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TITLE High Speed Single Transient Microwave Spectrum Analyzer

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High Speed Single Transient Microwave Spectrum Analyzer

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ABSTRACT

Recent experiments have required the measurement of short pulse high bandwidth microwave spectra. To meet this need we built a GHz-bandwidth acousto-optic spectum analyzer. The hardware includes a HeNe laser, collimating optics, Bragg cell, streak camera, microchannel plate intensifier and film cassette. The frequency range measured was 350-2000 MHz with a dynamic range greater than 20 dB. Pulse widths from 10 ns were measured with this system.

INTRODUCTION

We had a need for a wide bandwidth time resolved microwave spectrometer for diagnosing single shot experiments. The needed requirements included large frequency range, moderate frequency resolution, time resolution capable of measuring a short pulse of microwaves. An acousto-optic spectrum analyzer appeared appropriate. We built a spectrum analyzer that recorded the output of a high bandwidth Bragg cell on a streak camera, microchannel plate intensifier, film system.

In this paper we will describe the hardware, report the preliminary characterizations, and indicate future improvements to the system.

DESCRIPTION OF HARDWARE

Figure 1 is a schematic representation of the acousto-optic spectrum analyzer. Light from the HeNe laser was focused into a 0.4 mm spot on the Bragg cell. A microwave signal is input into the Bragg cell and a transducer changes it into an acoustical wave in the acousto-optic crystal. This acoustal wave diffracts some of the laser light at an angle that depends on the frequency of the microwave signal. The diffracted light was incident on the streak camera. The output of the streak camera was amplified using a microchannel plate intensifier and was recorded on film. A simple mask was put on the streak camera to lower the background on the streak camera.

The high bandwidth Bragg cell had a center frequency of 1.3 GHz and a FWHM of 1 GHz with a diffraction efficiency of 10% / watt. The streak camera was built by EG&G using a 40 mm RCA streak tube Model 7135 and was used with a sweep length of 2.5 μs. This sweep speed is variable. The microchannel plate intensifier was a HP model.

Two fibers carried pulses of light from a 10 MHz comb generator to the streak camera. One fiber was above the diffracted signal and one fiber was below the diffracted signal. These light pulses form a known time base both above and below the data area on the film. They also serve as baselines from which to measure the position on the film for a given frequency. A third fiber put a single pulse on the film. This single pulse represented a fiducial to time the experiment to the film.

This first system could be improved and our first attempt to improve the system was to improve the collimating lens system focusing the laser light onto the Bragg cell. We also put a lens system after the Bragg cell to focus the diffracted light onto the streak camera. The optimization and characterization of this system is presently in progress.

SYSTEM CHARACTERIZATION

To determine what frequencies could be measured by this system, a CW source from a sweep generator was input into the Bragg cell. Figure 2 is a sample of the reduced data taken at 700 MHz and 17.4 mwatt power into the Bragg cell. The FWHM in Fig. 2 represented 60 MHz. Thus, the resolution frequency of two neighboring frequencies were probably about 60 MHz for the first system. This system had to be dismantled before a more nearly complete characterization could be completed. Figure 3 shows the data taken on the new system when a frequency of 1 GHz was chosen and then a frequency of 1.020 GHz was recorded on the same film. This resolution will degrade when measuring a pulse shorter than the optical window of our Bragg cell, which is 1 0 μs.

Data similar to that shown in Fig. 2 was taken from 350-2000 MHz. Frequencies down to 350 MHz could be detected if enough power was input. The upper frequency limit of 2000 MHz also needed more power.

We did not determine the minimum detectable power due to lack of time. However, the Bragg cell should operate from 0.8 mW to 1 watt for a CW signal. The Bragg cell should accept more power than one watt in the pulsed mode.

The temporal response was investigated by adding the CW output of a sweep generator to a square pulse from a pulse generator through a microwave mixer. The result was a square pulse of microwaves, but outside the pulse the CW background power was 1/4 of the power in the pulse. This added to the background. Figure 4 shows the analysis of a 23 ns wide pulse at 10 mW input power to the Bragg cell. The FWHM, in Fig. 4, is 40 ns. The time spread was due to the time it took the acoustical pulse to traverse the laser beam on the Bragg cell. For our system, the expected time was 63 ns because the beam size was 0.4 mm diameter and the acoustical velocity was 6.3 km/s. Thus, for the 23 ns pulse, one expected some signal for about 86 ns which is in good agreement with the data in

Fig. 4. We could certainly see pulses 10 ns wide, but their amplitude was lower and a similar time spread existed.

FUTURE PLANS

Much more work can be done on this spectrometer. We have started a new lens system to get a better laser spot on the Bragg cell, as well as a lens system to focus the diffracted light onto the streak camera. Much more characterization should also be done on the system to determine the limits in frequency resolution for pulses and minimum and maximum detectable powers at various frequencies.

The diffracted light from the Bragg cell is proportional to the microwave power delivered to the Bragg cell. Hence, power versus time should be measurable simultaneously with frequency. We would like to attenuate the undiffracted light and put it into the streak camera. This would give one the initial light intensity needed to determine the fraction of diffracted light from which power into the Bragg cell might be inferred.

We want to replace the film with a CCD camera to facilitate data recording. This will make data entry into the computer much easier and speed up the analysis of the data.

CONCLUSIONS

We have built a high bandwidth acousto-optic spectrum analyzer using a streak camera to record the output of a Bragg cell. Early characterization suggests that we can record the full range of the output of the Bragg cell as a function of time. We measured frequencies from 350-2000 MHz with our Bragg cell. We measured 10 ns pulses at 10 mW. While we did not perform detailed measurements, we expect a dynamic range much greater than 20 dB.

Figure Captions

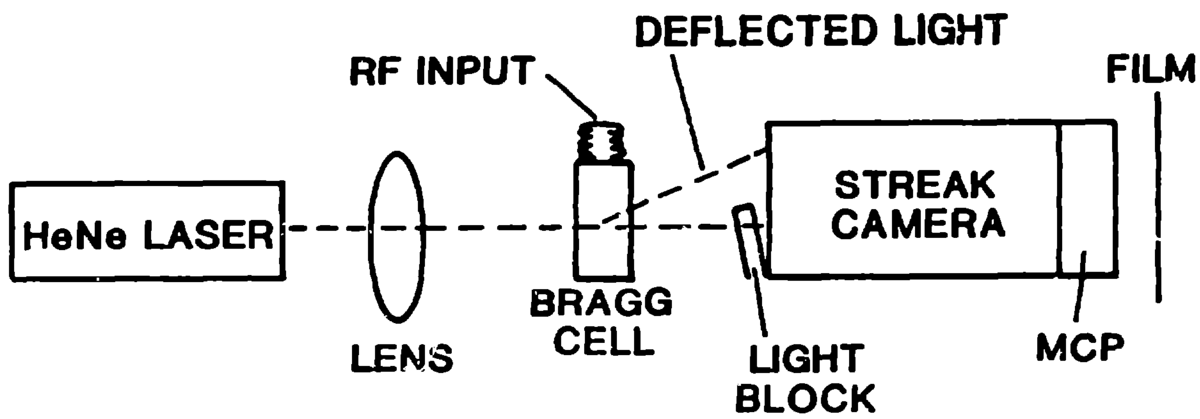
Fig. 1. Schematic of microwave spectrometer. Microwave energy input into a Bragg cell diffracts some of the laser light onto the face of a streak camera.

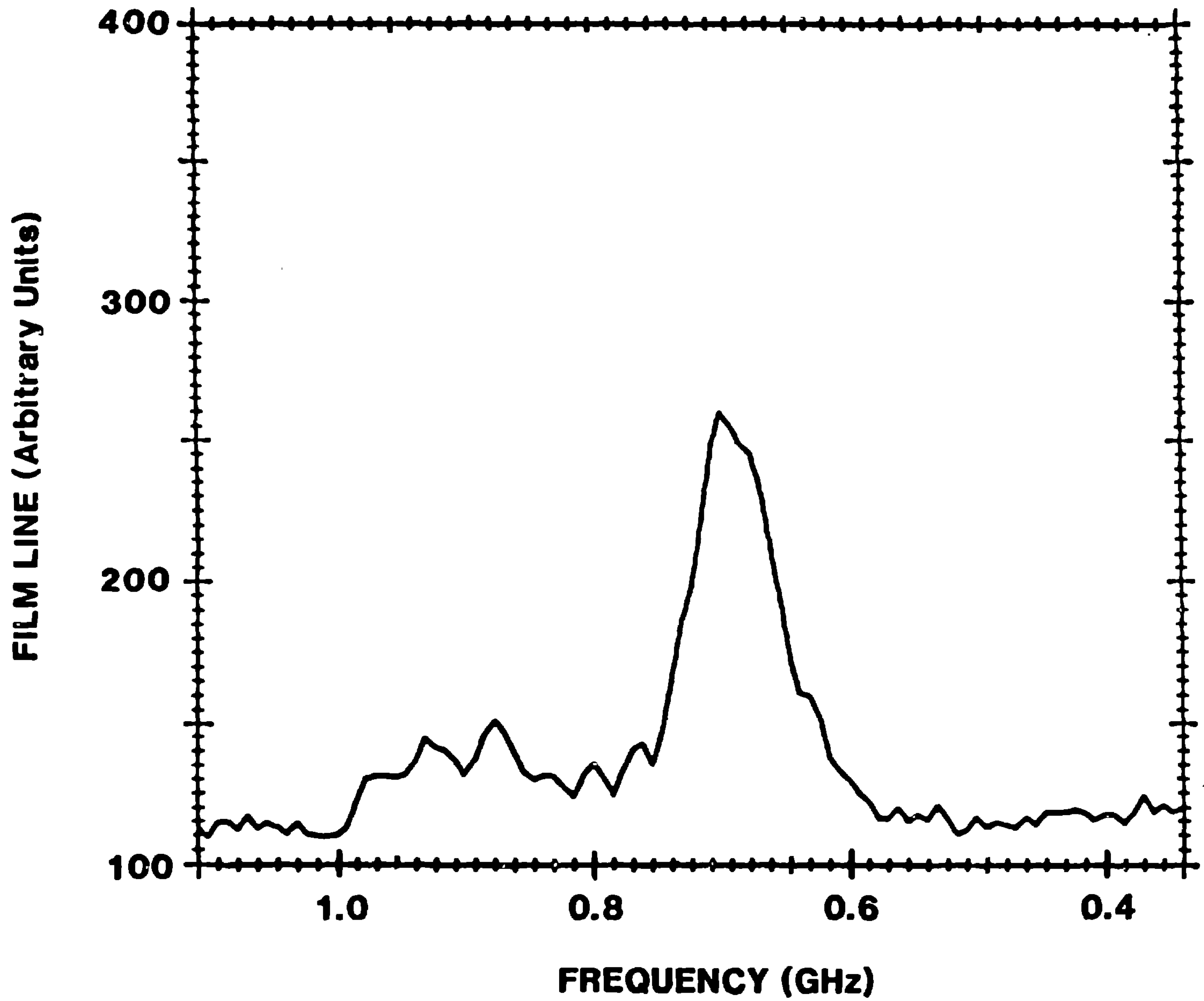
Fig. 2 Characterization data from an input signal of 700 MHz frequency and 17.4 mW power. The FWHM was 60 MHz.

Fig. 3. Characterization data showing frequency resolution data taken at 1.00 and 1.02 GHz.

Fig. 4. Characterization data showing results of a 23 ns wide square input pulse at 700 MHz and 10 mW. This pulse is time smeared to 40 ns FWHM due to the acoustical wave in the Bragg cell traveling across the width of the laser beam.

BRAGG CELL EXPERIMENT SCHEMATIC





400
300
200
100
FILM LINE (Arbitrary Units)
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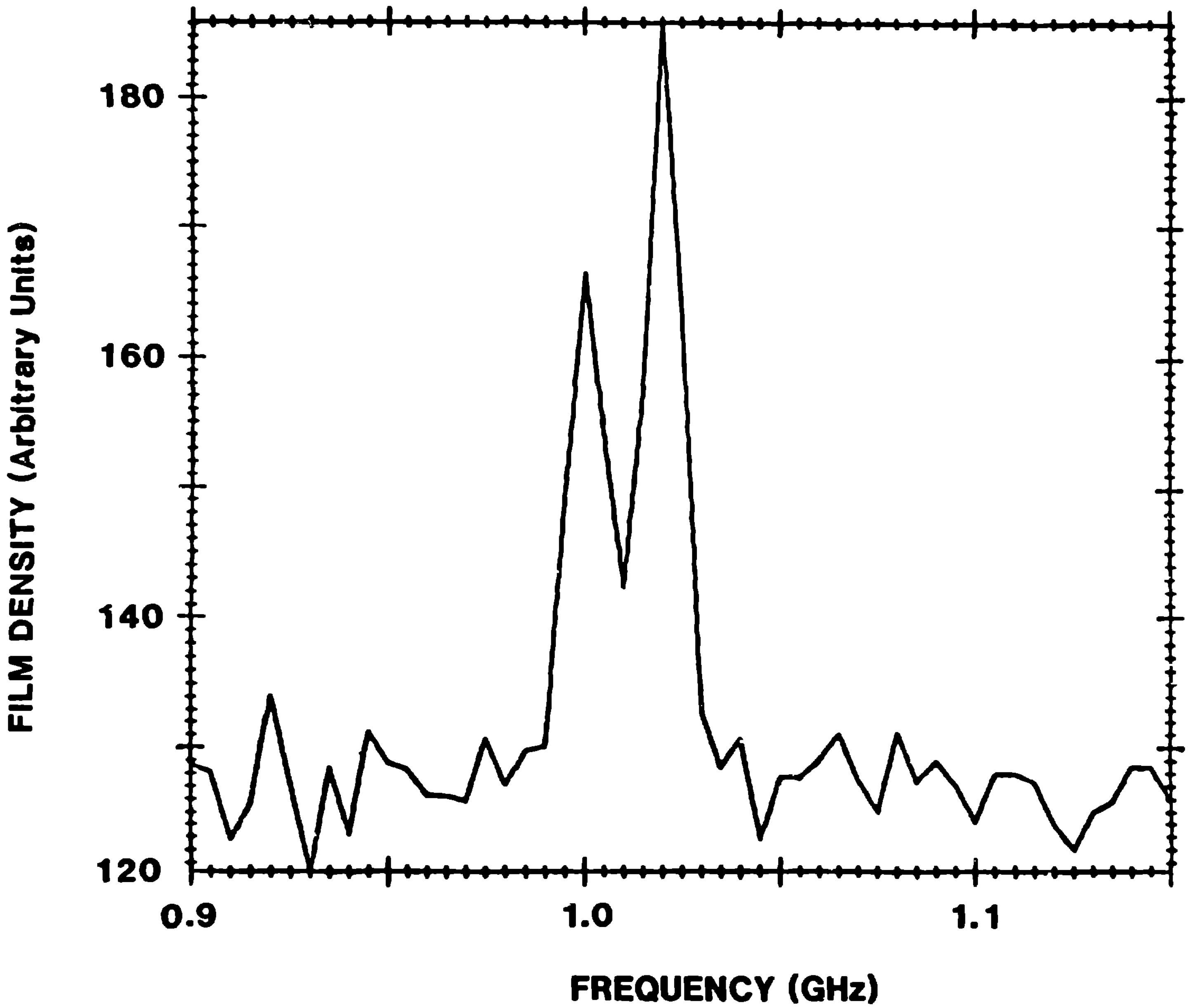
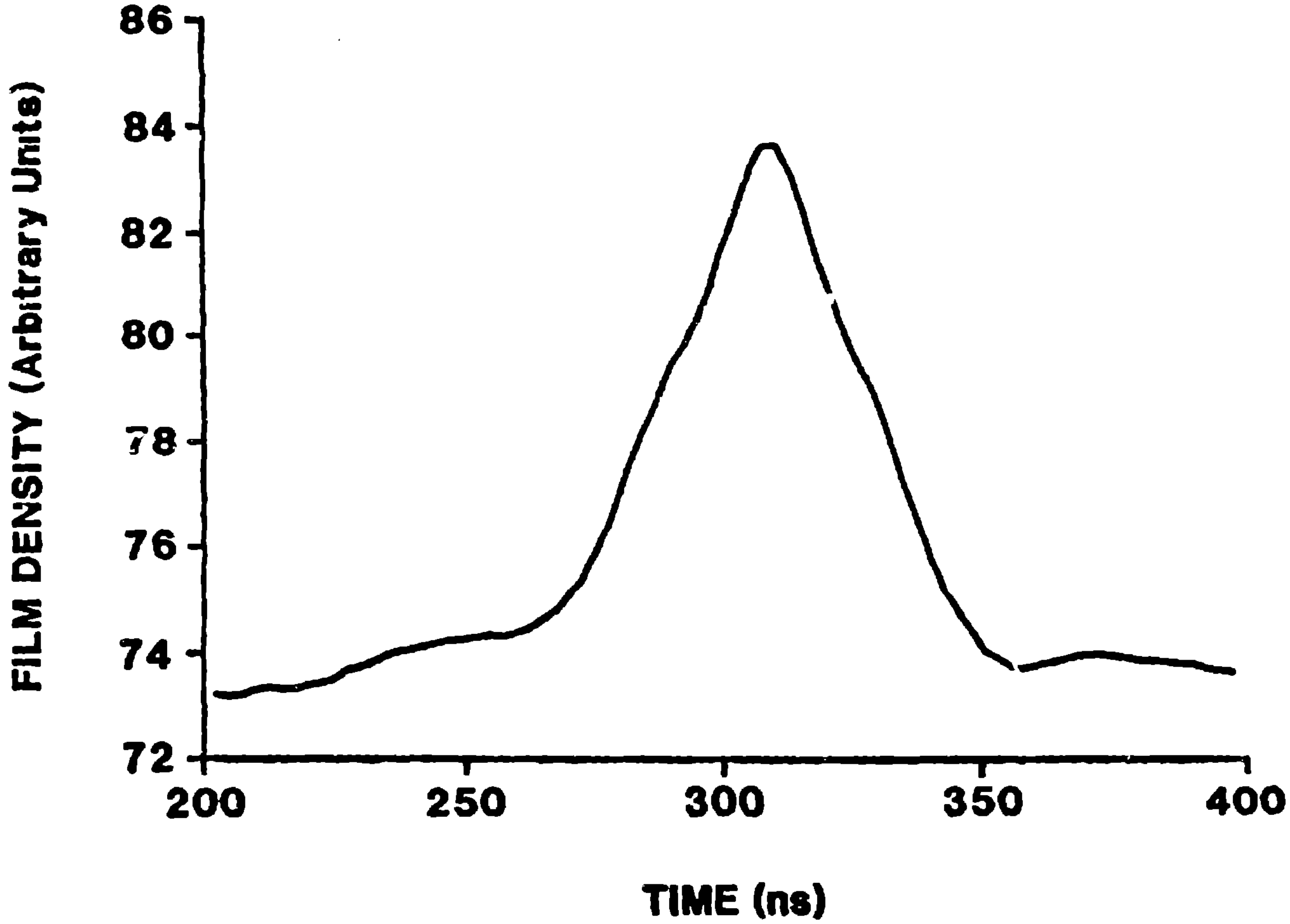
0.8
0.6
0.4
FREQUENCY (GHz)



180
160
140
120
0.9
1.0
1.1
FILM DENSITY (Arbitrary Units)
FREQUENCY (GHz)



FILM DENSITY (Arbitrary Units)
86
84
82
80
78
76
74
72
200
250
300
350
400
TIME (ns)