Abstract

Despite more than a hundred years since the inception of quantum mechanics, there is still much to be said about the exact nature of its transition to classical physics. The problem has perhaps never been as relevant as today, with more and more experimental setups comprised of few-to-many body systems, which lie precisely in the intersection between classical and quantum. Along with these practical developments came new theoretical tools for their description, most notably, *mesoscopic* frameworks – self-contained formalisms streamlining the full quantum description to be simple, yet useful in the relevant regime of particle numbers.

Recently, one such mesoscopic framework came in the form of the *reduced state of the field (RSF)*, originally devised by Robert Alicki as a way to describe quantum features of macroscopic bosonic fields, e.g. light waves. In this dissertation, we show that RSF also serves as a viable tool for probing classicality within quantum mechanics, and subsequently use it to investigate the classicality of *symplectic time evolution*, responsible for modeling the vast majority of dynamics in contemporary quantum-optical experiments. We fulfill our goals through a series of three papers.

First, we prepare symplectic evolution for its future study of classicality by addressing a conceptual gap within. As we observe based on RSF, viewed from the perspective of its usefulness in modern quantum optics, symplectic evolution is incomplete, failing to describe certain operations available in experiment. In our First Paper, we derive the missing component and provide its in-depth physical interpretation, most notably as a description of random scattering and a tool for entanglement creation in dissipative engineering.

We then advance on our main goal in our Second Paper. After analyzing various aspects of RSF to prove its semiclassicality, most significantly demonstrating its very limited use as a description of entanglement, we employ it to derive the exact conditions for classicality of symplectic evolution. As we find, such evolution is semiclassical only if it consists of passive transformations, like beam-splitters, which have a natural interpretation within classical physics.

Finally, in our Third Paper, we supply our previous results by revisiting the classicality of symplectic evolution from the point of view of Bogoliubov transformations: linear transformations of the field's creation and annihilation operators used in nearly all branches of many-body quantum physics. In particular, we study the dynamical Casimir effect, finding that from the perspective of an open quantum system, the effect reduces to semiclassical dissipation.