Radio Frequency Power Measurements Based on Rydberg Atom Spectroscopy

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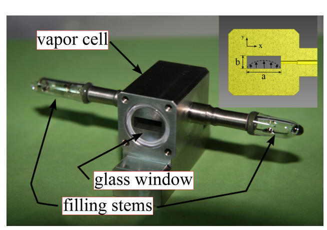
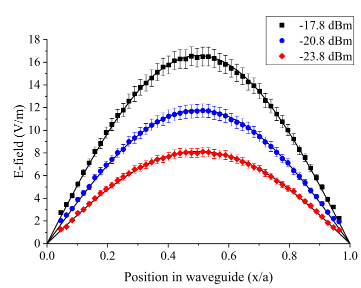
In this work we demonstrate a method for measuring the power carried by a radio-frequency (RF) field in a waveguide by use of Rydberg atom electric field (E-field) measurements. A section of WR42 waveguide was sealed off with glass windows, pumped down to vacuum, and filled with cesium atoms (waveguide vapor cell), shown in Fig 1a. An RF source was fed into the waveguide vapor cell using a directional coupler. The probe and coupling lasers were counter-propagated through the vapor cell, creating electromagnetically-induced transparency (EIT). The RF E-field inside the waveguide vapor cell is measured by monitoring the change in the EIT signal. The RF E-field distribution in the waveguide vapor cell was mapped by scanning the lasers across the long dimension, as shown in Fig. 1b. The distribution was mapped for three different RF input powers. The RF field was at 19.629 GHz, exciting the TE_{10} mode of the waveguide, which was verified by our direct measurements of the E-field distribution. The power can be determined from the peak E-field value of a TE_{10} mode by

$$P = E_0^2 \, \frac{ab}{4} \, \sqrt{\frac{\epsilon_0}{\mu_0}} \sqrt{1 - \left(\frac{c}{2af}\right)^2} \qquad ,$$

where E_0 is the field maximum (in V/m), a and b are the cross-sectional dimensions of the waveguide (in m), and f is the frequency of the field (in Hz). We measured the power at several different frequencies in the TE_{10} range, and compared these values with power measurements from a power meter made by coupling out a portion of the RF field through a second directional coupler. We also explore other aspects of this technique, including the effects of the glass windows on the RF field and high-power measurements.



(a)



(b)

Figure 1: (a) Photo of the waveguide vapor cell section, and (b) the measured E-field distribution in the waveguide vapor cell at three different RF input power values.