PhD Thesis Defense YANNICK ALAN DE ICAZA ASTIZ 'Optimal Signal Recovery for Pulsed Balanced Detection'

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Tuesday January 27, 11.00. ICFO Auditorium

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'Quantum Information with cold atoms and non-classical light'

ICFO-The Institute of Photonic Sciences

Measuring quantum features in a classical world constrains us to extending the classical technology to the limit, inventing and discovering new schemes to use the classical devices, while reducing and filtering the sources of noise. Balanced detectors, e.g. when measuring a low- noise laser, have become an exceptional tool to attain the shot-noise level, i.e., the standard quantum limit for measuring light. Detecting light pulses at this level requires decreasing and also filtering all other sources of noise, namely electronic and technical noise.

The aim of this work is to provide a new tool for filtering technical and electronic noises present in the pulses of light. It is especially relevant for signal processing methods in quantum optics experiments, as a means to achieve shot-noise level and reduce strong technical noise by means of a pattern function. We thus present the theoretical model for the pattern-function filtering, starting with a theoretical model of a balanced detector. Next, we indicate how to recover the signal from the output of the balanced detector, and a noise model is proposed for the sources of noise and the conditions that should satisfy the filtering algorithm. Finally, the problem is solved and the pattern function is obtained, the one which solves the problem of filtering technical and electronic noises.

Once the pattern function is obtained, we design an experimental setup to test and demonstrate this model-based technique. To accomplish this, we produce pulses of light using acousto-optics modulators. Such light pulses are precisely characterized together with the detection system. The data are then analyzed using an oscilloscope which gathers all data in the time domain. The frequency-domain representation is calculated using mathematical functions. In this way, it is proved that our detector is shot-noise limited for continuous-wave light. Next, it is shown how the technical noise is produced in a controlled manner, and how to gather the necessary information for calculating the pattern function. Finally, the shot-noise-limited detection with pulses without technical noise introduced is shown first, and next, an experimental demonstration where 10 dB of technical noise is then filtered using the pattern function.

The final part of this research is focused on the optimal signal recovery for pulsed polarimetry. We recall the Stokes parameters and how to estimate the polarization state from a signal. Next, we introduce a widely used signal processing technique, the Wiener filter. For the final step, we show how to retrieve, under the best conditions, the polarization-rotation angle with a signal that has 10 dB of technical noise. We achieve that our technique outperforms the Wiener estimator and at the same time obtains the standard quantum limit for phase/angle estimation. Because of the correlation between pulsed polarimetry and magnetic estimation using magnetic-atomic ensembles via Faraday effect, this pattern-function filtering technique can be readily used for probing magnetic-atomic ensembles in environments with strong technical noise.

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