frontiers | Frontiers in Physics

TYPE Editorial
PUBLISHED 20 September 2022
DOI 10.3389/fphy.2022.1029478

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Quantum Engineering and Technology, a section of the journal Frontiers in Physics

RECEIVED 27 August 2022
ACCEPTED 06 September 2022
PUBLISHED 20 September 2022

CITATION
León-Montiel RdJ, Quiroz-Juárez MA, Magaña-Loaiza OS and Torres JP (2022), Editorial: Quantum light for imaging, sensing and spectroscopy. *Front. Phys.* 10:1029478.
doi: 10.3389/fphy.2022.1029478

Editorial: Quantum light for imaging, sensing and spectroscopy

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KEYWORDS

non-classical light sources, quantum technologies, quantum imaging, quantum-enhanced spectroscopy, atomic quantum optics, quantum metrology, structured light, machine learning

Editorial on the Research Topic
Quantum light for imaging, sensing and spectroscopy

The last two decades have witnessed an enormous progress in the development of novel ideas and technologies for sensing and imaging based on the quantum properties of light. Our ability to generate, manipulate and detect non-classical states of light has opened new avenues in experimental imaging, sensing and spectroscopy, where unprecedented levels of sensitivity and resolution can be attained. In this Research Topic, we aim at highlighting state-of-the-art research, and their potential applications, in imaging, spectroscopy and metrology. This includes the generation and control of quantum optical states, such as single-photon sources, entangled photon pairs, and structured light beams.

This Research Topic, issued within the Quantum Engineering and Technology section of Frontiers in Physics, includes one brief research report, eight original research articles, and one review article. These contributions cover applications of entangled light in metrology and spectroscopy, the generation of spatially-structured non-classical states of light, as well as imaging applications using correlated thermal light and machine learning.

Chen et al. provide a review article on both theoretical and experimental entangled-photon-enabled quantum interferometric metrology. Topics covered by the review include Hong-Ou-Mandel interferometry with frequency and time resolution, entanglement-assisted single-photon absorption and two-photon absorption spectroscopy using energy-time correlated photon pairs. Scully et al. introduce a spectroscopy technique based on the monitoring of quantum beats in the cooperative light emission from an atomic (or molecular) sample. The use of entangled photon pairs in the context of spectroscopy is discussed by Schlawin, who explores the possible role of the sample's inhomogeneous broadening and photons' polarization degrees of freedom in the quantum enhancement that entangled two-photon absorption might offer to experimental nonlinear spectroscopy. Debnath and Rubio further show that entangled light can also be used as a probe for extracting information about dissipative cavity exciton-polariton dynamics in the ultrafast regime.

The generation and control of non-classical states of light are discussed in two contributions. Puentes discusses a method for the generation of entangled two-photon states in high-dimensional Hilbert spaces by placing multiple angular slits in the path of spontaneous parametric down-converted entangled photon pairs. This result can be relevant for quantum information protocols where high-dimensional encryption is required. Mendoza-López et al. demonstrate theoretically and experimentally the frequency conversion of multiple optical vortices by inducing a four-wave mixing process in a hot vapor of rubidium atoms. The authors' study adds to the available protocols for the generation and control of photonic orbital angular momentum in atomic ensembles.

The potential of structured light for quantum physics is discussed by Gutiérrez-Jáuregui and Jáuregui who show that nonlinear processes, at the single-photon level, might be produced in the light-matter interaction of tightly trapped atoms in the focus of vectorial waves. Furthermore, Lv et al. demonstrate that propagating spatially-structured modes of light can be identified (and reconstructed) using deep learning. This method is particularly relevant in quantum applications where structured light is susceptible to phase distortions due to propagation in noisy environments.

Wang et al. demonstrate a theoretical and experimental scheme for "fractional" ghost imaging. This is managed by symmetrically placing the object to be imaged and a fractional spiral phase filter in the test and reference pseudo-thermal beams of a lensless ghost imaging system. Finally, Fernandez-Guasti and Garcia-Guerrero demonstrate an interesting scheme that allows for two non-degenerate photon beams to exhibit first-order optical interference. These results call for a possible reformulation of the "which-way information" concept for non-degenerate photon interference.

To conclude, we would like to mention that the study of quantum light for imaging, sensing, and spectroscopy is a timely and exciting research field at the forefront of physics and technology. It has the potential to impact many areas of science and engineering, from material science to quantum communications and quantum computing. We expect this Research Topic to provide valuable information and guidance for future research along these lines.

Finally, we would like to thank all authors, reviewers and administrative staff at Frontiers, without whom this Research Topic could not have been possible.

Author contributions

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

Acknowledgments

RJLM thankfully acknowledges financial support by DGAPA-UNAM under the project UNAM-PAPIIT IN102920. OSML acknowledges support from the National Science Foundation through Grant No. OMA MPS—2231387.

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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