Microwave magnetic field imaging based on frequency-domain Rabi spectroscopy with an ultrathin atomic vapor cell

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Topic(s)

Quantum Sensing/Metrology

Background

Miniaturized atomic vapor cells enable high-resolution imaging of GHz frequency microwave fields [1-3], e.g., the near-fields close to a microwave circuit. The microwave magnetic field component is imaged by recording Rabi oscillations on hyperfine transitions [1,2], while the electric field component can be detected on transitions between Rydberg states [3]. In both cases, the field strength is connected to the detected signal through well-known atomic properties and fundamental constants. Compared with conventional antenna-based probing, atomic microwave imaging methods are intrinsically calibrated, non-invasive, offer high spatial resolution, and real-time imaging capability.

In previous work [2], we used a 140 µm thin Rb vapor cell attached to a filling station to record images of magnetic near fields at the Rb hyperfine transition frequency of 6.8 GHz close to coplanar waveguide structures with a spatial resolution of < 100µm. Motivated by the demand to image microwave fields in a large frequency range, we applied a strong static magnetic field (up to ~ 1 T) to tune the transition frequency to the desired value. In such a strong field the atoms enter the hyperfine Paschen-Back regime, and microwave magnetic fields from 3 GHz to 26.5 GHz can be detected [4]. A challenge in this approach is to obtain a sufficiently homogeneous static magnetic field, so that the microwave field to be imaged is resonant with the atomic transition in a sufficiently large spatial region.

Presentation

Here we present the first microwave imaging results with a new setup [5] that features a microfabricated 200 µm thin vapor cell filled with isotopically pure Rb-87 and a strong static magnetic field generated by a pair of SmCo permanent magnets. To relax the requirements on field homogeneity, we record frequency domain Rabi oscillations in a spatially-resolved way, which allows us to scan through the resonance and determine the local resonant Rabi frequency in an efficient way Fig. 1. We use this approach to image the circularly polarized component of a 15 GHz magnetic near field above a coplanar waveguide structure. Besides being the first microwave imaging results at variable frequency, not constrained by fixed atomic resonances, our method shows improved accuracy compared to former work [4].

Moreover, the same setup can be suitably adjusted to operate as an atomic vapor cell based microwave spectrum analyzer, exploiting an inhomogeneous static magnetic field to map microwave frequency to position on the image. We briefly discuss the dynamic range, sensitivity as well as the detection scheme of this method.

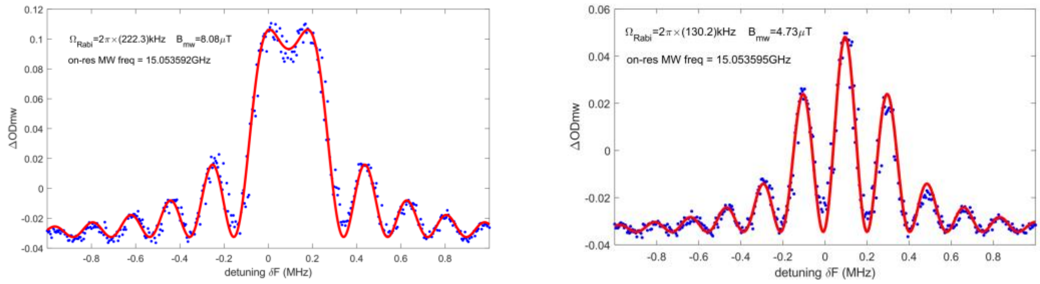

Figure 1: Frequency-domain Rabi spectroscopy signals on two pixels of our atomic vapor cell microwave imaging device, allowing us to measure the local microwave magnetic field strength.

References

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