IF1 M-9

W-BAND OPTICALLY CONTROLLED GUNN SUBHARMONIC OSCILLATOR

Xiao Wei Zhu(Student Member IEEE), Yi Yuan Chen(Member IEEE) and Si Fan Li(Senior Member IEEE)

State Key Laboratory of Millimeter Waves
Southeast University , Nanjing 210018, P.R. China

ABSTRACT

This paper describes a new method of controlling the frequency of W-band subharmonic Gunn oscillator using laser beam. In our experiment the maximum optical tunning frequency shift of 7MHz has been observed. A cavity with a silicon piece glued on backshort is analyzed. The complex frequencies of the cavity as a function of plasma densities are obtained.

I. INTRODUCTION

Interest in opticlly controlled oscillator has been grown in recent years. Many researchers devoted themselves to microwave optically controlled GaAs-MESFET oscillators with illumination effects both on devices and circuits(e.g. dielectric resonantors). Millimeter wave optically controlled oscillators have also been reported. Yu et al described a oscillator at Ka-band with the illumination on a Si piece which is a part of circuit[1]. Few work on optically controlled oscillators at W-band has been done. Seeds et al reported a frequency modulation oscillator of IMPATT diode by optical illumination, the maximum frequency shift of $9.4MHz$ has been observed[2]. It can be seen, however, that the coupling light to active area of a diode is somewhat difficulty. One prefers changing the circuit parameters to device parameters. In this paper a W-band optically controlled subharmonic Gunn diode oscillator is reported, in which the light illuminates directly on a silicon piece glued on backshort of a cavity. The frequency shift of $7MHz$ is demonstrated as an optical response, which is comparable with the one[2] of illumination on active area of diodes. The cavity with Si piece loaded is also analyzed by using transverse resonant technique.

II. THEORETICAL ANALYSIS

From the theoretical predictions of the Drude theory[3], we know that the relative dieletric constant of Si illuminated by light is a complex value, which is a function of light injected plasma density. The configuration of the resonant cavity to be analyzed is shown in Fig.1. According to transverse resonant principle[4], the complex frequency ω of rectangular waveguide cavity with a Si piece loaded and illuminated by light can be calculated in terms of following equation:

$$\beta_2 tg\beta_1 d + \beta_1 tg\beta_2 t = 0$$

where

$$\beta_1^2 = \omega^2 \mu_o \epsilon_o - (\frac{\pi}{a})^2$$

$$\beta_2^2 = \omega^2 \mu_o \epsilon_o \epsilon_p - (\frac{\pi}{a})^2$$

and ϵ_p is complex dielectric constant of the Si piece, a is width of the cavity. Fig.2 shows the results of calculation. The real part of complex frequency ω is resonant frequency and imaginary part is loss. In Fig.2(a) the resonant frequencies of the cavity are ploted as a function of the plasma densities. The imaginary parts of frequencies are ploted in Fig.2(b). When plasma densities are between $10^{14}cm^{-3}$ and $10^{16}cm^{-3}$, the frequency changes abruptly from $46.60GHz$ to $48.70GHz$ and approaches to maximum at plasma density of $10^{16}cm^{-3}$. The loss peak has been observed at plasma density of $10^{14}cm^{-3}$. When the plasma density is below $10^{15}cm^{-3}$, the resonant frequency of the cavity is nearly a constant and loss increases as plasma density increasing because the illuminated Si shows dielectric nature. When the plasma density is above $10^{16}cm^{-3}$, the resonant frequency is no longer changed and loss decreased as plasma density increasing. This is due to the metallic nature of illuminated Si material. It can be seen that the size of cavity is equivalently reduced because of metallized Si piece when plasma densities are high enough.

III. EXPERIMENTAL WORK

The configuration of an experimental oscillator is shown

CH3141-9/92/0000-0365$01.00 © 1992 IEEE

in Fig.3. Gunn diode is a ceramic packaged diode and is used in resonant cap type circuits. Silicon piece is $1.2 \times 4.1 \times .4mm$ and its dark relative dielectric constant is 11.9. It is slightly P-type with an intrinsic carrier density of $10^{16}cm^{-3}$ and a resistivity of $1.0 \times 10^{4}\Omega.cm$. The Si piece is put in waveguide cavity which is resonant at about $48GHz$, 2nd harmonic wave is coupled to WR10 waveguide and output. The optical signal is generated by GaAs/GaAlAs laser emitting at a wavelenth of $863nm$ and power is about $6mW$. The optical power is coupled to the Si piece with optical fiber through a hole in the backshort, which is actully a cutoff cylindrical waveguide. The diameter of cylindrical waveguide is $.9mm$. The free-running frequency of the oscillator is $95.58GHz$ and output power is about $14mW$.

In our experiment, the oscillator is connected to measurement system which uses subharmonic mixing technique, and the IF spectrum can be observed on spectrum analyzer firstly under dark condition. When the Si piece is illuminated by laser beam, the frequency shift of $7MHz$ is observed on the screen of spectrum analyzer. Fig.4 shows the spectrum of the optically controlled oscillator. The right-hand peak is the free-running frequency under dark condition and left-hand is oscillation frequency under illumination. When laser beam is cut off, the oscillation frequency returns to original frequency. In this experiment the output power of oscillator is not changed with or without laser beam illuminating.

IV. DISCUSSION

It can be seen that the frequency shift is negative. The positive one is expected in our analysis above. The explanation for it is that the Si piece is now close to the diode, the illuminated Si piece gives more effects on external circuit impedances looking out from the diode than the impedance of cavity. The analysis of a Si piece in the neighbourhood of a diode is for the moment difficult. In addition the frequency shift is small as compared with theoretical result. In our analysis the plasma is considered to be full of whole Si material. In fact, however, the plasma exists only whthin the area of optical spot. For this case the frequency shift is surely more less than the theoretical case. The analysis of a cavity with partly illuminated semiconductor piece are in progress.

V. CONCLUSION

In this paper the W-band optically controlled subharmonic Gunn oscillator by illuminating a Si piece glued on backshort is reported. By this new technique the optical power can more conveniently coupled to oscillator circuits than illuminating the active area of diode. The frequency shift of $7MHz$ has been observed. The cavity with illuminated Si piece is firstly analyzed.

This technique of optically controlled oscillator can be used in W-band optically modulated oscillators and locked phase oscillators.

ACKNOWLEDGMENT

This work is funded by National Science Foundation of China.

REFERENCES

[1] Z. Yu et al, "A new way to optically control a millimeter wave oscillator", IEEE Trans. on MTT, Vol. MTT-38, pp.1360-1362, Sept. 1990.

[2] A.J. Seeds et al, "The optical control of IMPATT oscillators", IEEE Journal of Lightwave Tech., Vol. LT-5, pp.403-411, Mar. 1987

[3] C.H. Lee et al, "Optical control of millimeter wave propagation in dielectric waveguide", IEEE Trans. on Quantum Electron., Vol. QE-16, pp.277-288, Mar. 1980.

[4] R.E. Collin, *Filed Theory of Guided Waves*, Chapter 6

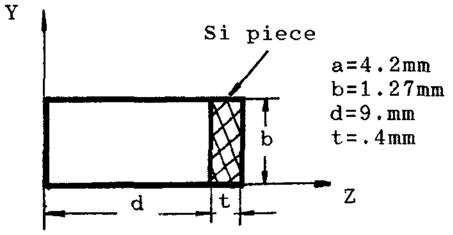

Fig.1 A cavity with semiconductor loaded

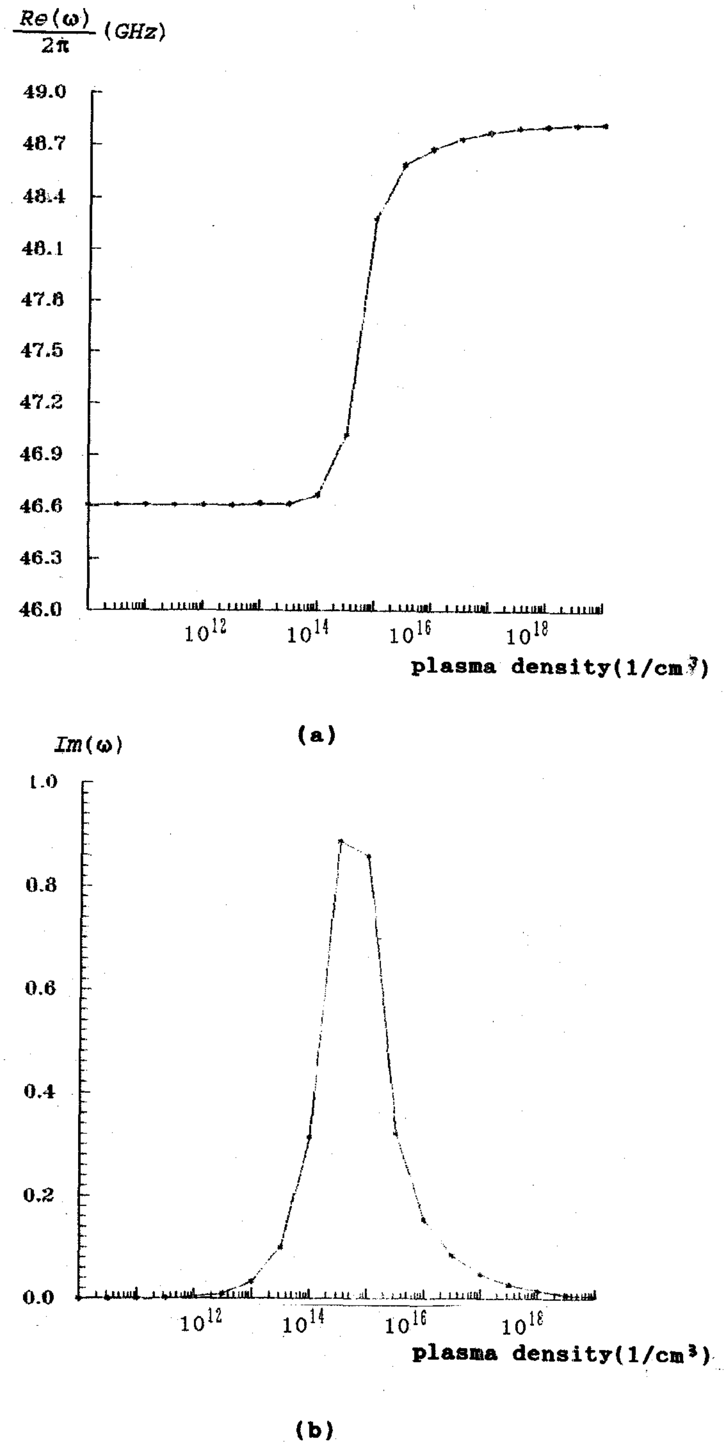

Fig.2 Calculated complex frequency versus plasma density
(a) resonance frequenccy of the cavity
(b) imaginary part of complex frequency

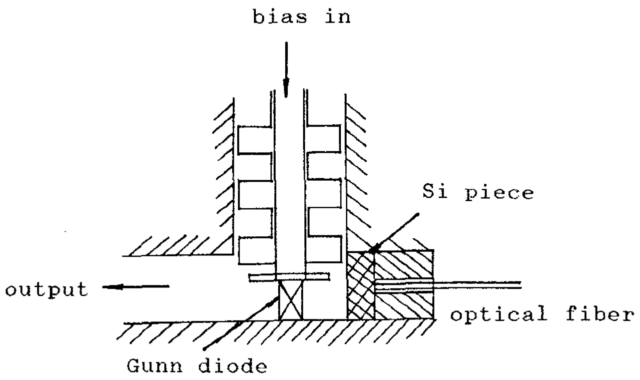

Fig.3 Experimental W-band optically controlled Gunn subharmonic oscillator

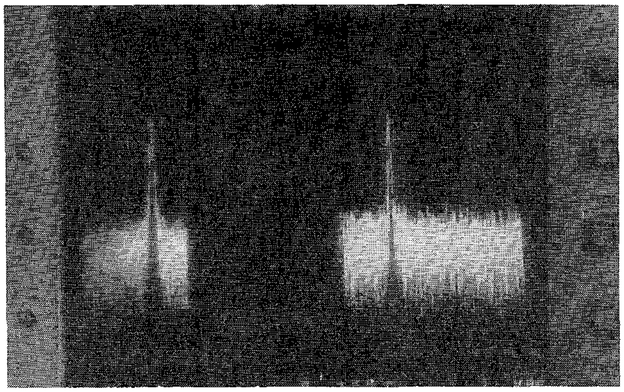

Fig.4 Spectrum showing optically tunning frequency