Multi-element Quasi-optical Oscillator Arrays for Terahertz Region

M.Nakayama, M.Hieda, T.Tanaka, K.Mizuno

Research Institute of Electrical Communication, Tohcku University, Sendai, 980 Japan

ABSTRACT

Multi-elements oscillator with quasi-optical resonator is reported. The resonator consists of a Fabry-Perot cavity with a grooved mirror. It has capability for power-combing of solid-state sources in the millimeter wave region. X-band models consisting of Gunn diodes or GaAs MESFET's are demonstrated. Power combining and frequency-locking of 18 diodes and 6 FET's have been successfully observed. 50GHz-band Gunn diode oscillator with the resonator is also reported.

INTRODUCTION

Recently many kinds of oscillators are developed in the millimeter and submillimeter wave region. Solid-state devices have many advantages: small size, light weight, and low-voltage requirements. As the frequency increases, however, output power becomes smaller. In addition, the dimensions of conventional waveguide cavities become very small and ohmic losses in the metal wall increases. Therefore coherent power combining of a large number of devices using quasi-optical resonator is attractive. Young and Stephan demonstrated power-combining in a quasi-optical resonator of two devices [1]. Popović et al. proposed and demonstrated power-combining using grid oscillators with GaAs MESFET's at 10GHz [2]. We have proposed a Fabry-Perot resonator with a grooved mirror for solid-state oscillators [3],[4]. In this paper, we report the results of the experiments with the X-band model consisting of Gunn diodes or GaAs MESFET's and the results of 50GHz-band Gunn diode oscillator with the resonator.

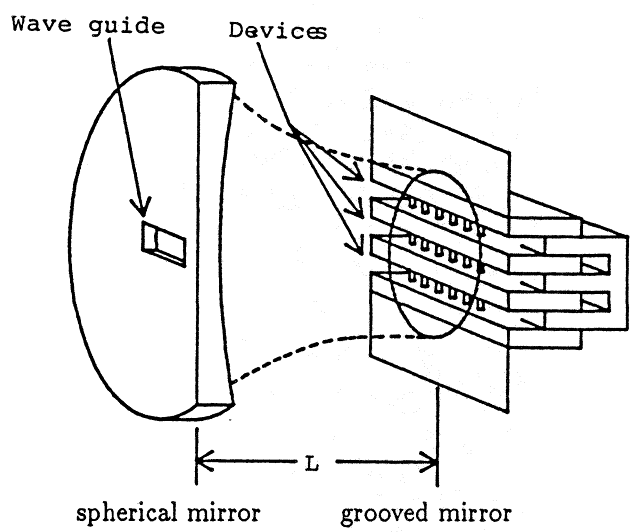

Fig. 1 Resonator configuration.

CONFIGURATION

The configuration of the model resonator is shown in Figure 1. It consists of a grooved mirror and a concave spherical mirror facing each other. Figure 2 shows the structure of the grooved mirror. The groove pitch D must be less than half of oscillator wavelength to avoid diffraction losses [5]. The Gunn diodes(JRC NJX4410) are mounted in grooves and biased by the top and the bottom plates of each groove (Fig.2a). These plates are insulated by thin (80μm)teflon tape. Similarly, FET's(Fujitsu FSX52-LF) are mounted on the surface of the groove. Gate and drain ribbons are connected to adjacent insulated plates. The groove depth t could be continuously changed to adjust the impedance of the groove. The size of the grooved mirror is $5.0\lambda \times 5.0\lambda$. This is large enough for the beam waist size($2.5\lambda\phi$) on the mirror surface. Output power is taken out by a wave guide at the center of the spherical mirror.

The 50GHz-band resonator consists of plane mirror (100mm×100mm) or metallic mesh output coupler instead of concave spherical mirror.

The resonator proposed here has the following advantages: it has a large heat dissipation capacity, can mount large number of devices, is lager enough than wave length, and has simple bias circuit.

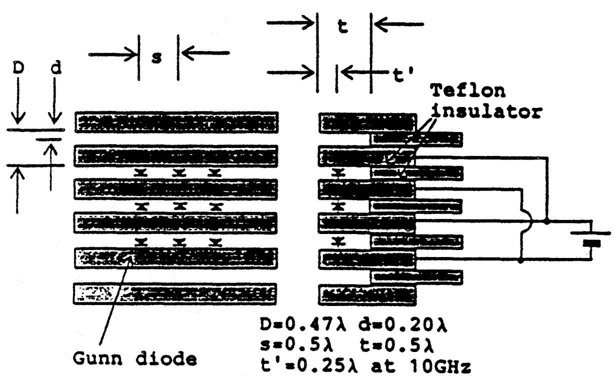

Fig. 2a Grooved mirror for diodes.

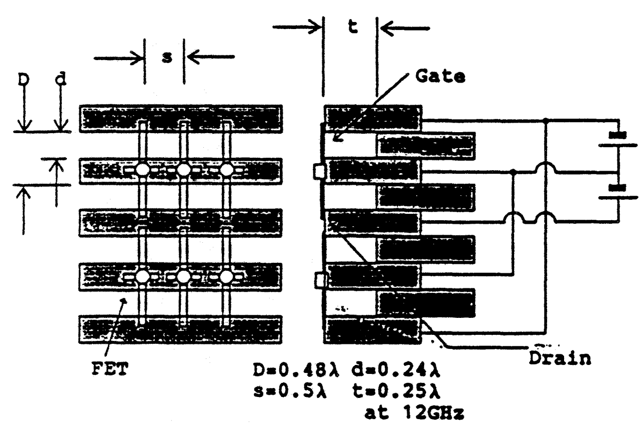

Fig. 2b Grooved mirror for FET's.

EXPERIMENTS

Figure 3 shows the spectra for diode oscillators. We have succeeded frequency locking and power combining. Further, it can be seen that the spectrum for nine diodes is much narrower than that for a single one. The similar phenomena were observed with FET oscillator. The optimum depth of each groove was about $\lambda/2$ for diodes and $\lambda/4$ for FET's. The optimum spacing between elements in a groove has been

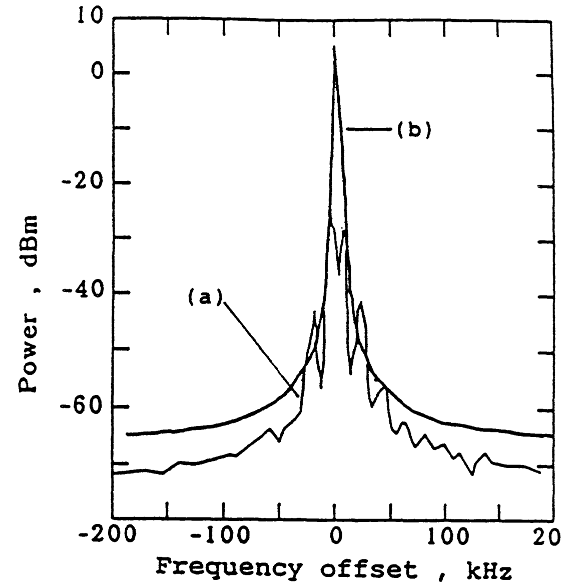

Fig. 3 Spectra of Gunn diode oscillators.
(a) Single diode. (L=107.2mm,fc=10.0336GHz)
(b) Nine (3×3 grid) diodes.
(L=104.2mm,fc=10.2293GHz)

chosen experimentally. We had good results with the spacing of $\lambda/2$. At present, we have succeeded in frequency locking and power combining for the 18 diodes (six by three grid) and the six FET's (three by two grid).

Figure 4 shows how the oscillation frequency varies with the length of the resonator with 6 FET's. The mechanical tuning range is about 5%. Oscillation frequency agrees with theoretical resonant frequency of the fundamental (TEM_{00}) mode of the Fabry-Perot resonator. The oscillation frequency of Gunn diode also agrees with resonant frequency. We have measured the field distribution through moving a small piece of absorber around in the resonator .

Figure 5 shows simplified equivalent circuit of FET oscillator. The ribbons are represented as inductance and capacitance. Phase change between port1 and 2 should be π at oscillation frequency, if the oscillation mode is the fundamental of Fabry-Perot resonator. This simple consideration predicts an oscillation frequency of 12GHz, which agrees with experiments.

Figure 6a shows the spectrum for 50GHz-band Gunn diode oscillator with the resonator consists of plane and grooved mirrors. The Gunn diode(Alpha DGB8266) is mounted at the center of the grooved mirror. Figure 6b shows the spectrum using the same Gunn diode with a waveguide cavity. It can be seen that the resoator has a higher Q-value than the waveguide.

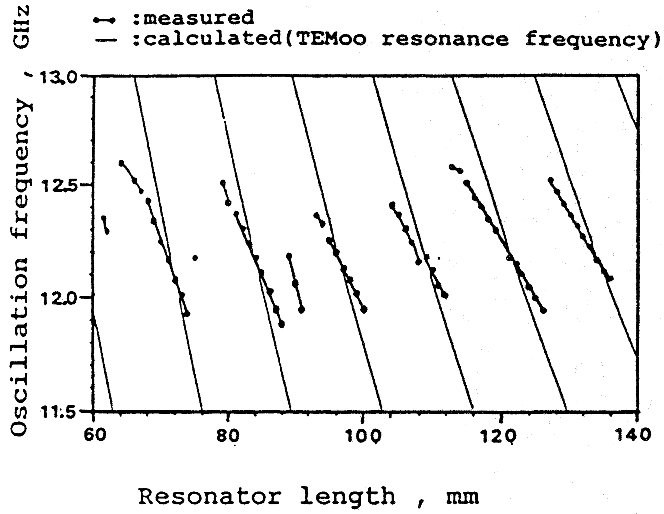

Fig. 4 Oscillation frequency of six FET's oscillator versus resonator length. Calculated line shows resonance frequency of TEM_{00} mode.

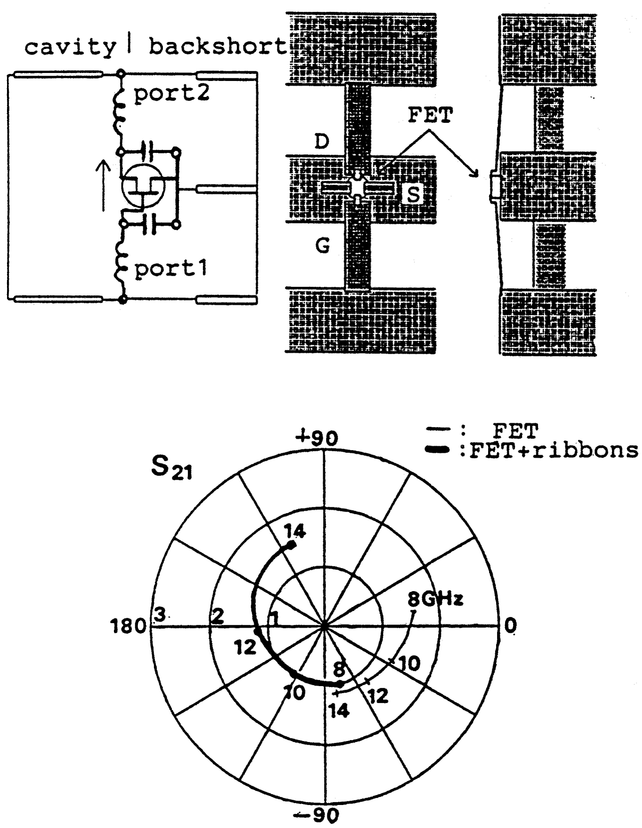

Fig. 5 (a) Equivalent circuit of FET oscillator.
(b) S_{21}-parameters of FET(between gate and drain) and port1-2(including impedance of the ribbons).

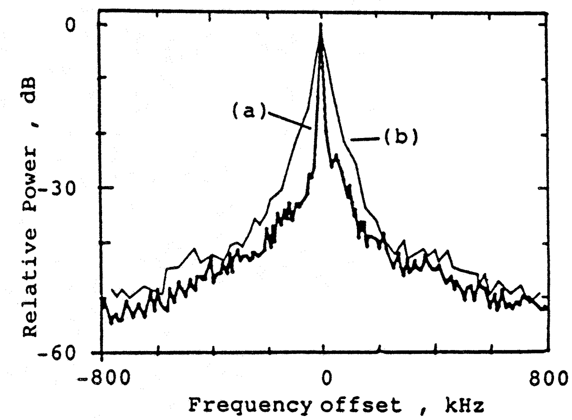

Fig. 6 Spectra of 50GHz-band Gunn diode oscillators.
(a) With quasi-optical resonator (fc=55.19GHz)
(b) With waveguide cavity (fc=55.72GHz)

CONCLUSION

We have demonstrated the utility of a quasi-optical oscillator with multi-elements. Its resonator consists of Fabry-Perot cavity with a grooving. It has capability for power combining of solid-state sources in millimeter and submillimeter wave regions. Frequency-locking and power combining of 18 Gunn diodes and 6 GaAs FET's have been successfully observed in X-band. Mechanical frequency tuning range is about 5%. The oscillation mode is the fundamental (TEM_{00}) mode of the Fabry-Perot resonator.

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