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Abstract

A single and a multiple Gunn diode oscillator using an image NRD guide have been investigated. The LSM_{01} mode which is the operating mode of the image NRD guide can be the dominant mode because undesired modes are suppressed due to existence of the image plane. In experiments at X–band for oscillators with Gunn diodes mounted in the dielectric strip of the image NRD guide, the oscillation frequencies could be varied by a movable shorting plane for the single diode case and an effective power combining operation was obtained for the double diode case.

1. Introduction

Recently, various methods for combining output powers of solid-state active devices have been developed[1] [2]. In the millimeter–wave frequency range, power combiners using NRD guides[3] are considered effective because NRD guides have low loss and non-radiative characteristics. In an ordinary NRD guide, however, the LSM_{01} mode which is used as the operating mode of the guide is not the dominant mode, so some circuit attachments are often necessary to prevent mode conversion to undesired modes. In this paper, we develop multiple Gunn diode oscillators using an image NRD guide[4] in which the dominant mode is the LSM_{01} mode.

2. Image NRD guide

The structure of an image NRD guide is shown in Fig.1 where an image plane conductor is placed at the center of a dielectric rectangular strip of an ordinary NRD guide. The LSM_{01} mode is the dominant mode of the image NRD guide because the LSE_{01} mode is suppressed due to existence of the image plane. Experiments were carried out at X–band for the sake of precise fabrication. The dimensions of the image NRD guide were $a = 12.6$[mm] and $b/2 = 6.5$[mm], and the relative dielectric constant of the rectangular strip was 2.04. The cutoff frequency of the LSM_{01} mode was 9.92GHz and the guide has non–radiative characteristics in the frequency range less than 11.9GHz.

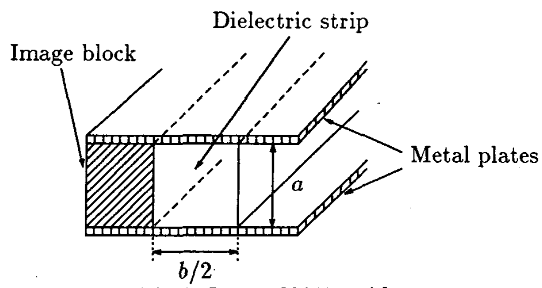

Fig.1 Image NRD guide

3. Circuit elements

3.1 Transition horn

The characteristics of oscillators were measured using a rectangular waveguide, so a transition horn from the image NRD guide to the rectangular waveguide was utilized as shown in Fig.2. The structure of the horn is similar to one of a transition horn from the ordinary NRD guide to the rectangular waveguide[5]. The aperture of the horn to the image NRD guide have a width of 40.1mm and a height of 12.6mm which is equal to the height a of the dielectric strip. The other end of the horn was connected to the rectangular waveguide WRJ–10. The horn has a linear taper with a length of 70.2mm and converts LSM_{01} mode of the image NRD guide to TE_{10} mode of the rectangular waveguide.

In order to measure the characteristics of the transition horn, the scattering parameters of the image NRD guide connected to the horns at both its end looked at the waveguide were measured. The dielectric strip, whose end portions have tapers along E–plane, was inserted by 100mm into the horn and the waveguide. The measured result is shown in Fig.3. In the frequency range lower than 9.9GHz, the transmission coefficient was nearly equal to 0 due to cutoff of LSM_{01} mode, and in the upper frequency range, the transmission coefficient was a little less than 1. The reason is considered to be that some electromagnetic wave leaked out from the very small gap between the parallel metal plate and the metal block of the image plane.

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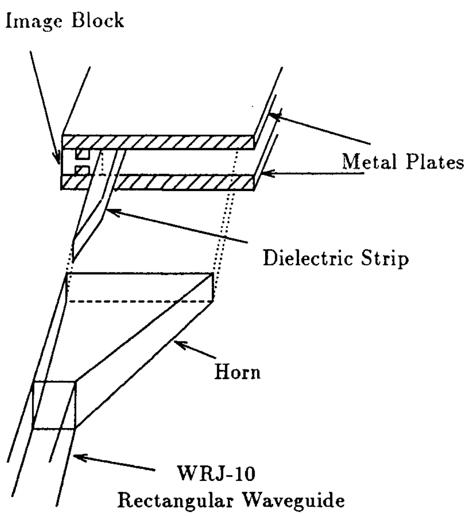


Fig.2 Transition horn from the image NRD guide to the rectangular waveguide

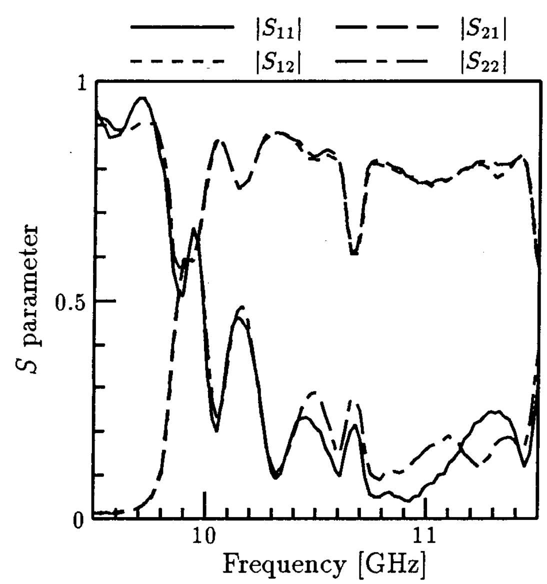


Fig.3 Scattering parameters of the image NRD guide connected to the transition horns at both its end looked at the waveguide

3.2 Short plunger

The electric field of LSM_{01} mode is parallel to the metal plates of the image NRD guide, so the adjustable short plunger can be realized by inserting a thin metal plate parallel to the electric field as shown in Fig.4. When the shorting metal plate with a width of 26.5mm, a length of 70mm and a thickness of 0.5mm was inserted by 30mm into the dielectric strip, the reflection coefficient versus frequency and the standing wave distribution in the vicinity of the short plunger were measured. The result is shown in Fig.5, where the position of the short is $z = 0$ and the shorting metal plate exists in the region of negative z. The magnitudes of the loops of the standing wave were different because the coaxial probe for measurement could not be moved parallel to the dielectric strip of the guide. A weak standing wave existed along the shorting metal plate, so it is considered that the image NRD guide could not be perfectly shorted at $z = 0$ and weak electromagnetic wave propagated along the image NRD guide with the short plunger.

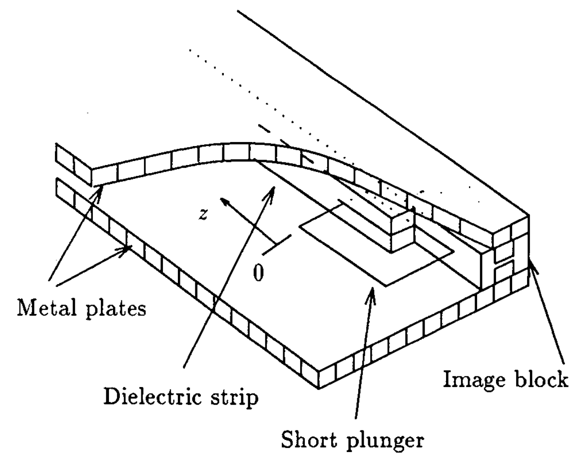
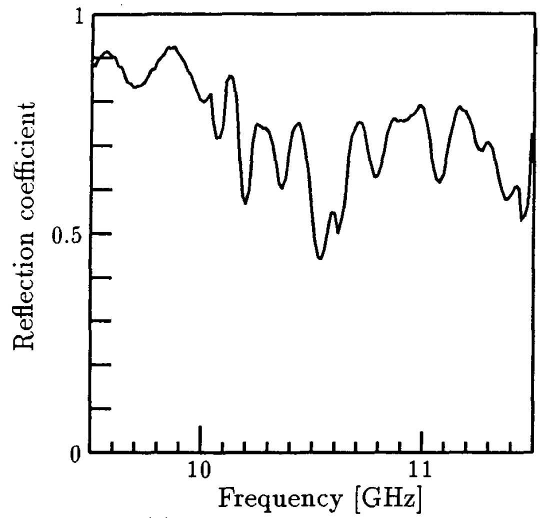


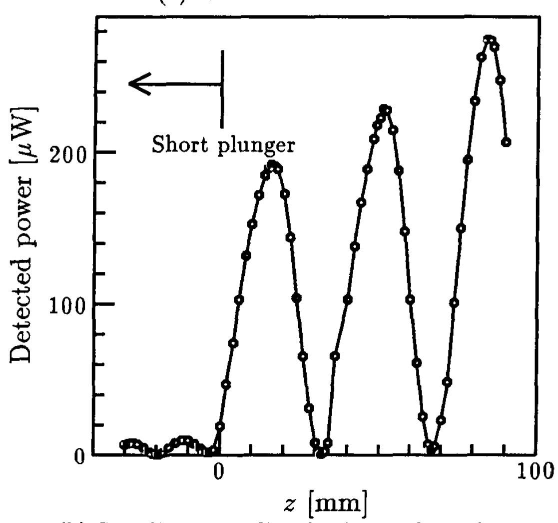
Fig.4 Adjustable short plunger for the image NRD guide

4. Single diode oscillator

Figure 6 shows the structure of a single Gunn diode oscillator using the image NRD guide. A Gunn diode was installed on the image plane at the center between the parallel metal plates and was supported by a metal rod through which DC bias voltage was applied to the Gunn diode. The metal rod was connected to a metal block in the shape of a trapezoid which came into contact with the dielectric strip and was insulated from the parallel metal plates in order to apply DC bias. The electromagnetic wave generated from the Gunn diode propagates along the image NRD guide and is reflected by the adjustable short plunger. The oscillation frequency can be controlled by adjusting the distance between the Gunn diode and the short plunger. The output power was extracted through the image NRD guide in the opposite direction to the short plunger. The image NRD guide was converted to a rectangular waveguide in the experimental setup using a transition horn as shown in Fig.2. The load of the oscillator was adjusted for maximum output power by a stub tuner on the rectangular waveguide. Figure 7 shows the measured variation of the oscillation frequency and the output power with the dis-



(a) Reflection coefficient



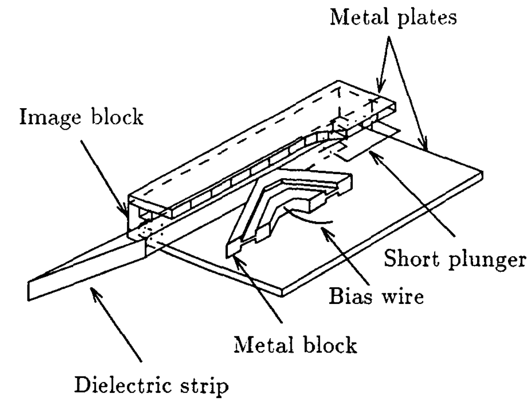
(b) Standing wave distribution in the vicinity of the short plunger at 10.5GHz

Fig.5 Measured characteristics of the short plunger

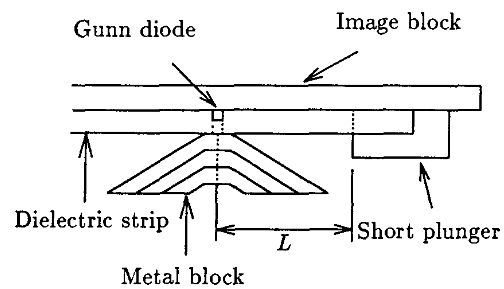
tance L between the Gunn diode and the short plunger. The measured maximum output power did not reach the available power of the Gunn diode due to loss of the image NRD guide mentioned in Section 3.1.

5. Double diode oscillator

Figure 8 shows the structure of a double diode oscillator which is similar to the single diode oscillator except that two diodes are arranged along the image NRD guide. The oscillator of this configuration may be called a ladder oscillator[6]. For two values of the distance d between two diodes, the measured variation of the oscillation frequency and the output power with the distance L between the



(a) Aspect



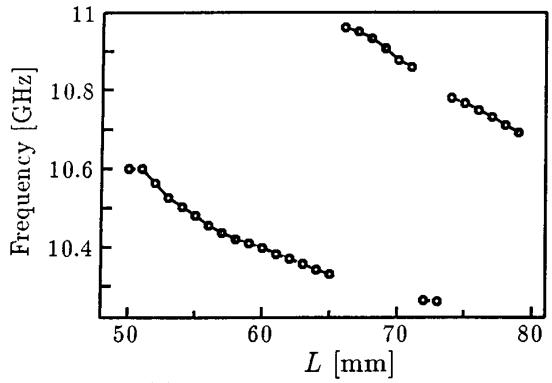
(b) Vicinity of diode

Fig.6 Structure of a single Gunn diode oscillator

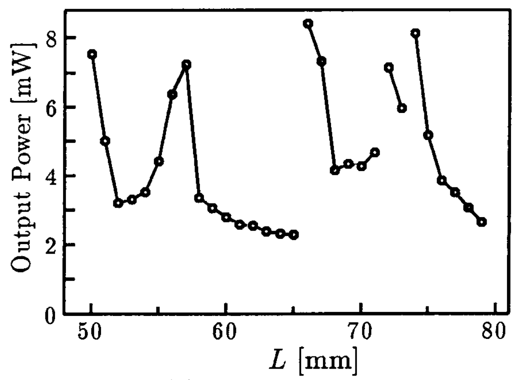
Gunn diode #1 and the short plunger is shown in Fig.9. The oscillation frequency could vary with L in narrower range compared with the single Gunn diode case because the oscillation frequency depends on not only L but also the distance between two diodes. This oscillator tended to oscillate near the frequency at which the distance between the two diodes were equal to half of wavelength of the waveguide. It is considered that the distance between two diodes must be longer in order to oscillate about at 10.9GHz where the maximum power was derived for the single diode case. The output power of the double diode oscillator was more than 1.5 times as much as that of the single diode case because the output powers of our Gunn diodes decreased with increasing frequency.

6. Conclusion

A new approach to power combining of solid-state active devices using the image NRD guide was discussed. In the experiments at X-band for the oscillator by mounting a single or double Gunn diode in the dielectric strip of the image NRD guide, the oscillation frequency and the output power characteristics were obtained. We expect that larger output powers will be brought by improvements of the diode mount and the contact between the image block and the parallel metal plates.



(a) Oscillation frequency



(b) Output power

Fig.7 Experimental result for case of the single diode oscillator

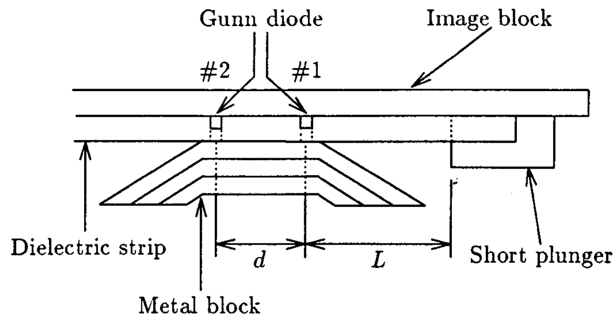
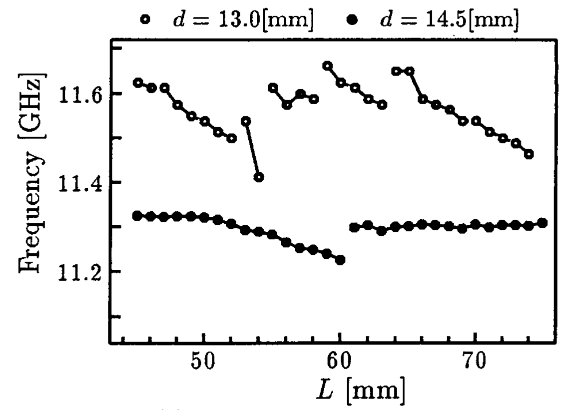
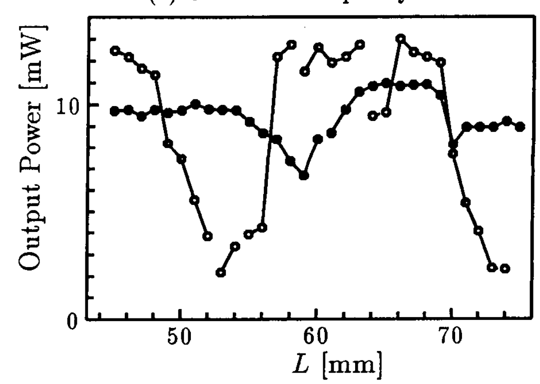


Fig.8 Structure of a double diode oscillator



(a) Oscillation frequency



(b) Output power

Fig.9 Experimental result for case of the double diode oscillator

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