfaces have been proposed in graphene to break the dependency of current electron optics technology on extreme-low-temperature environments.

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- **Quantum effect and manipulation of ultra-cold atoms:** Study the new quantum matter and new interesting phenomenon with the synthetic gauge potential, optical lattices and periodically modulation based on the interaction of laser light and ultra-cold atoms. Find the possible way to manipulate the quantum states and simulate important phenomenon not easy to be observed.

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- **Non-equilibrium quantum many body physics in atomic, molecular and optical (AMO) systems:** Studying entanglement dynamics in ultracold atom-cavity coupling system, using out-of-time-order correlator (OTOC) to characterize how entanglement are distributed in a quantum system via many body interactions, also study the possibility to generate quantum chaos.

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- **Rydberg physics:** i) Super-resolution atomic imaging by machine learning. This direction aims at developing technologies about super-resolution atomic microscopy that can break the optical diffraction limit by the way of machine learning. ii) Quantum information with Rydberg atoms. This direction aims to reveal some appealing features of highly-excited Rydberg states that can be used for quantum information processing. iii) Many-body physics based on strong Rydberg-Rydberg interactions. We focus on the collective properties of strongly-interacting Rydberg atoms, showing novel many-body behavior induced by the atom-light coupling as well as the interatomic long-range interactions.

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