Quantum squeezing with optical fibres: simulations and experiment

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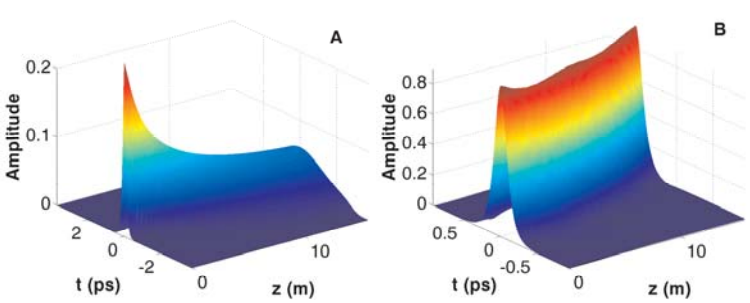
The search for efficient means of quantum squeezing, in which quantum fluctuations in one observable are reduced below the standard quantum limit at the expense of increased fluctuations in the conjugate, has been at the heart of modern developments in quantum optics. The use of optical fibre for quantum squeezing has considerable technological advantages, such as generating squeezing directly at the communications wavelength and use of existing transmission technology. There is, however, a significant disadvantage in the excess phase noise that arises from acoustic waves, molecular vibrations, and defects in the amorphous silica.

We have undertaken an in-depth numerical and experimental study of polarisation squeezing in a single-pass scheme that successfully reduces the impact of this excess phase noise [1]. The numerical simulations represent a quantitative, experimentally testable solution of quantum many-body dynamics. The single-pass setup achieved -6.8 ± 0.3 dB of polarization squeezing, the greatest measured in fibres to date [2]. From known losses, we infer that -10.4 ± 0.8 dB of squeezing was generated in the fibre. Possible improvements in the losses after the fibre, through for example employing more-efficient photodiodes in a minimal detection setup using highest quality optics, may allow measured squeezing in excess of -8 dB.

By analysing the Raman and guided acoustic wave Brillouin scattering (GAWBS) effects in the simulations, we find that the former is a limiting factor for high pulse energies, whereas the latter is detrimental at low energies. Investigation of a range of fibre lengths revealed that greater squeezing is not achieved going beyond 13.2 m. Indeed, simulations indicate that slightly greater squeezing may be achievable at a lower fibre length of around 7 m for the pulse width used (130 fs, FWHM).



Dynamics of optical pulses. (A) A weak pulse disperses before significant squeezing can be acheived and is also affected by GAWBS. (B) Soliton pulses produce the greatest amount of squeezing for a given pulse width. However, at long fibre lengths Raman effects reduce the amount of squeezing achieved.

Further improvement may be possible through the use of photonic crystal fibres (PCF), which have been used in several squeezing experiments. PCFs offer the advantage of higher effective nonlinearities, due to the smaller mode areas that can be achieved, and less GAWBS noise, since there are fewer low-frequency acoustic vibrations. Such an advance would bring fibre-produced squeezed states closer to minimum-uncertainty states

References

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