



PhD Thesis Defense LUIS JOSE SALAZAR SERRANO 'Weak Value Amplification: New Insights and Applications'

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Thursday October 13 , 11:00. ICFO Auditorium

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Quantum Engineering of Light

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Weak Value Amplification (WVA) is a signal enhancement technique proposed in 1988 by Aharonov, Albert, and Vaidman that has been widely used to measure tiny changes that

otherwise cannot be determined because of technical limitations. It is based on: i) the existence of a weak interaction which couples a property of a system (the system) with a separate degree of freedom (the pointer), and ii) the measurement of an anomalously large mean value of the pointer state (weak mean value), after appropriate pre and post-selection of the state of the system.

The usefulness of weak value amplification for measuring extremely small quantities has been demonstrated under a great variety of experimental conditions to measure very small transverse displacements of optical beams, beam deflections, angular shifts, temporal shifts, phase shifts, frequency shifts, velocity measurements and temperature differences, among others.

In this thesis we make use of this concept to improve current technologies and analyse the true usefulness of this technique with respect to other experimental alternatives. In particular, we have applied the concept to measure femtosecond temporal delays between pulses much smaller than their pulse width. From the theoretical model we estimate that the ultimate sensitivity of this scheme will allow to measure delays of the order of attoseconds using femtosecond laser sources.

In addition, we have developed an innovative experimental scheme that makes use of the interference effect present in a WVA scheme to generate a highly-sensitive tunable beam displacer that can outperform the limitations imposed by the use of movable optical elements. From the experimental results, we were able to perform a scan of a Gaussian beam with waist

600 μm over an interval of 240 μm in steps of 1 μm .

Moreover, we have implemented a proof-of-concept experiment aimed at increasing the sensitivity of Fiber Bragg Grating (FBG) temperature sensors. The sensors behave as frequency filters whose center is determined by its surrounding temperature. By means of a WVA scheme we were able to measure a polarization dependent frequency shift that is small compared to the width of each FBG spectrum, and from that value we were able to obtain a four-fold enhancement of the sensitivity with respect to current schemes.

Finally, we address the question of what can offer the concept of WVA and what can not in terms of achieving high sensitivity measurements. By using a specific example and some basic concepts from quantum estimation theory, we have found that while WVA cannot be used to go beyond some fundamental sensitivity limits that arise from considering the full nature of the quantum states, WVA can notwithstanding enhance the sensitivity of real and specific detection schemes that are limited by many other things apart from the quantum nature of the states involved, i.e. technical noise.

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