PHOTONICS Research

Quantum photonics: feature introduction

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Photons, the individual quanta of the light field, are what the science of quantum photonics is dedicatedly investigating. The manipulation and coherent control of photons in quantum photonics enables the exploration of various quantum phenomena of high fundamental interest. In the meantime, due to the fast speed and a lack of the interaction with the environment, photons are now regarded as a promising platform for the emerging quantum information processing (QIP) studies. Therefore, there is a growing number of works on quantum computing, quantum communication, and quantum metrology that are solidly based on the techniques of quantum photonics.

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In this feature issue, we have selected the research works with a wide coverage on such fields as quantum computing, quantum communication, and quantum metrology. For quantum communication, Hu *et al.* [1] experimentally demonstrate the transmission of blue-green photonic polarization states through 55-m-long water. The air-to-sea quantum communication was firstly investigated in Ref. [2] with an elementary proof-of-principle study and this work further demonstrates an impressive distance that reaches a region allowing potential real applications. The air-to-sea quantum communication is an indispensable part of the complete quantum communication network along with the quantum communication in optical fibers and free-space air. Besides, in this issue, Liang *et al.* [3] contributes to quantum communication by demonstrating an InGaAs/InP single-photon detector (SPD) with widely tunable repetition rates and extremely low-noise characteristics. The SPD would become a suitable device for quantum key distribution, laser ranging, and optical time domain reflectometry.

For quantum computing, Lie and Jeong [4] present an interesting perspective that the previously proposed "hybrid" approach of using a two-mode squeezed state to teleport a photonic qubit faces an upper bound of fidelity under a lossy environment, and therefore they suggest that suppressing photon loss rate is vital for making this hybrid approach a valid fault-tolerant quantum computing scheme. For more general applications, Aqua *et al.* [5] introduce a multi-step protocol for optical quantum state engineering with single-atom-based bright quantum scissors, and show the approaches to generate Fock and W states. This protocol could serve as a useful and versatile building block for the generation of advanced optical quantum states that are vital for quantum communication, distributed quantum information processing, and all-optical quantum computing.

Apart from quantum communication and quantum computing, quantum metrology, another important field for quantum information processing using quantum photonics, has also been covered. Xu *et al.* [6] present a comprehensive review of the recent progresses of quantum squeezing and its applications in measurements of position, rotation, dynamic motion, magnetic fields, and gravitational waves. These squeezed light experiments are representative schemes that play an important role in pushing forward the research on quantum metrology.

Meanwhile, there are many fundamental issues to be addressed in quantum photonics. For instance, quantum tomography is a most widely used tool for various topics in quantum photonics and how to improve its efficiency is to be concerned. In this feature issue, Curic *et al.* [7] present a high-dimension experimental tomography of a path-encoded photon quantum state using a rotating one-dimensional optical Fourier transform with a good performance. Liu *et al.* [8] also experimentally test the error-disturbance uncertainty relation with continuous variables for Gaussian states, which confirm that Heisenberg's error-disturbance uncertainty relation with continuous variables is violated, while Ozawa's and Branciard's error-disturbance uncertainty relations with continuous variables are validated. In another work, Mondain *et al.* [9] cover continuous variable quantum optics, another important field for quantum photonics that cannot be neglected.

It is further worth mentioning that integrated photonics is playing an increasingly important role. We are delighted to see that Mondain *et al.* [9] demonstrate their squeezing experiment taking advantages of both integrated optics and telecom technology. The integrated photonics using either three-dimensional waveguide lattice [10] or programmable Mach-Zehnder interferometer arrays [11] can form a large Hilbert space and enjoy a much higher stability than bulk optics. The integrated quantum photonics is a promising approach worthy of further exploration. We hope that through the selection of works in this feature issue, the readers will have a comprehensive view of the various fields in quantum photonics, and the works may inspire brainstorming for more insightful ideas and works to boost this science.

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