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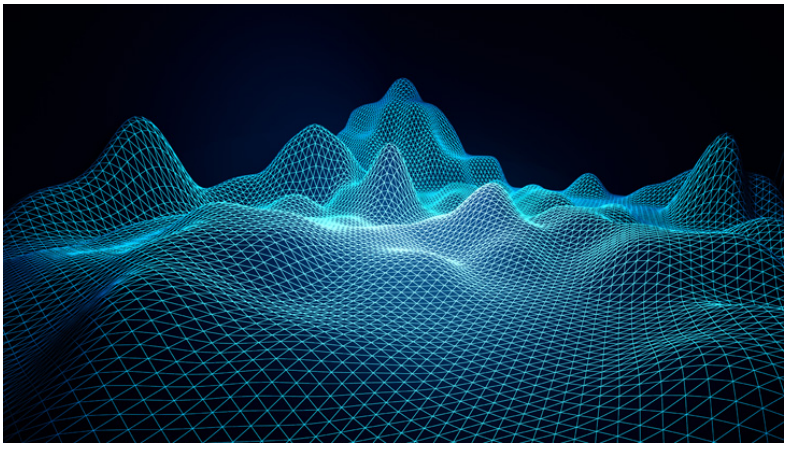
Towards non-linear dynamics for quantum information processing



Researchers from the Department of Physics explore a series of transformations in quantum states occurring outside the linear world which only need a source of non-Gaussian states and simple linear operations. This framework may have an effect on future optical technologies for quantum information processing.

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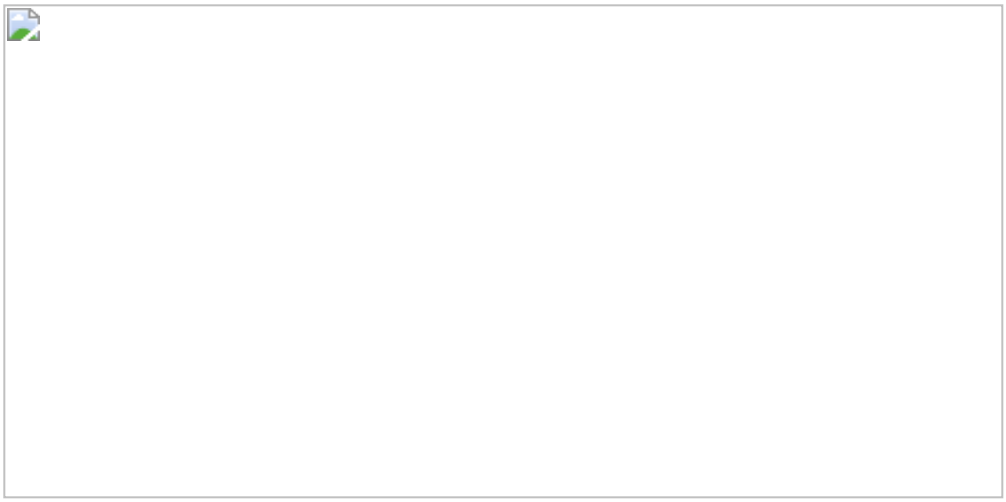
One of the most exciting, and experimentally viable, possible implementations of quantum information processing is by means of photons, or to be more precise, in the quantum degrees of freedom of light. The practical difficulties of achieving full-blown quantum computing are manifold, but among them is a limitation of fundamental character: we need to overcome the boundary between so-called linear and non-linear optics.

The former part we command reasonably well in the laboratory, and also its theory is sufficiently well-understood, but it is restricted to ground states and equilibrium states of the harmonic modes that make up the quantum electro-magnetic field, and so-called linear (or Gaussian) transformations, which always ever produce quantum states of the same kind. While undeniably having quantum characteristics (superposition, uncertainty relations, etc), these "Gaussian states" are in a certain sense the most classical ones among the possible states of light. It is well-known that to demonstrate nonlocality through the violation of Bell inequalities, to distill quantum entanglement, to build a universal quantum computer, or indeed any quantum

information processing device superior to classical computers, some degree of optical nonlinearity is necessary. In practice, however, non-linearities are few and not easy to harness, which is of course why they are of extreme interest, both experimentally and theoretically.



https://www.iqst.ca/quantech/wiggalery.php, and open source figures

In our recently published paper [Phys. Rev. A 95, 062309 (2017)], we explored an, admittedly simple, class of quantum state transformations that are outside the linear world. They only require a source of non-Gaussian states and otherwise the "easy" linear operations, and thus present a testing ground for non-linear effects in quantum optics. We demonstrated simple applications to optical communication and a quantum resource known as optical non-classicality. We showed that certain quantum features or resources are activated in the presence of certain non-Gaussian states. Additionally, we lay a framework for studying the general set of non-linear dynamics and make connections to the linear domain.

With our work, we are moving from the linear (Gaussian) to the non-linear (non-Gaussian) domain of quantum processes. We expect our foundational framework to inform and impact future optical technologies for quantum information processing.

Andreas Winter
Department of Physics
Universitat Autònoma de Barcelona

References

Krishna Kumar Sabapathy, Andreas Winter, **Non-Gaussian operations on bosonic modes of light: Photon-added Gaussian channels**, *PHYSICAL REVIEW A* 95, 062309 (2017). DOI: 10.1103/PhysRevA.95.062309

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