V-band Faraday Rotation Measurement Apparatus

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Introduction

In terms of engineering practical components, Faraday rotation is perhaps the most important manifestation of magnetically-broken time-reversal symmetry. It has been used to enable the most common types of non-reciprocal components (e.g. gyrators, isolators, and circulators), which can manipulate the propagation direction of electromagnetic (EM) waves. An anisotropic material (such as a ferrite immersed in an external magnetic field B applied in the direction of EM propagation) produces a value of Faraday rotation θ that is directly proportional to the path length L of the EM wave through the material such that $\theta = VBL$ where V is a material-dependent constant. Fig.1 depicts how the phenomenon of Faraday rotation is used to create a waveguide-based isolator, which allows an EM wave to pass in one direction but not the other direction.

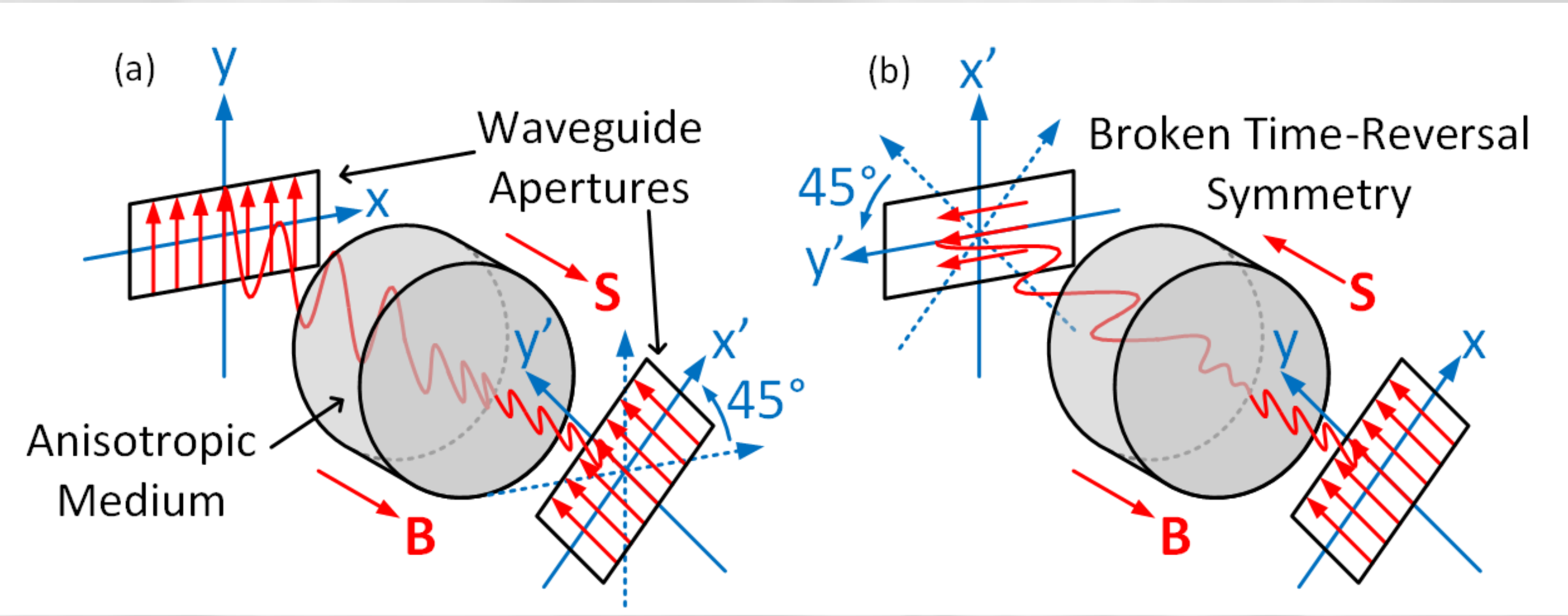

Fig. 1. Depiction of non-reciprocal behavior from a wave-guide based isolator

Apparatus Design

The apparatus consists of a customized signal generator, an ellipsoidal reflector antenna, a grid polarizer, a customized sample holder with static magnetic field biasing, a receiving antenna with power detection system and a lock-in amplifier. The signal generator is built from the commercially off the shelf components (Fig.2). The signal generator can produce signals that can be tuned within the frequency range of 57 GHz - 67 GHz by up-converting the output of a 10 MHz to 20 GHz local oscillator (LO) with a 4x active multiplier, removing unwanted distortion products with a filter and preventing reflections from a Faraday rotation isolator. A level set attenuator controls the output power that is fed in to the ellipsoidal dish antenna.

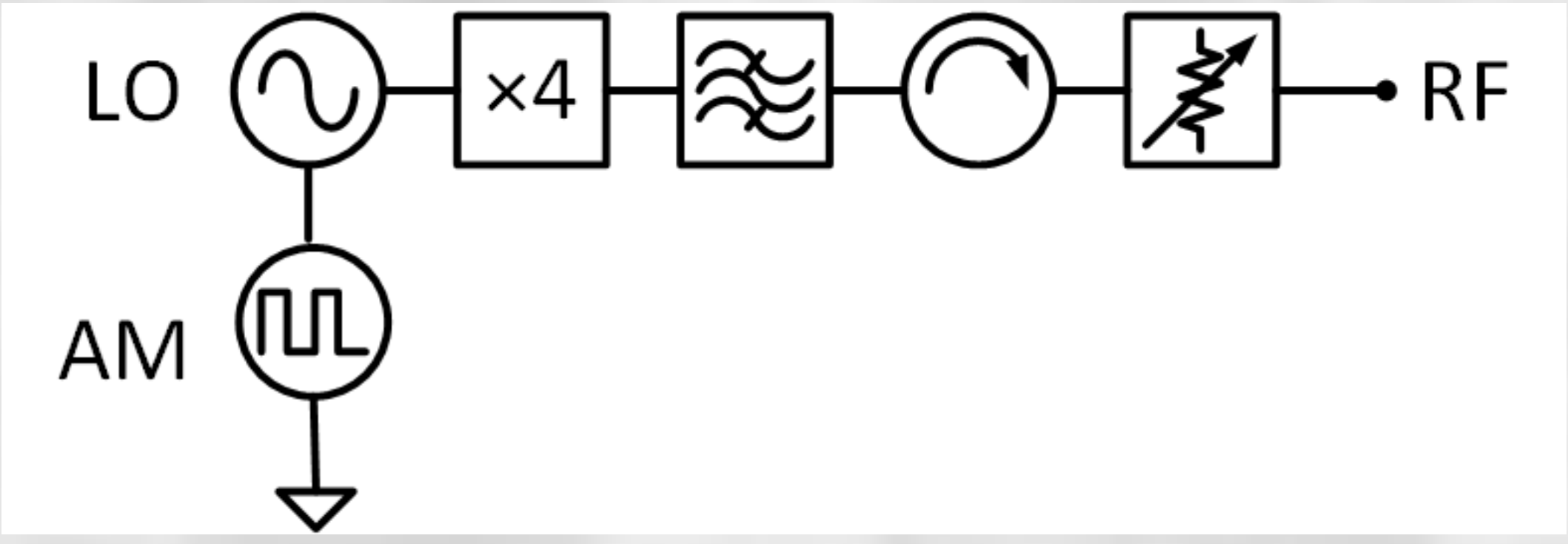

Fig. 2. Schematic of customized signal generator

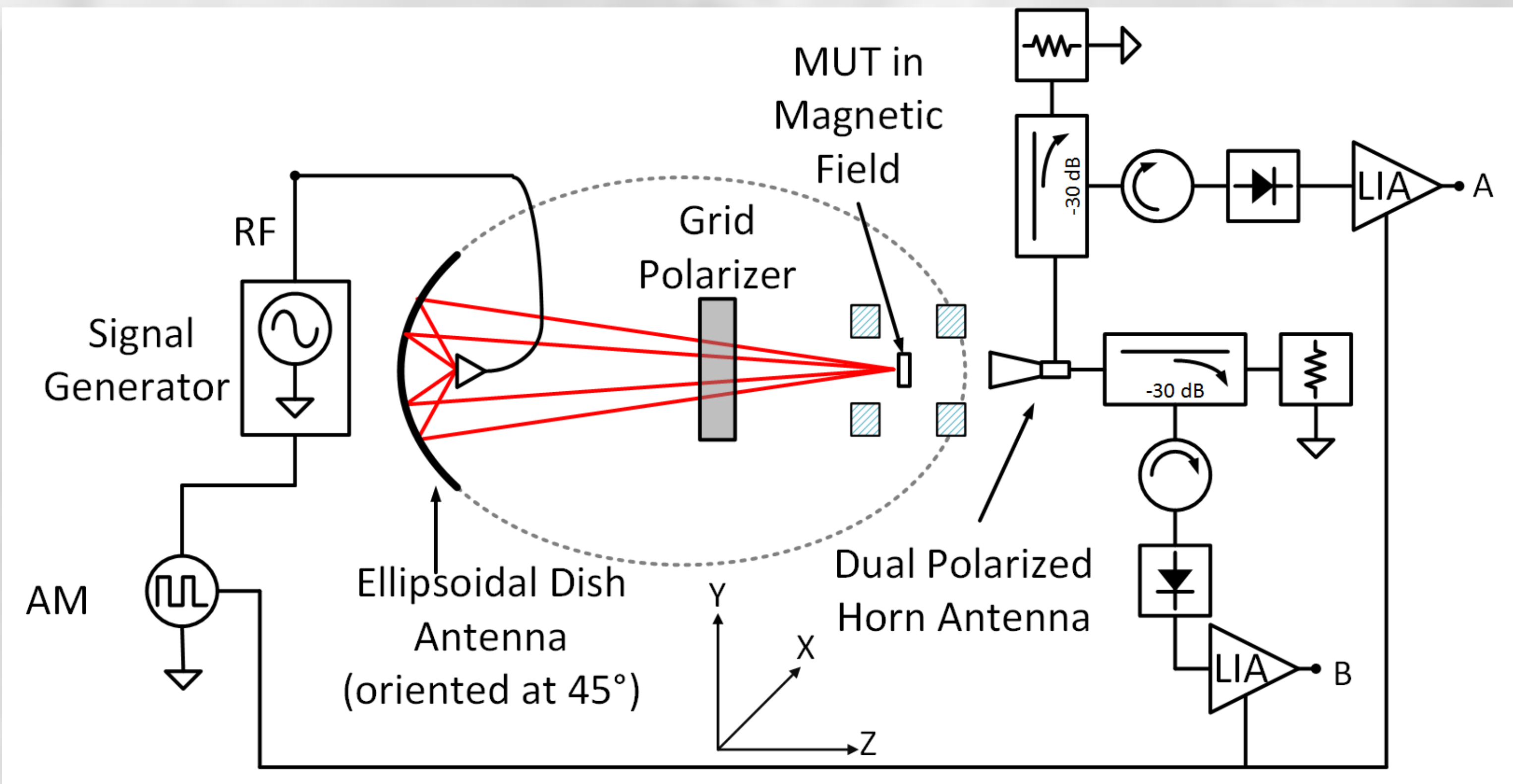

Fig. 3. Schematic of the experimental set-up

Experiments and Results

Two sets of experiments were performed at 61.25 GHz with similar set-up as shown in the Fig. 3. The input power in both the experiments was maintained at 5 dBm and the receiver antenna was swept along the X-axis. In the first set of experiments a standard gain pyramidal horn antenna was used as a receiving antenna as shown in Fig. 4 , and the material under test (MUT) is a nanoporous polycarbonate template filled with nickel nanowires (Fig. 5). The input RF signal in the first set of experiments was amplitude modulated with a frequency of 13.7 kHz and the lock-in amplifier was phase locked at this frequency.

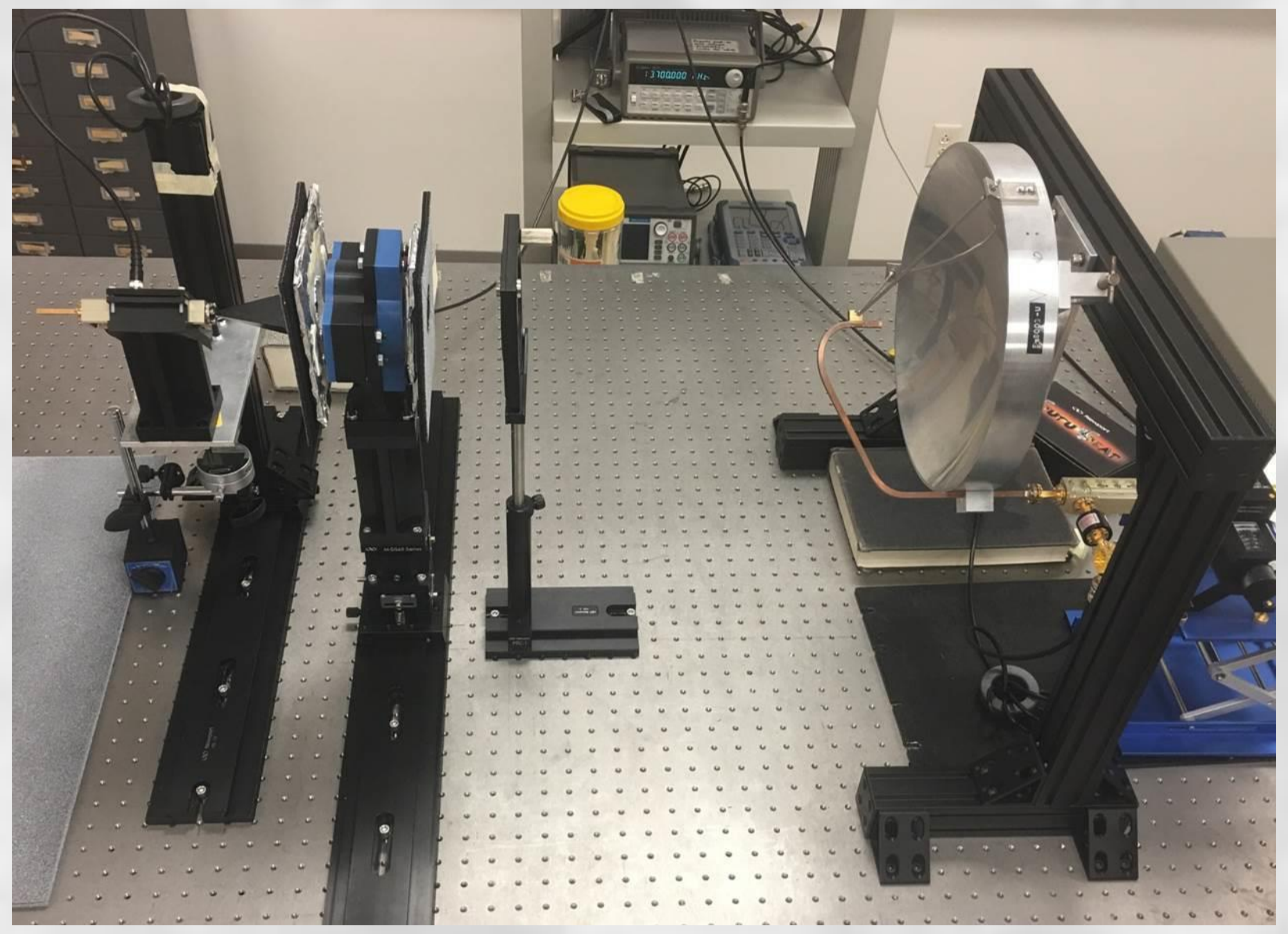

Fig. 4. Experimental set-up

In the second set of experiments a dual polarized horn antenna was used as a receiving antenna. The lock-in amplifier was synchronized to the radial resonant frequency of the piezo ring (106 kHz) and a continuous RF signal was fed in to the ellipsoidal dish antenna. The MUT is silicone with nickel microparticles attached to a piezo ring.

Fig. 5.MUT for first set of experiments

The peak value corresponding to filled template in Fig. 6 indicates the presence of Faraday rotation. To confirm the presence of Faraday rotation, the dc bias magnetic field is varied and the change in peak value is observed.

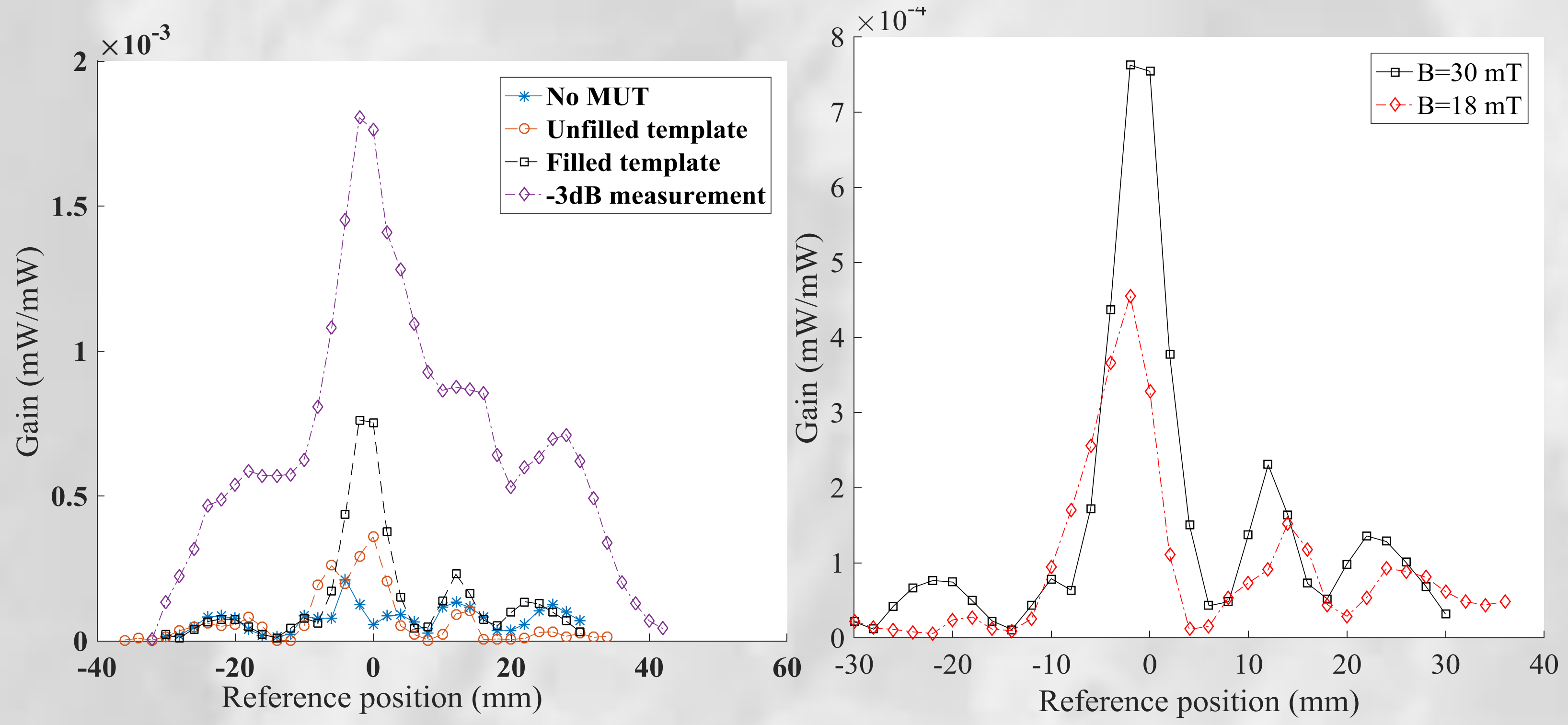

Fig. 6. Experimental results

The horizontally polarized signal is detected in channel A on the lock-in amplifier and the vertically polarized signal is detected in channel B on the lock-in amplifier. |A-B| gives information about Faraday rotation imparted on mm-waves.

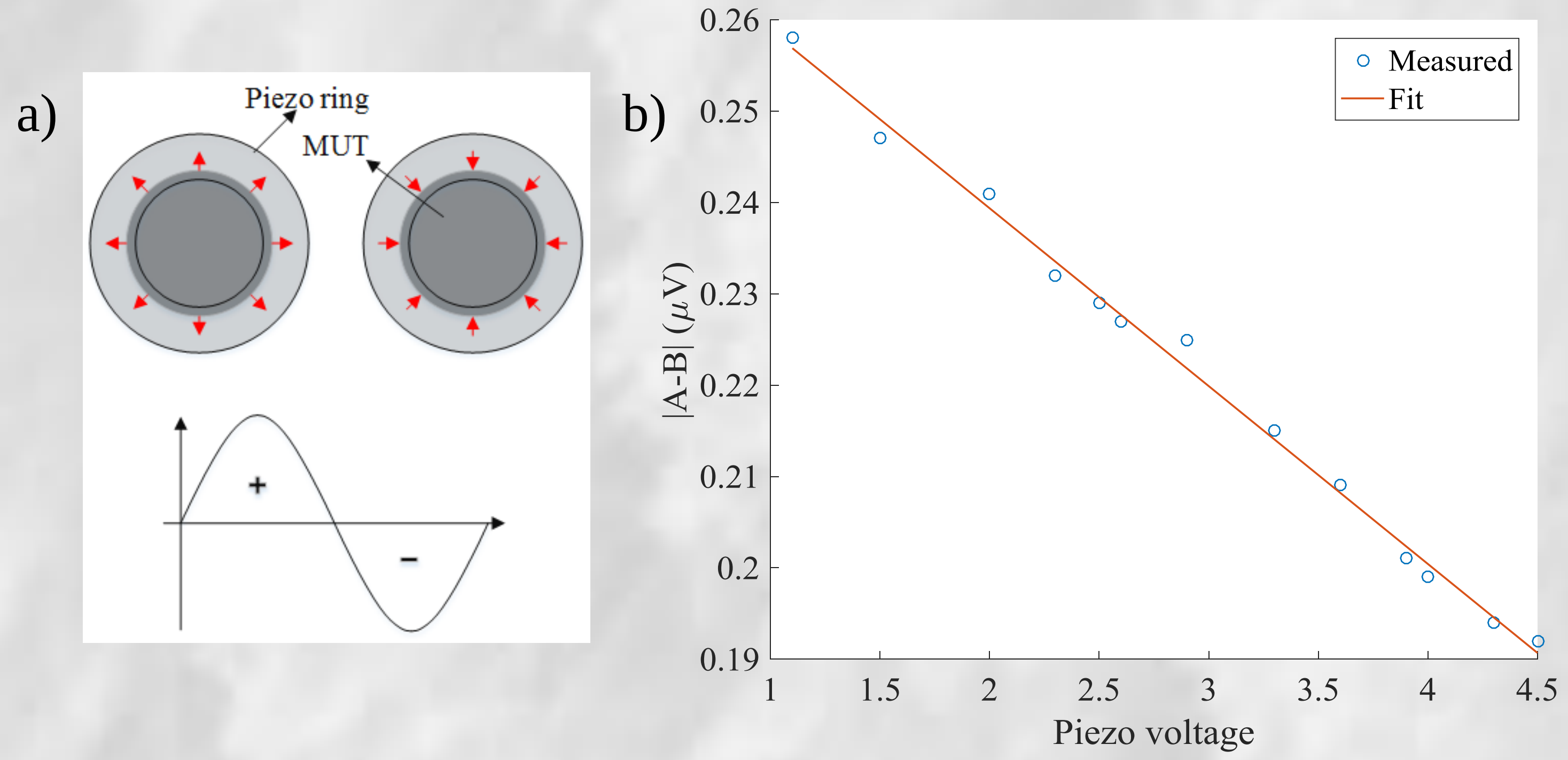

Fig. 7. a) Schematic explaining piezo ring actuation with MUT b) change in detected output voltage with the applied actuation voltage

Efforts are currently underway to accurately determine the Faraday rotation angle imparted on mm-waves, due to the presence of these materials.

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