Microwave electric field sensing with Rydberg atoms

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We have shown that Rydberg atoms can be used for high-sensitivity, absolute sensing of radio frequency (RF) electric fields[1] including vector resolution[2] and sub-wavelength imaging[3]. We present and compare test results of this atom-based approach using different read-out methods. We achieve a sensitivity of $5\,\mu\mathrm{V cm^{-1} Hz^{-1/2}}$ for two read-out strategies. Results using a Mach-Zehnder interferometer [4] and frequency modulated (FM) spectroscopy [5] both achieve similar sensitivity and are compared. Fundamental limits to the sensitivity of the atom-based sensing are addressed [6]. In particular, we discuss power broadening, collisional broadening and transit time broadening and their relationship to the geometry of the sensor. These effects limit the coherence time and the number of atoms participating in a measurement. The fundamental limits of the atomic sensor are then compared to the sensitivity limits imposed by the optical readout. A theoretical analysis of a 3-photon readout approach suggests that it can aid in some aspects of the problem. Our analysis shows that photon shot noise in the signal readout is currently a limiting factor.

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