Towards a frequency-tunable microwave magnetic field imager with ultrathin atomic vapor cells

Yongqi Shi[1], Roberto Mottola[1], Andrew Horsley[2], Philipp Treutlein[1]

[1] Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland
[2] Laser Physics Center, Research School of Physics and Engineering, Australian National University, 2601 Canberra, Australia

Using dielectric atomic vapor to image the GHz microwave magnetic field [1] [2], electric field [3] and THz band electric field [4] is an emerging field, in which the field strength measurement is enabled by detecting either the magnetic-field-driven Rabi frequency or electric-field-induced Rydberg EIT/Autler-Townes splitting via the well-known nature constants. Compared with conventional metal probe method, atomic methods are calibration-free, non invasive and highly spatial resolved. In our group, the near field magnetic strengths above a typical CPW structure working at 6.8GHz with spatially resolution of $<100\ \mu$m [2] has been achieved using an ultra-thin vapor cell. All vector components of the microwave magnetic field can be imaged.

Motivated by the demand for a frequency-tunable microwave magnetic field imager, 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 [5]. We use a pair of permanent magnets and elevate the cell temperature to get sufficient optical depth. We will present our latest results on frequency-tunable microwave field imaging and sensing.

[1] P. A. Boehi 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. (Fast Track Communication) **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**(10), 3030-3033 (2014).
[4] L. A. Downes, A. R. MacKellar, D. J. Whiting, C. Bourgenot, C. S. Adams and K. J. Weatherill, Full-Field Terahertz Imaging at Kilohertz Frame Rates Using Atomic Vapor, Phys. Rev. X, **10**(1), 011027(2020).
[5] A. Horsley and P. Treutlein, Frequency-tunable microwave field detection in an atomic vapor cell, Appl. Phys. Lett. **108**, 211102 (2016).