# Millimeter and Submillimeter Wave Quasi-optical Oscillator with Multi-elements

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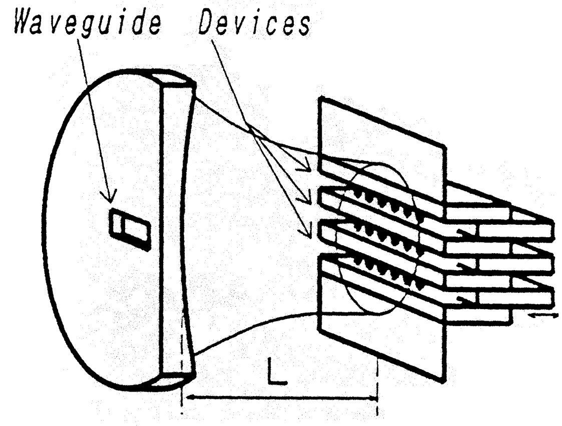
## ABSTRACT

Multi-elements oscillators with a quasi-optical resonator are reported. The resonator consists of a Fabry-Perot cavity with a grooved mirror and concave mirror. The oscillator has capability for power-combing of solid-state sources in the millimeter and submillimeter wave region. X-band models consisting of Gunn diodes or GaAs MESFET's have been demonstrated. Coherent power combining and frequency-locking of 18 diodes (6x3 grid) and 6 FET's (3x2 grid) have been successfully observed at X-band. We have also succeeded frequency-locking of 3 Gunn diodes at U-band. A W-band InP Gunn diode oscillator using a same configration is also reported.

## INTRODUCTION

Recently, many kinds of oscillators have been developed for use of millimeter and submillimeter wave frequencies. Solid-state devices have many advantages: small size, light weight, and low-voltage power supplies. As frequency increases, however, output power becomes small. In addition, the dimensions of conventional waveguide cavities become very small and ohmic losses in the metal wall increase. Therefore, coherent power combining of a large number of devices using quasi-optical resonators is attractive. A wide variety of quasi-optical power-combining method using Gunn diodes and MESFET's have been demonstrated [1],[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 experiments with an X-band model consisting of Gunn diodes and GaAs MESFET's and the results of a U-band Gunn diodes oscillator.



spherical mirror grooved mirror

**Fig. 1** Resonator configuration.

## CONFIGURATION

The configuration of the 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 oscillator wavelength to avoid diffraction losses. The Gunn diodes are mounted in grooves and biased by the top and the bottom plates of each groove (Fig.2a). These plates are insulated by thin (80$\mu$m)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 spherical mirror's radius of curveture is 200mm or 400mm. The groove depth $t$ could be continuously changed to adjust the impedance of the groove. Output power is taken out by a waveguide at the center of the spherical mirror.

The U-band and W-band resonators consist of spherical mirror which radius of curveture are 100mm and 60mm respectively.

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.

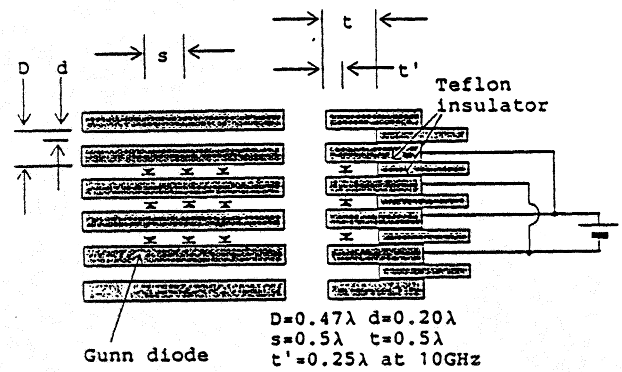


Fig. 2a Grooved mirror for diodes.

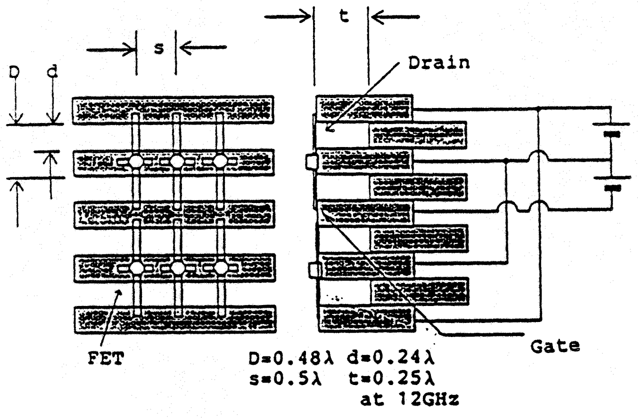


Fig. 2b Grooved mirror for FET's.

## X-band Gunn diode oscillator

Figure 3 **shows the spectra for the** Gunn diode(JRC NJX4410) **oscillators. We have succeeded** in frequency locking and power combining. Furthermore, it is seen that the spectrum for nine diodes is much narrower than that for a single diode. The optimum depth of each groove was about λ/2. The optimum spacing between elements in a groove has been chosen experimentally. Good results were obtained with spacing of λ/2. At present, we have succeeded in frequency locking and power combining for up to 18 diodes ( 6×3 grid), obtaining an output power of

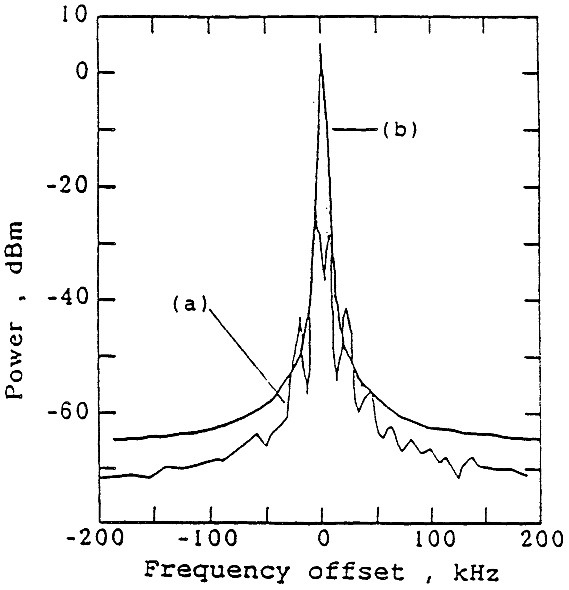


Fig. 3 Spectra of Gunn diode oscillators.
(a) Single diode. (L=107.2mm,fc=10.0336GHz)
(b) Nine (3×3 grid) diodes.
(L=104.2mm,fc=10.2293GHz)

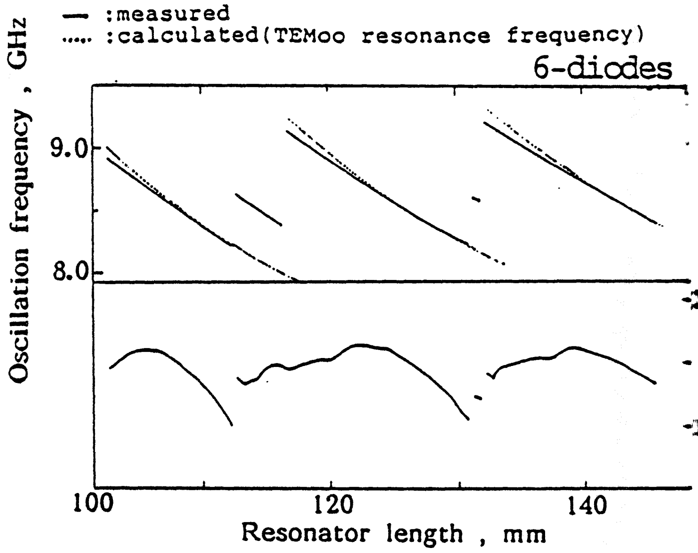


Fig. 4 Oscillation frequency and output power of 6(6×1grid) diodes oscillator versus resonator length. Calculated line shows resonance frequency of $TEM_{00}$ mode.

123mW at 8.3GHz. This is roughly 18 times the power from a single diode oscillator with a waveguide cavity. The C-N ratio is 83dB/Hz at a 12.5kHz offset.

Figure 4 shows how the oscillation frequency varies with the length of the resonator with 6 Gunn diodes. The mechanical tuning range is about 11%. Oscillation frequency agrees with theoretical resonant frequency of the fundamental ($TEM_{00}$) mode of the Fabry-Perot resonator. Resonant modes were identified by measuring the field distribution in the cavity. This was measured by moving a small ( $< \lambda/10$) piece of absorber through the cavity.

## 12GHz FET oscillator

We have succeeded in frequency locking and power combining 6 FET's in a 3 x 2 grid at 12GHz. Noise reduction was observed just as in the case of the Gunn diode oscillator. We had 6dB more power with locked 6FET's than single FET. As the resonator length varies, the oscillator frequency shifts over 600MHz. The oscillation frequency agree with the calculated resonant frequency of fundamental mode($TEM_{00}$).

## U-band Gunn diode oscillator

We have succeeded frequency locking and power combining with U-band Gunn diodes. Figure 5 shows the spectra for U-band Gunn diode oscillator. The spectrum for three diodes is narrower than that for single diode. The 3dB more output power have been obtained with three diodes. The Gunn diodes(Alpha DGB8266) are mounted in the same groove. The spacing of the diodes $s$ and groove depth $t$ are same as X-band model experiments.

## W-band Gunn diode oscillator

We have constracted W-band InP Gunn diode oscillator with same resonator configration. Figure 6 shows how oscillation frequency varies with the resonator length. The mecanical tuning range is 2.6%. The maximum output power is 4dBm. The InP Gunn diode (Acrotec NT-W50) is mounted at the center of grooved mirror.

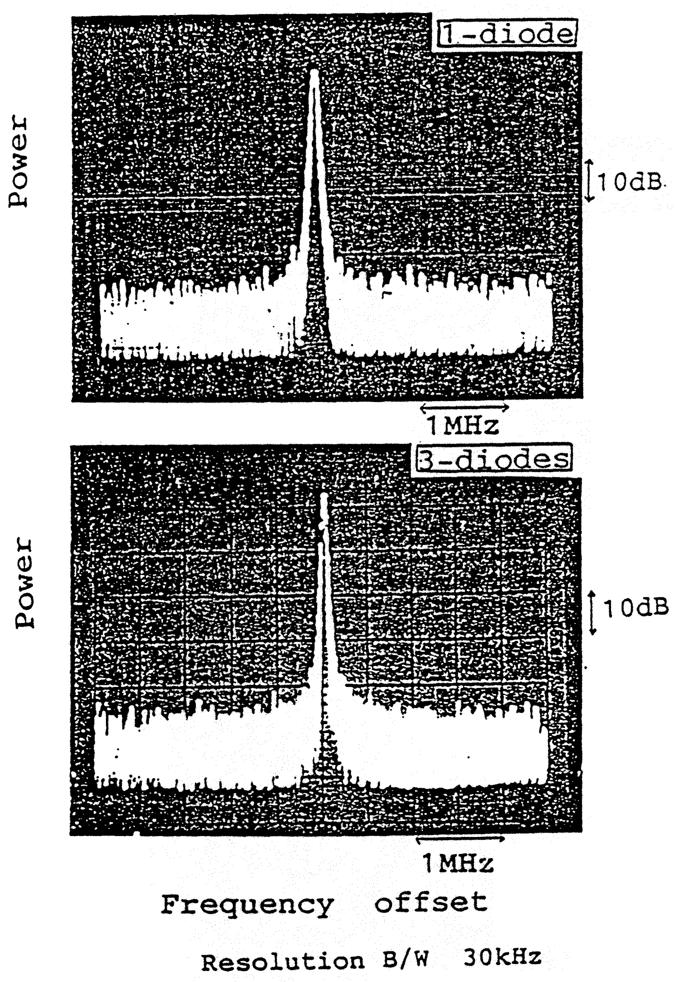


**Fig. 5** Spectra of U-band diodes oscillators.
(a) Single diode.
(b) Locked 3 diodes.

## CONCLUSION

We have demonstrated the utility of a quasi-optical oscillator with multi-elements. The resonator consists of Fabry-Perot cavity with a grooved mirror. It has the capability of power combining many solid-state sources at millimeter and submillimeter wave regions. Frequency-locking and coherent power combining of 18 Gunn diodes and 6 GaAs FET's have been successfully observed at X-band. The oscillation mode is the fundamental mode ($TEM_{00}$) of the Fabry-Perot resonator. We have also reported U-band 3 Gunn diodes oscillator and a W-band Gunn diode oscillator with the same configuration.

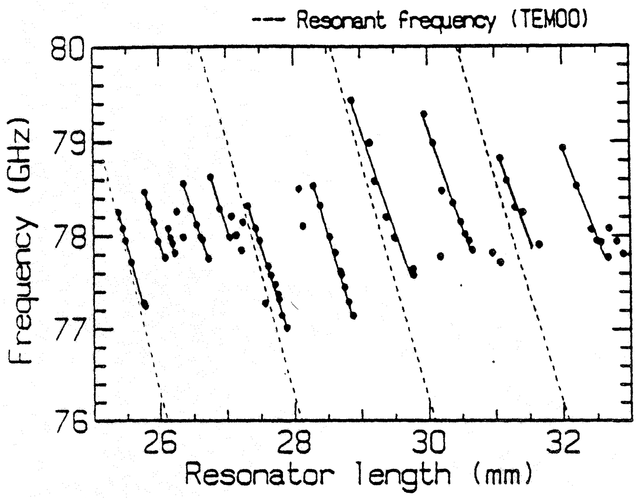


Fig. 6 Oscillation frequency W-band diode oscillator versus resonator length. Broken line shows resonance frequency of $TEM_{00}$ mode.

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