Sensitivity and Bandwidth in Rydberg Atom Systems

Christopher L. Holloway[1], Nikunjkumar Prajapati[1], Noah Schlossberger[1], Samuel Berweger[1], Alexandra B. Artusio-Glimpse[1], Dangka Shylla[2,3], William J. Watterson[2,3], Dixith Manchaiah[2,3], Charles Patrick[2,3], Adil Meraki[2,3], and Matthew T. Simons[1]

[1] National Institute of Standards and Technology, Boulder, Colorado 80305, USA
[2] Associate of the National Institute of Standards and Technology, Boulder, Colorado 80305, USA
[3] Department of Physics, University of Colorado, Boulder, Colorado 80309, USA

Sensors utilizing warm alkali vapor have become a staple in quantum communications, magnetic field sensing, and electric field sensing. The coherence established in the atomic ensemble allows for the measurement of uniform effects for atoms within the interaction region and can boast highly sensitive detection and interaction strengths. With the great progress in the development of Rydberg atom-based sensors in the past 14 years, interesting and unforeseen applications are emerging in the detection and receiving of time-varying fields and communication signals [1]. These applications include, (1) SI-traceable measurements for electric field and power, (2) amplitude and phase detection of time-varying signals, (3) angle-of-arrival, (4) waveforms and spectrum analyzers, (5) plasma sensors, (6) near-field and sub-wavelength imaging, (7) blackbody detection and thermometry, (8) DC/AC voltage measurements, and many others [1]. One of the more intriguing applications for Rydberg atom-based sensors is in the detection of time-varying signals. These atom-based receivers allow for the detection of amplitude-, frequency-, and phase-modulated signals. In fact, in receiver applications, these Rydberg-atom sensors act like an antenna (to detect the signal) and the atoms perform the demodulation and down conversion automatically. That is, these Rydberg receivers can eliminate the antenna and a lot of the front-end devices and electronics when compared to conventional receivers.

While these Rydberg atoms-based receivers have shown respectable field sensing capabilities and bandwidths, there are certain limits that groups across the world are struggling to overcome. In this presentation, we present the path towards achieving sensitivity and bandwidth currently established and the potential avenues for improvement we are pursuing. These include introducing decoherence mechanisms in the ensemble, multi-photon approaches, six-wave mixing, large Rabi oscillations, and broadband multiplexing utilizing frequency combs. With these improvements, we expect to surpass current best practices in the field.

[1] A. Artusio-Glimpse, M. T. Simons, N. Prajapati and C. L. Holloway, "Modern RF Measurements With Hot Atoms: A Technology Review of Rydberg Atom-Based Radio Frequency Field Sensors," in IEEE Microwave Magazine, vol. 23, no. 5, pp. 44-56, May 2022, doi: 10.1109/MMM.2022.3148705.