Ideas on Ultracold Coherent Systems and Communication

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Abstract

In this note, the authors discuss some intriguing investigations that can be carried out on BECs, and their applications.

One of the intriguing aspects of AMO physics is the detailed explanation of the lines seen in spectroscopy measurements, and how this knowledge increased over the course of the twentieth century. Atoms, especially simple ones like Hydrogen, can be studied in detail with respect to their quantum properties. Their spin, their angular momentum, can all be studied in detail, and detailed relations can be derived between these quantities and their various properties. This is very intriguing work.

The study of AMO via the model system of Bose Einstein Condensates in the laboratory setting is very exciting. It is built upon the theory mentioned above, but also involves a lot of patience and experimental skill. We wonder if spectroscopy can also be applied to the atoms within a BEC and would like to investigate this. The rewards would be worth the effort - to view two BECs interfering or to see an atom laser in action! Those must be stunning experiments.

Recently we read that cosmology is also being studied in table-top fashion by means of expanding BEC rings. These then model the expansion of the cosmos and many similar properties between the two systems are observable. If a BEC can be put in an expanding ring format, we wonder if it can be put in other formats as well.

Ultimately, the question we would want to address is if one can encode information in the BEC's format. Thereafter the BEC is treated as an atom laser and transferred from point A to point B, forming an atomic communication system. Networks of such BECs could be studied, and we could investigate fundamental limits such as capacity and reliability in this setting for the point-to-point case and throughput for the network case. The interplay between "falling" or gravity and BECs is another exciting area of investigation and can lead to novel insights into the nature of space and time at a fundamental level.

Our prior work taught us how simple PDEs can be coupled together leading to emergent phenomena such as phase synchronization. In the key paper from this work we studied these PDEs in a new three-dimensional geometric arrangement, and how that impacted the phase synchronization. We also learnt how such systems can be discretized and then simulated on a computer, knowledge that can help with computer simulation studies of BEC communication networks.

Currently we are studying security and privacy in data communication networks via theory and simulations. These issues are not specific to the 5G networks we have looked at but can be envisioned to be addressable in the future BEC network case as well. The fundamental motivation for studying BECs is that they represent a mass of atoms jointly in a coherent state. Coherence is something that is critical for preserving the quantum mechanical properties of a system. We are currently revising a paper that is in the submission pipeline with a leading physics journal. This paper looks at decoherence and its deleterious impact on the preservation of quantum effects in the nervous system.

AMO physics is a rich field, enriched even further by BEC studies. Novel formats of these condensates which can encode information would be useful for transmission of data, both classical and quantum. Studying security and privacy issues such as protection against physical layer attacks on BEC communication networks could possibly leverage the fact that the BEC is on the borderland between classical and quantum physics. This would provide a novel canvas on which to create new communication systems.