High Speed THz Spectroscopy Using Fast Scanning Fabry-Perot

John R. Middendorf and Elliott R. Brown
Wright State University, Dayton, OH, 45435, USA

Abstract— **A fast-scanning tunable Fabry-Perot filter has been developed for signature identification in reflective THz sensor systems. The reflectors are metal mesh filters having reflectivity between 0.90 and 0.95, depending on the specific frequency. A demonstration of the filter has been carried out at 530 GHz with a resolution of ~10 GHz (Q ~ 50), a scan range of ~50 GHz, and a scan time of 0.5 seconds. The higher-order harmonic longitudinal modes are blocked by a lower-Q metamaterial bandpass filter located outside the Fabry Perot and having no harmonic passbands. This will enable high-rate THz spectroscopy without frequency ambiguity.**

I. INTRODUCTION And BACKGROUND

Fabry Perot tunable filters are one of the oldest "quasi-optical" components in the mm/submillimeter-wave field but ae surprisingly absent in THz laboratories around the world today. Part of the reason is technological: practical Fabry Perot filters have resolution too low to do frequency metrology, and too ambiguous to do wideband spectroscopy. The ambiguity stems from the higher-order longitudinal modes which are always harmonically related. A third issue is speed. The distance that a Fabry Perot cavity must scan to cover one free-spectral range at, say 600 GHz, is too great for piezoelectric stacks, but too short to warrant the expense of air-bearing or similar high-speed translation approaches.

II. NEW DESIGN

Our filter design and system implementation is shown schematically in Fig. 1. The fundamenetal mode of the Fabry Perot cavity defines the resolution bandlimit and center frequency through the plate separation [2]. The metamaterial bandpass filter makes this passband unique. A good example of such a metamaterial filter is described in Ref. [1]. A qualitative view of the two filter components is shown in Fig. 2. This combination can be applied in identifying THz signatures of illicit drugs, explosives, and other materials of interest to security and medicine.. Most of these signatures are tens of GHz broad or more, so that a modest Fabry-Perot Q of 50 can provide enough resolution elements for positive identification. However, the Fabry-Perot cavity length must be scanned quickly to acquire signatures before targets (often on human bodies) move significantly.

Our Fabry Perot reflectors are composed of two metallic meshes, each stretched flat over a circular ring and secured in a square plate. To scan the cavity length, one of the mesh reflector plates was attached to a precision linear actuator, with a minimum linear step of 0.381 microns. With the maximum speed of this linear actuator being more than 4 inches per second, the Fabry-Perot can be moved quickly, and accurately [3]. To control the mesh separation, software was written to operate the linear actuator, using the MATLAB programming environment. This unique-passband, tunable THz-Fabry-Perot filter, to the best of our knowledge, is the first of its kind.

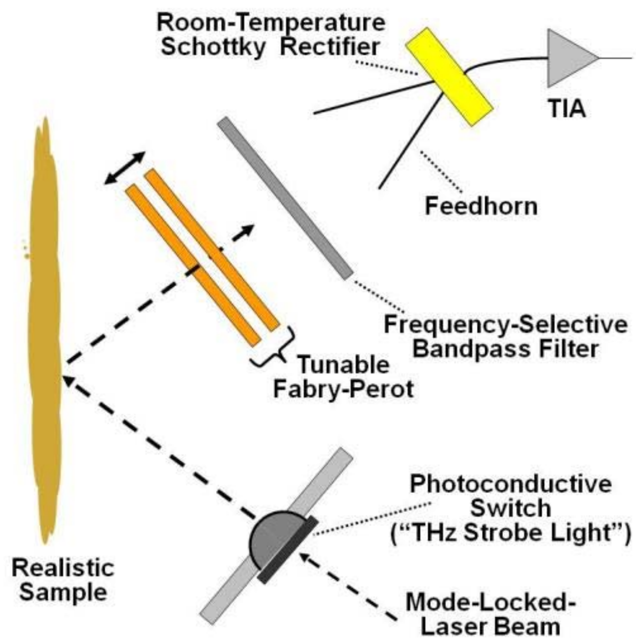

Fig. 1

The experimental layout of the tunable Fabry-Perot is shown in Fig. 3. Each wire mesh has a 1in. diameter, while the total travel of the linear actuator is 30mm [4]. A Teflon lens, with a THz transparency of approximately 90%, was used to collimate the THz radiation before it entered the interferometer; to maximize signal. The pictured source was used, and is a 530 GHz FEM source made by Virginia Diodes Inc. The peak Voltage of this source, with no interference, was measured at 2.5V. The detector used was a Schottky rectifier, and is just above the linear actuator in Fig. 1.

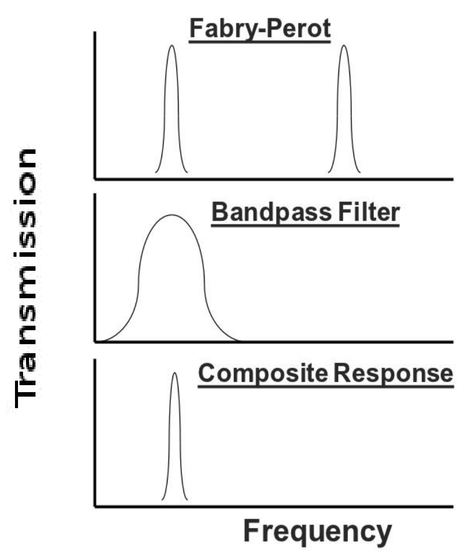

Fig. 2

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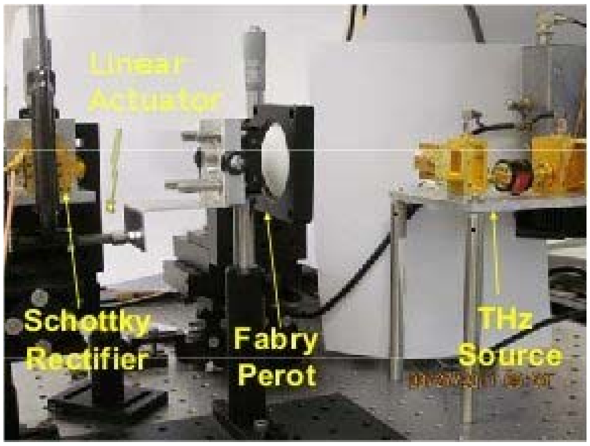

Fig. 3

III. Results

The output of the Schottky rectifier was boosted with a voltage pre-amplifier having a gain of 1000. The signal was then sent to a lock-in amplifier and recorded using a LabJack U3 DAQ. Several spatial resolutions were tested, shown in Fig. 3 is a measured voltage versus position plot with the spatial resolution being 0.167 microns. The total distance covered in Fig 4. is 0.41mm. With data collection occurring at 6000Hz, the total time needed to collect this information was 0.5 seconds. However, other tests show that acceptable results can be obtained with significantly decreased spatial resolution, and thus in significantly less time. It is our belief that the same spatial range can be accurately covered in 0.2 seconds.

The source was a known 530 GHz, and the covered spatial distance was enough to detect two harmonic pass bands. Analyzing the center-to-center distance L of the peaks in Fig. 3 shows that the measured experimental frequency, according to $\Delta f = c/2L$, is almost exactly 530 GHz. With the result, 530.04 GHz, within a fraction of a percent of the known value, this is an excellent result. The measured line width, or Q, of the peaks, $f_o/\Delta f$ is less than what was expected, however it is within a factor of two. This may be attributed to non-optimal alignment of the Fabry-Perot in the beam path. This could also explain excess ripple that can be seen in the stop band.

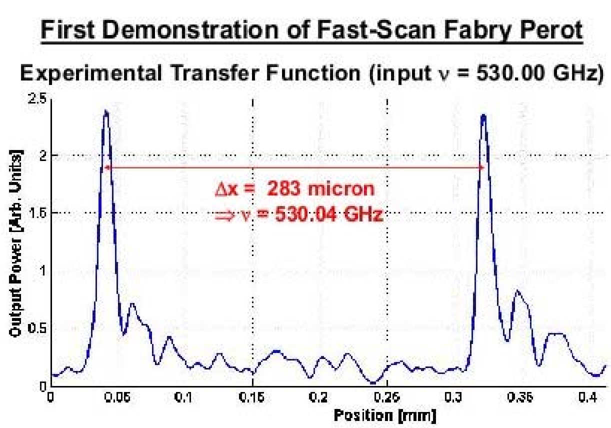

Fig 4. Results from Fabry-Perot scan. The experimental results are visible

Figure 5 shows results from three separate scan speeds. System alignment is still less than optimal in this test, causing some stop band ripple. All experimental conditions, other than speed, are the same between the tests. In these tests, the integration rate of the lock-in amplifier is 100 micro-seconds. As the scan time decreases, The low-Q band-pass harmonics remain visible. Eventually the scan speed becomes so fast that the hardware in use has difficulty moving accurately. The 0.05 second scan of the 0.5 mm range in figure 5 is where this begins to happen. The best case scenario is shown here; often times the first peak is completely lost at this scan rate. However, simply moving to a 0.075 second scan rate yields good results consistently. This means that our system is indeed a very fast scan.

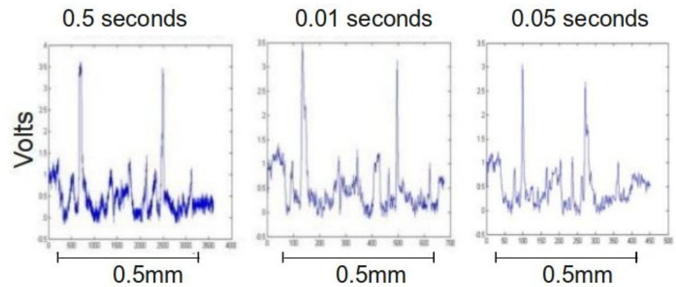

Fig. 5

Acknowledgements

This work was supported by the NSF I/UCRC program through the Center for Surveillance Research at Ohio State University.

References

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