Towards optical magnetometry beyond the shot noise limit

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MOTIVATION
Optical magnetometers are fundamentally limited by spin projection noise, optical shot noise, and measurement back action. To study ways to surpass the limits imposed by these noise sources we are developing Bayesian inference techniques for spin state estimation. Here we present our recent work involving Kalman filtering for the task of waveform estimation [1].

TRACKING SPINS WITH KALMAN FILTER

The Kalman filter (KF), pioneered by Rudolf E. Kalman [2], relies on an iterative Bayesian estimation approach involving all available information to the observer (including measurements, and statistical model for system dynamics and sensor outputs), to yield state estimates for the system of interest. For linear Gaussian systems KF estimates are guaranteed to be optimal.

ATOMIC SENSOR MODEL

A waveform, carried by an optical field, is mapped onto the collective spin orientation of an ensemble of N ground state alkali atoms:

The spins are read out via optical Faraday rotation (FR) of an off-resonance light beam, whose rotation angle is detected with a balanced polarimeter that is inherently noisy due to optical shot-noise:

Sensor calibration is performed via spin noise spectroscopy [3,4].

REFERENCES


ACKNOWLEDGEMENTS

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Work supported by the Spanish MINECO projects MAGO (RTI2018-101077-100001-C22) and EPEC (RTI2018-101078-100001-EXP), Catalan 2014-SGR-1295, by the European Research Council project AQUOMET, Horizon 2020 FET Proactive project QUIC, by Fundació Privada CELLEX and the Marie Sklodowska-Curie projects QUITRMAG No 654399 and C-METIAP No. 655161, and ICFO-NEST fellowship.