Practical Quantum Sensing at Ultra Trace Levels with Squeezed States of Light

Raphael Pooser and Benjamin Lawrie

Oak Ridge National Laboratory, Oak Ridge, TN, 37830-8050 USA
lawriebj@ornl.gov

Abstract: We experimentally demonstrate practical quantum enhancements to several ubiquitous sensors, including ultra-trace quantum plasmonic sensors with state of the art quantum noise levels well below the photon shot noise limit.

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Quantum sensors are devices that exploit quantum mechanical effects to obtain enhanced sensitivity over their classical counterparts. Sensors that exploit quantum noise reduction, or squeezed light, have seen renewed interest in recent years as a growing number of devices that utilize optical readout – from gravitational wave detection to ultra-trace plasmonic sensing at the nanoscale – have approached their absolute limits of detection as defined by the Heisenberg uncertainty principle. At this limit, the noise is dominated by the quantum statistics of light (the shot noise limit when coherent light is used). Simultaneously, many devices, including nanoscale sensors, have reached tolerance thresholds in which power in the readout field can no longer be increased. Beyond these limits, squeezed light is required to further improve sensitivity in these platforms. Here, we present our work geared towards producing practical, ubiquitous quantum sensors that break through the shot noise limit to achieve state of the art sensitivities beyond the capabilities of classical devices. We demonstrate atomic magnetometers [1], atomic force microscopes [2], compressive imaging [3], quantum plasmonic imaging [4], and ultra-trace quantum plasmonic sensors [5,6] with state of the art quantum noise levels well below the shot noise limit. In particular, we will describe a new plasmonic ultra trace sensor that utilizes a ubiquitous, off-the-shelf configuration enhanced with squeezed light in order to beat the state of the art achieved in the analogous classical sensor. Further, we will explore the potential of compressive plasmonic imaging for parallelized plasmonic sensing at the quantum noise limit. These

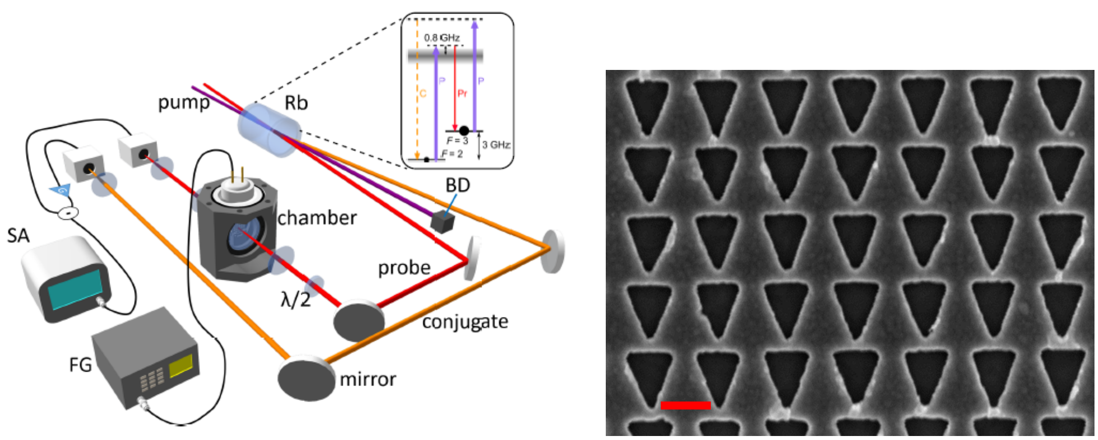

Fig. 1. Schematic of quantum plasmonic sensor and scanning electron microscope image of triangular nanohole array (Scale bar: 200 nm). Four wave mixing in a rubidium vapor generates entangled probe and conjugate fields. The probe is used to interrogate the local index around a Ag triangular nanohole array in a pressure chamber, and the power spectrum of the difference signal between the entangled channels is used to describe changes in pressure in the chamber. A half wave plate is used on the probe channel to optimize transmission through the nanohole array. BD: beam dump, SA: spectrum analyzer, FG: function generator.

devices represent our end goal of pushing quantum sensing far into the realm of practicality in a highly accessible format for the first time.

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