GA–A22897

QUASI-OPTIC COMPONENTS IN OVERSIZED CORRUGATED WAVEGUIDE FOR MILLIMETER-WAVE TRANSMISSION SYSTEMS

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This is a preprint of a paper to be presented at the 23rd International Conference on Infrared and Millimeter Waves, September 7–11, 1998, Wivenhoe Park, Colchester, United Kingdom and to be published in the *proceedings*.

Work supported by
General Atomics and the U.S. Department of Energy
under Contract No. DE-AC03-89ER51114

GA PROJECT 4945
JUNE 1998

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INTRODUCTION

Propagation of the HE_{11} mode in corrugated waveguide is attractive for low-loss transmission. This mode has a well-defined polarization that is independent of transverse position across any waveguide cross section. Diffraction effects at discontinuities are small, because the field is very small at the waveguide walls. In oversized waveguide, the longitudinal field components are also small everywhere. Hence in many situations the HE_{11} mode behaves like a plane wave.

Quasi-optical components based on plane wave designs have been designed and successfully implemented in oversized corrugated waveguides. We describe below components based on miter bend mirrors, grid polarizers, and plastic films.

COMPONENTS BASED ON MITER BENDS

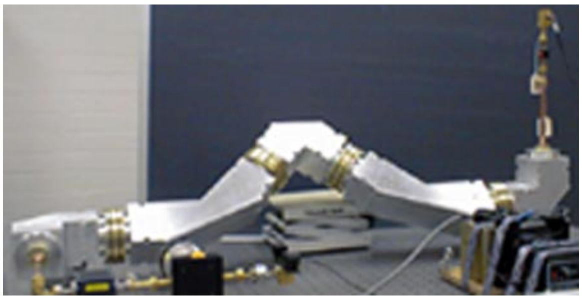

Fig. 1. Broadband polarization rotator in 63.5 mm waveguide.

A simple broadband polarization rotator is a useful component for rotating the HE_{11} mode polarization by any angle. It consists of an ordinary 90° miter bend between two 135° miter bends. The polarization is rotated by two times the angle between the incidence polarization and the plane of the miter bends. Figure 1 shows the measurement setup with a 90° polarization rotation in 63.5 mm corrugated waveguide. At both ends of the polarization rotator in Fig. 1 are broadband transitions from WR8 waveguide to 63.5 mm corrugated waveguide. In the broadband transitions, a taper and horn are attached to a miter bend with a paraboloidal mirror. The radiation patterns from one of these transitions measured at 110 and 165 GHz were in close agreement with the theoretical HE_{11} patterns. The total insertion loss of two transitions in series was about 1 dB at both frequencies, in agreement with the expected 10% loss per transition.

Polarizing miter bends using grooved mirrors have been described earlier [1]. Since then, similar polarizers have been made in 31.75 mm and 88.9 mm waveguide miter bends for use near 84, 110, and 168 GHz. Sinusoidal grooves are used when there is concern over field enhancement at high power. Some of these polarizers allow remote control of the polarization even when the waveguide is evacuated. Simple circular polarizers were made for 60 GHz in 63.5 mm waveguide miter bends with fixed mirrors. Circular polarization is desirable for transmission through rotary joints, for example.

By using grooved mirrors above the frequency where Bragg diffraction may occur, we can make low pass filters such as those previously made for rectangular waveguide [2,3]. The best performance is obtained when the electric field is in the plane of the miter bend. Using theory for sinusoidal shaped grooves [4], we found that excellent low pass filters could be made. Figure 2 shows the response measured with a scanning Michelson interferometer for one of these filters in 63.5 mm waveguide. The vertical line shows the designed cutoff frequency of 168 GHz. The measured structure was in agreement with theory except for the peak near 200 GHz. This peak was found to be an artifact of the measurement due to Bragg diffraction occurring at 180 degrees to the ray incident on the mirror.

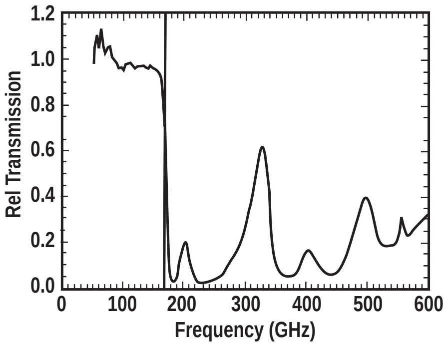

Fig. 2. Transmission through 63.5 mm miter bend low pass filter as measured by Michelson interferometer.

COMPONENTS BASED ON GRID POLARIZERS

Standard free space grid polarizers consist of either parallel gold lines photolithographically deposited on Mylar® film or of parallel stretched thin wires. Figure 3 shows such a polarizer that can be rotated between two back-to-back miter bends (the broadband transitions seen in Fig. 1 are also visible in this figure). An absorber is glued to a metal cap on the unused miter bend port. This device can be used as a polarization diplexer, or as a variable beam combiner and splitter.

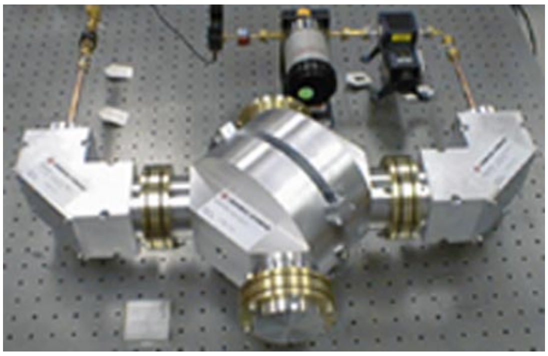

Fig. 3. Measurement of 63.5 mm variable beam combiner with rotatable grid polarizer.

In addition, polarization filters can be made by grid polarizers that are inserted between two corrugated waveguides. The polarization parallel to the grid is reflected. We have made remotely controllable rotatable filters of this type.

COMPONENTS BASED ON PLASTIC FILMS

To evaluate various plastics, we pressed films of the same type together to make a total thickness of 2.2 mm. Broadband measurements made with the Michelson interferometer showed that capacitor grade polypropylene and polystyrene had much less loss than Mylar® (see Fig. 4).

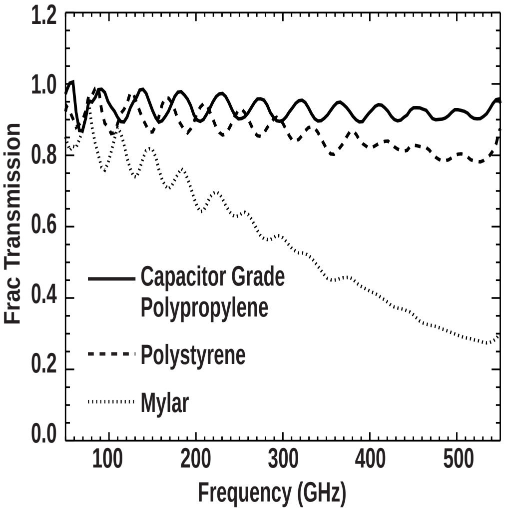

Fig. 4. Transmission through 2.2 mm thick stacks of various plastic films. The individual film thicknesses were 12.7 μm, 25 μm and 31.75 μm for the Mylar®, polypropylene, and polystyrene, respectively.

Using closely spaced parallel films of 32 μm thick polystyrene, artificially birefringent structures were made with low reflections. One such device is a polarimeter to determine the wave polarization [5]. Each time the polarimeter is rotated, two measurements of the polarization can be obtained by analysis of the power received in a horn placed behind the rotating films. Rotational speeds up to 20 rotations per second are used. The measurements can be averaged to remove noise even in low power measurements.

The polarimeter was attached to the rear of a high power 31.75 mm miter bend whose mirror was made of high thermal conductivity diamond coated with suitable metallic and resistive layers. This mirror coupled a small amount of the power from the high power waveguide to the polarimeter. Representative measurements are shown in Fig. 5 for the polarization from a high power polarizing miter bend as a function of rotation angle of the grooved mirror. The theoretical polarizations are shown by the solid line and the polarimeter measurements are shown as points.

Another artificially birefringent device with the polystyrene film is used as a remotely controllable polarization rotator for 60 GHz in 63.5 mm waveguide. The total differential phase shift between the polarizations parallel and perpendicular to the films was adjusted to 90°. In combination with a fixed miter bend circular polarizer, this device produces an output polarized at 45° to the film direction.

Bragg reflection notch filters were made by using 150 to 200 periodically spaced polypropylene films each 25 μm thick. The films were spaced by thin rings of corrugated waveguide machined precisely to the same thickness. A narrowband measurement of such a notch filter is shown in Fig. 6. Other similar filters exhibited nearly 40 dB notches near 82.6 and 84 GHz. Broadband measurements with the Michelson interferometer showed low loss between the high loss harmonics.

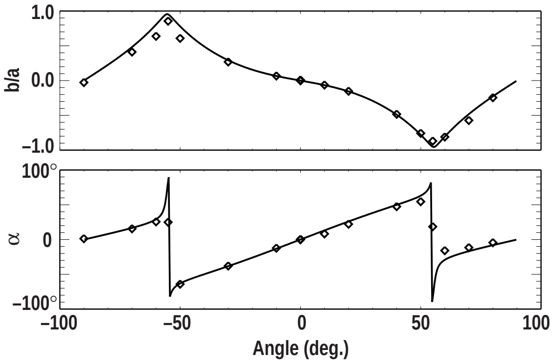

Fig. 5. Polarization parameters as a function of rotation angle of the mirror in a polarizing miter bend, as measured at 110 GHz at low power by a spinning polarimeter. The ellipticity b/a is the ratio of the minor and major axes, and alpha is the orientation angle of the major axis.

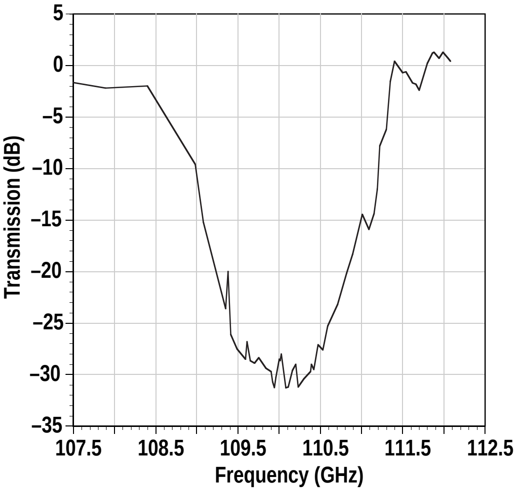

Fig. 6. Transmission through a 110 GHz Bragg reflection notch filter in 63.5 mm waveguide. Data were taken point-by-point. Baseline (reference) signal with no notch filter was manually subtracted.

ACKNOWLEDGMENT

Measurements shown in Figs. 2 and 4 were made by Max Austin of the University of Texas using the DIII-D scanning Michelson interferometer developed by the University of Maryland. This work was supported by General Atomics and the U.S. Department of Energy under Contract No. DE-AC03-89ER51114.

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