Remote Sensing with Rydberg Atoms

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Rydberg atoms—atoms in highly excited quantum states—are uniquely sensitive to electric fields across a broad frequency spectrum, from kHz to THz. When excited using precisely tuned lasers, these atoms can serve as compact, low-power sensors capable of detecting and analyzing weak electromagnetic signals with high fidelity. Their exceptional sensitivity and spectral tunability arise from controllable interactions between atomic energy levels and the excitation laser fields. These attributes make Rydberg sensors a promising platform for reconfigurable, multi-band electromagnetic detection.

At NASA's Jet Propulsion Laboratory, Dr. Arumugam's team is advancing Rydberg-based remote sensing techniques for Earth science, including bistatic radar using existing satellite transmissions as illumination sources. Applications include soil moisture retrieval through passive reflectometry, using GNSS and communications signals of opportunity to probe land surface properties at high spatiotemporal resolution. In parallel, the team is developing a new class of low-frequency Rydberg sensors based on dissipative time crystal (DTC) dynamics, enabling ultra-sensitive field detection in the ELF, VLF, and SLF bands. These emerging techniques could open new pathways for subsurface sensing, earthquake precursor detection, and space-based monitoring of ultra-weak signals.
This talk will cover the enabling atomic physics, system-level architectures, and recent experimental progress toward deploying Rydberg-enabled remote sensing platforms for both airborne and future spaceborne missions.

References

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