Fiber-coupled Probe for Atom-based RF Electric Field Metrology

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We demonstrate a fiber-coupled probe for atom-based RF electric (E) field metrology. This probe can be moved off of the optical table and into useful environments, such as TEM cells and anechoic chambers, and can be moved around for spatial imaging of RF fields. This is a step towards developing Rydberg atom-based metrology as a new practical standard for RF E-field strength measurements.

Rydberg atom-based metrology is a new measurement approach that uses electromagnetically-induced transparency to probe the response of highly excited alkali atoms (cesium (Cs), for example) to a RF E-field. Previous research has demonstrated that it can be used for measurements < 500 MHz up to > 200 GHz (and possibly to THz) using a single probe apparatus, can provide direct traceability to the SI, and perform sub-wavelength imaging of RF fields (for more info on the technique see Holloway et al., IEEE Trans. Antenna Propag., vol. 62, no. 12, 6169 - 6182, 2014, and Holloway, et al., IEEE Trans Electromagnetic Compat., vol. 59, no. 2, 2017). However, such measurements have thus far been confined to the optical bench.

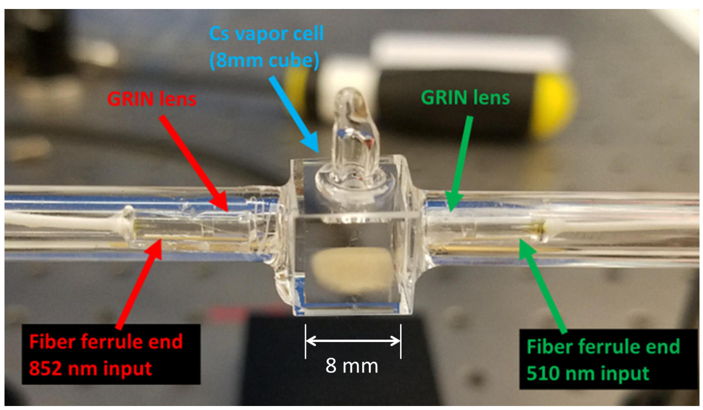

Figure 1: Photo of fiber-coupled probe showing the Cs-filled cubic vapor cell, the fibers, and GRIN lenses inside of retaining sleeves. Inside diameter of the vapor cell is 8 mm.

In this work we constructed and used a fiber-coupled probe for RF E-field measurements away from the optical table. The atom-based measurements require alkali atoms be exposed to both the probe and coupling lasers simultaneously to respond to the RF field, so the lasers (on the order of 50 μm in diameter) must be overlapped. The probe consists of a small cubic vapor cell containing Cs atoms, two optical fibers, and small gradient-index (GRIN) lenses. The fibers and GRIN lenses were aligned to overlap the counter-propagating lasers, and attached using a UV-curing epoxy (see Figure 1). We used the probe to measure RF fields across CPW line antennas, TEM cell apertures, and the spatial distribution of fields in other environments.