Microwave field imaging at 15 GHz based on frequency-domain Rabi spectroscopy in an ultrathin atomic vapor cell

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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 can be imaged by recording Rabi oscillations on hyperfine transitions [1,2], while the electric field component is 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 $< 100\mu$m. Motivated by the demand to image microwave fields in a large frequency range, we apply 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.

Here we present first imaging results with a new setup [5] where we use a microfabricated 200 μm thin vapor cell filled with isotopically pure ^{87}Rb. The strong static field is 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. We use this approach to image the circularly polarized component of a 15 GHz magnetic near field above a coplanar waveguide structure with improved accuracy compared to former work [4].

[1] P. A. Böhi and P. Treutlein, Simple microwave field imaging technique using hot atomic vapor cells, Appl. Phys. Lett. **101**, 181107 (2012).
[2] A. Horsley, G.-X. Du and P. Treutlein, Widefield microwave imaging in alkali vapor cells with sub-100 μm resolution, New J. Phys. **17**, 112002 (2015).
[3] H. Q. Fan, S. Kumar, R. Daschner, H. Kübler, and J. P. Shaffer, Subwavelength microwave electric-field imaging using Rydberg atoms inside atomic vapor cells. Opt. Lett. **39**, 3030 (2014).
[4] A. Horsley and P. Treutlein, Frequency-tunable microwave field detection in an atomic vapor cell, Appl. Phys. Lett. **108**, 211102 (2016).
[5] This work is supported by the EU quantum technologies flagship project macQsimal.