Rydberg Atoms and Metamaterials for Enhanced Evaluation of mmWave Radar Chips

Rydberg atoms, known for their exaggerated atomic properties and extreme responsiveness to external electric fields, offer a promising alternative to traditional techniques of measuring weak RF fields. The quantum nature of such atomic detectors, offers numerous advantages, such as direct electric field measurements, intrinsic calibration, tunability to various bands and more [1,2]. Recent developments that utilize hot Rydberg atomic vapors, demonstrate great sensitivity [3,4], as well as new techniques for imaging [5] and single photon counting [6].

In this context, mmWave technologies, particularly those operating in the EHF band (30 GHz to 300 GHz), are essential for applications such as high-resolution radar systems, which are increasingly prevalent in the automotive industry. However, these frequencies present challenges, mostly resulting in the lack of applicable off-the-shelf equipment, as they lie close to the notorious THz gap.

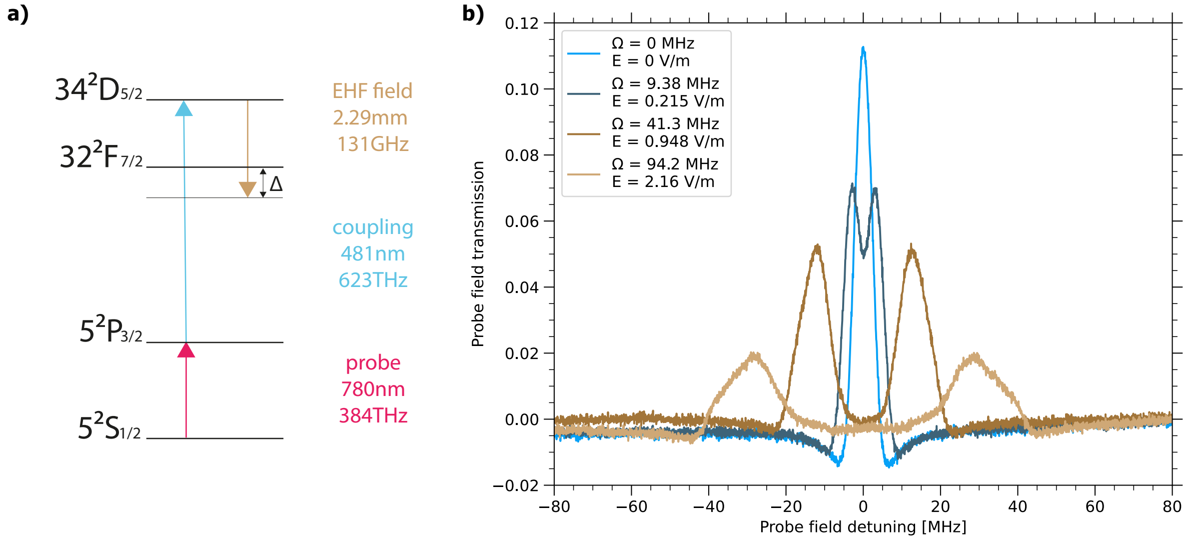

Fig. 1. Caption

We propose a scheme for calibration and testing of chip based sensors operating in the mmWave regime. Our approach centers on using room temperature Rydberg atoms as sensitive probes for the electric fields emitted by such devices. The setup relies on standard Autler-Townes splitting measurements, inside a Rubidium hot atomic vapor cell. The transition under evaluation is illustrated in Fig. 1a. In order to maximize the sensitivity, the EHF field must be circularly polarized and properly focused on to the cell. This is achieved using custom made metamaterial elements, such as diffractive lenses and waveplates allowing for control of the incident intensity, polarization and directional beam propagation. The metamaterials are 3D-printed high-impact polystyrene (HIPS) components, designed using finite difference time domain (FDTD) software.

The testing was performed on a Indie Semiconductor TRA_120_045 chip, tuned to emit frequencies around 131 GHz. Standard Autler-Townes splitting measurements, visible in Fig. 1b were performed to extract the electric field amplitude, offering around 20 dB of the absolute calibration range. Additionally, measurements for calibrating the frequency with respect to the atomic transition frequency were also observed, by detuning the TRA frequency by value Δ. The estimation results over the range of $\pm 100MHz$ give an average deviation of $1.1MHz$, giving a reasonable estimate.

References

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