Quantum information

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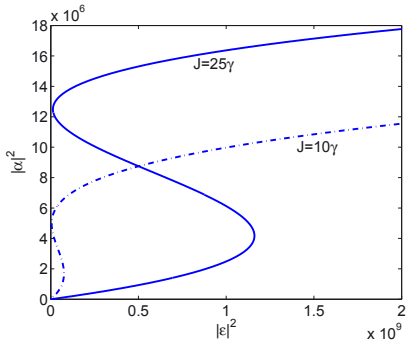
This research studies continuous variable entanglement and states which exhibit the Einstein-Podolsky-Rosen (EPR) paradox, both central to quantum mechanics [1]. This year we have placed special emphasis on investigating the utility of different entanglement criteria, in both the bipartite and tripartite situations, and have developed two three-mode versions of the Einstein-Podolsky-Rosen paradox. The first investigation analysed the degree of violation of certain inequalities in three mode systems using twinned nonlinearities, both concurrent and cascaded, in the cavity and travelling wave configurations [2]. The second investigation extended previous work on evanescently coupled optical parametric oscillators to consider the above threshhold regime, finding that a good degree of bipartite entanglement and violations of the EPR inequalities was available with bright optical outputs [3]. A further investigation analysed the entanglement properties of two evanescently coupled Kerr nonlinear materials inside a Fabry-Perot cavity [4]. This was also found to provide entangled outputs and may be experimentally simpler due to the absence of the phase-matching requirements of $\chi^{(2)}$ media, and could possibly be achieved with optical fibres and commercially available components. Both of these coupled systems provide spatially separated entangled modes, which means that they do not have to be separated by optical devices before measurements can be made, avoiding a possible source of loss.



The nonlinear coupler analysed in Ref. [4] also exhibits bistable behaviour. Here we show the output intensity as a function of pump intensity, for an interaction strength of $\chi = 10^{-6}$, cavity loss rates of $\gamma = 1$ and at resonance, with $\Delta = 0$, and two different values of the coupling, J, as a function of the cavity loss rate. In this symmetric configuration, both inputs and both outputs are equal. The ability to tune both halves of the device separately gives access to a large region of behaviour whose quantum properties await further investigation.

We also rigorously proved that three-mode generalisations of the EPR paradox provide inequalities whose violation is sufficient to demonstrate the presence of full tripartite entanglement, without any conditions as to whether the states involved have Gaussian statistics [5]. These inequalities were used to examine systems with triple $\chi^{(2)}$ nonlinearities, in an extension of previous work [6]. The final project was an intensive investigation of the applicability and utility of several different tripartite entanglement criteria to an experimental scheme which is under investigation in Italy [7]. For this asymmetric scheme, which is a combination of down conversion and sum-frequency generation, we found that it was crucial to choose the appropriate quantum correlations to be measured, with some of the standard inequalities not being violated even though quantum entanglement was demonstrably present.

References

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