Rydberg Atom Based Self-Calibrating RF E-Field Probe

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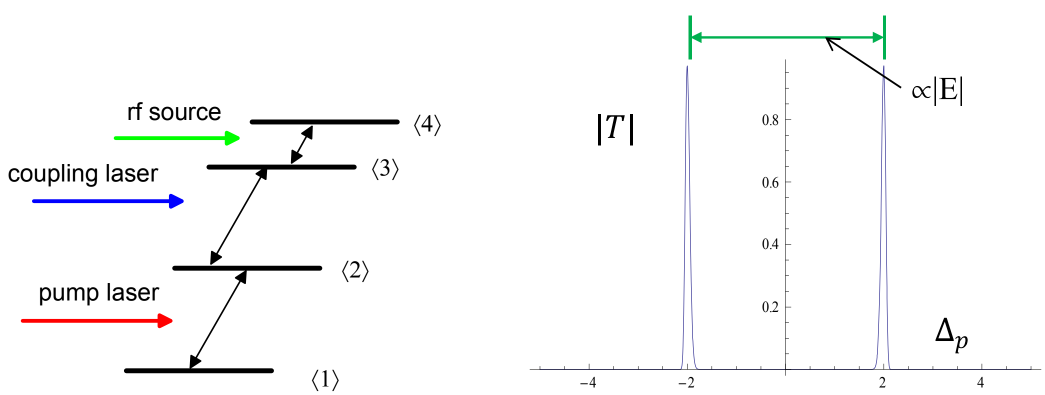
We present a significantly new approach for an electric (E) field probe. The probe is based on the interaction of RF-fields with Rydberg atoms, where alkali atoms are excited optically to Rydberg states and the applied RF-field alters the resonant state of the atoms. For this probe, the Rydberg atoms are placed in a glass vapor cell. This vapor cell acts like an RF-to-optical transducer, converting an RF E-field to an optical frequency response. The probe utilizes the concept of Electromagnetic Induced Transition (EIT), where the RF transition in the four-level atomic system causes a split of the transition spectrum for the pump laser, as seen in Figure 1. This splitting is easily measured and is directly proportional to the applied RF field amplitude. Therefore, by measuring this splitting we get a direct measurement of the RF E-field strength. The significant dipole response of Rydberg atoms over the GHz regime suggests this technique could allow traceable measurements over a large frequency band including 1-500 GHz.

This new approach for E-field measurements has the following benefits: 1) it will allow direct SI units linked RF *E*-field measurements, 2) it is self-calibrating due to atomic resonances, 3) it will provide RF field measurements independent of current techniques, 4) the probe will not perturb the field during the measurement, since no metal is present in the probe, 5) it will have vastly improved sensitivity and dynamic range over current E-field probes (<0.01 mV/m, *two orders of magnitude improvement over current approaches)*, and 6) it will be a very small and compact probe: optical fiber and chip-scale. Possible applications for this probe are numerous, ranging from spectrum measurement to biomedical. In this paper, we will report on our results in the development of this probe.



(a) (b)

Figure 1. E-field Probe concept: (a) four-level atomic system and (b) EIT signal in the pump laser for an applied RF E-field.