The Einstein-Podolsky-Rosen Paradox

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This report covers a Colloquium review[1] commissioned by the most prestigious review journal in Physics - Reviews of Modern Physics. The Colloquium covers the field of the EPR paradox from the original paper of Einstein Podolsky and Rosen, together with the responses of Schroedinger and Bohr, through to modern proposals of how to demonstrate and utilise the paradox as an inequality in an optical or ultra-cold atom experiment.

Einstein, Podolsky and Rosen[2] originated the famous EPR paradox. Their argument concerned two spatially separated particles with perfectly correlated positions and momenta, as predicted by quantum mechanics, and showed an inconsistency between the premise of local realism and the completeness of quantum mechanics. Thus, the insightful analysis of EPR played a key development role in showing how quantum reality differs from classical reality. The purpose of the Colloquium review is to analyze the theoretical and experimental status of the EPR paradox at the start of the twenty-first century.

The Einstein-Podolsky-Rosen gedanken-experiment was realized through a series of important developments. The first was theoretical: a practical inequality that could be experimentally violated, rather than an unattainable state with perfect correlations[3]. The second was the transformation of the EPR concept to a second-quantization environment, in which field quadratures that are measurable at the quantum limit replaced the original momentum and position variables[4]. The third was an actual experimental measurement violating the inferred Heisenberg uncertainty principle, which was therefore the first demonstration of continuous-variable entanglement.

This recent theoretical work as well as the best quality current experiments[5, 6, 7] were carried out by researchers within the ACQAO Center and its partner Centers. Accordingly, the review has been a great opportunity to bring together theoretical and experimental researchers throughout ACQAO, and to describe both theoretical and practical experimental work in a unified way.

In the review, we analyse the experimental confirmation of the EPR paradox in laser-based experiments. As well as the EPR paradox itself, we treat the links and relationships with entanglement criteria[8], and Bell's inequalities. Recent experiments covered include the continuous-wave parametric amplifier experiments and the fibre soliton technique, which gives a pulsed signature of the paradox. In addition, we discuss the current proposals for extending these types of experiment to massive-particle systems, including spin-squeezing, atomic position entanglement, and quadrature entanglement in ultra-cold atoms[9].

References