GHz microwave field imaging with atomic vapor cells

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Microwave devices and circuits are the core parts of modern communication technology and precision instrumentation, with applications ranging from wireless networks, satellite communication, navigation systems to precision measurement. To perform the function and failure analysis of various microwave devices, a calibrated technique for high-resolution non-perturbative imaging of microwave fields is needed. Microwave detectors with high spatial resolution and low crosstalk are also essential for emerging applications of microwaves in medical imaging.

Our group developed a calibration-free technique for high-resolution imaging of microwave fields using atoms in miniaturized vapor cells as sensors [1]. In this technique, the microwave field to be measured drives Rabi oscillations on atomic hyperfine transitions. The oscillations are recorded in a spatially resolved way by absorption imaging with a laser and a camera. From the measured distribution of Rabi frequencies, we obtain an image of the microwave field distribution. All vector components of the microwave magnetic field can be imaged and the technique is intrinsically calibrated because the properties of the atomic transitions are precisely known. Using a custom vapor cell with thin walls and a proper amount of buffer gas our technique provides a spatial resolution of $<100\ \mu$m [2].

In order to make our GHz microwave imaging technique frequency-tunable, we applied a static magnetic field (up to Tesla level), where the Zeeman splittings are larger than the hyperfine splitting (hyperfine Paschen-Back regime), and microwave magnetic fields from a few GHz to a few tens of GHz can be detected [3]. For a more homogenous DC magnetic field, we use a pair of permanent magnets and elevate the cell temperature to get sufficient optical depth. To achieve high spatial resolution, we use microfabricated cells with thin walls. We will present our latest results on frequency-tunable microwave field imaging and sensing.

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