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Deterministic phase measurements exhibiting super-sensitivity and super-resolution

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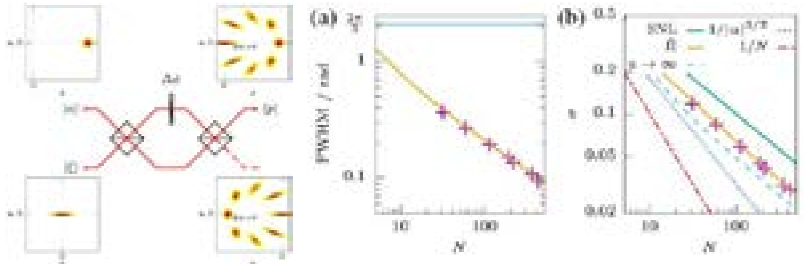
Phase measurements by optical interferometry is a ubiquitous tool, with applications ranging from biological studies, over profiling surfaces, to sensing gravitational waves for fundamental research. A cornerstone in the achievable accuracy of interferometry, and metrology, in general, was then set by quantum mechanics: due to Heisenberg's uncertainty relation, a definite limit of the measurement's accuracy was found. In retrospective, Heisenberg's finding was challenged in various ways ever since, either by preparing the input in ways only accessible by quantum mechanics or by measuring the output with "non-classical" techniques. Achievements of these attempts are techniques which enhance the measurement of phase changes, referred to as supersensitivity and super-resolution. More precisely, phase super-sensitivity is obtained when the sensitivity in a phase measurement goes beyond the quantum shot noise limit, whereas super-resolution is obtained when the interference fringes in an interferometer are narrower than half the input wavelength. Here we verify experimentally that these two features can be simultaneously achieved using a relatively simple setup (sketched in figure 1) based on Gaussian states and homodyne measurement. Using 430 photons shared between a coherent and a squeezed vacuum state, we demonstrate a 22-fold improvement in the phase resolution, while we observe a 1.7-fold improvement in the sensitivity (refer to figure 2). In contrast to previous demonstrations of super-resolution and super-sensitivity, this approach is fully deterministic. Finally, we attempt to resolve a long-standing debate about the actual usefulness of super-resolution by simulations. Here we find that super-resolution in settings where Gaussian noise dominates, super-resolution offers no benefits over other techniques.



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