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110 GHz GaAs FET OSCILLATOR

Indexing terms: Microwave devices and components, Field-effect transistors, Oscillators

A W-band GaAs FET oscillator has been demonstrated for the first time. A 75 μm gate width device with sub-half-micrometre (0·2 μm) electron-beam defined gates was used as a common-gate oscillator for operation in the 70 to 110 GHz frequency range. The highest oscillation frequency achieved was 110 GHz.

Recent progress in the development of sub-half-micrometre GaAs FETs has generated considerable interest in using FET-based solid-state millimetre-wave components for system applications. These high-performance devices have demonstrated useful gains as amplifiers up to 60 GHz.[1–3] When used as an oscillator, oscillation frequency as high as 69 GHz and efficiency as high as 10% have been reported.[4,5] For local-oscillator applications, it is desirable to further increase the operation frequency into the 90 to 100 GHz range. Owing to these intensive research activities, the GaAs FET based integrated receiver front end will soon become a practical reality for millimetre-wave systems. This letter describes the design and performance of the first transistor oscillator operated beyond 100 GHz. The maximum frequency of oscillation observed was 100 GHz.

For the oscillator design, an FET having a gate width of 75 μm and gate length of 0·2 μm was used. Fig. 1*a* shows an SEM photograph of the device. The device features a single gate stripe with three gate feeding pads for minimising the gate finger attenuation. Fig. 1*b* shows the 0·2 μm-long gate defined by the electron-beam machine. Details of the device fabrication process were reported elsewhere.[3] To induce negative resistance (or conductance), a simple bond wire was used from the gate to ground. To further enhance the oscillation, capacitive feedback from the source to ground was used. This feedback capacitor can be realised with the two source pads, which will have a combined capacitance of approximately 0·008 pF. A relatively long source wire was then connected to ground for the DC return. The gate feedback bond wire was connected directly to ground. This scheme is essentially the same as that used for the Q-band oscillators described in Reference 5, except that the bond wire inductance was reoptimised for operation in the 90 to 110 GHz frequency range. To determine the gate inductance and source capacitance required, an appropriate device model derived from low-frequency S-parameter data was used. The values of the feedback elements were optimised using a computer-aided design technique. Fig. 2 shows the negative conductance band of the output looking into the drain terminal with a 50 Ω drain load. It is seen that a peak in negative resistance exists. This broadband negative conductance allows for the oscillator to be tuned over a broad frequency range, either mechanically or electronically.

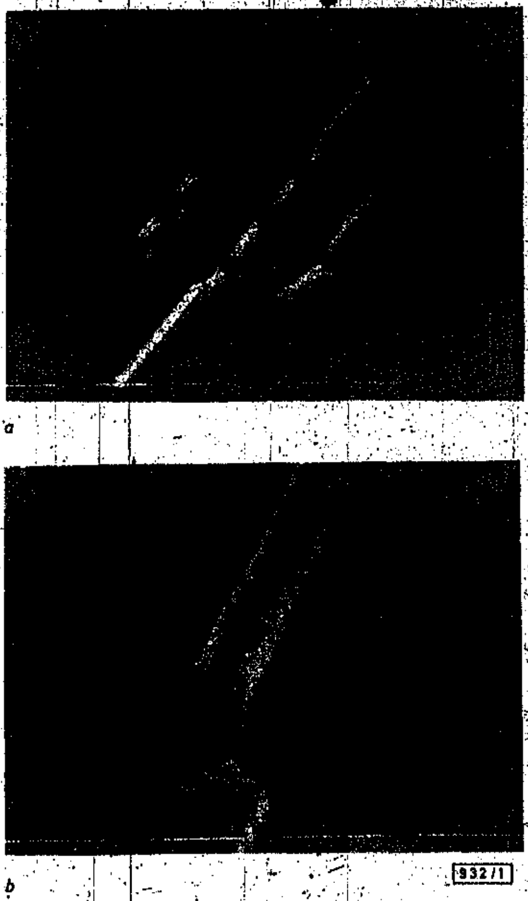

Fig. 1 *SEM photograph of a millimetre-wave GaAs MESFET*

a Device configuration
b 0·2 μm-long gate with 0·5 μm-thick metal

The device with its associated feedback bond wire was mounted in a gold-plated copper block with the drain output

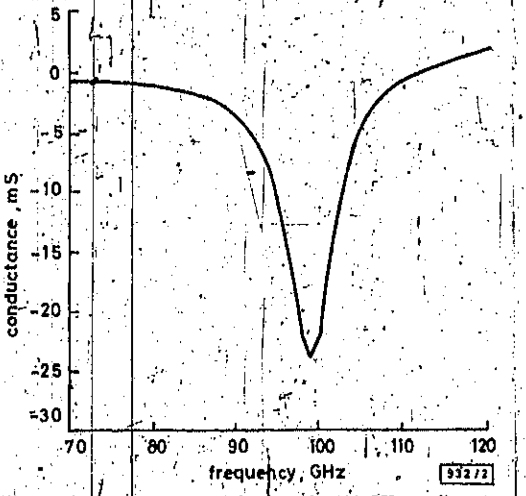

Fig. 2 *Computed negative conductance for 100 GHz oscillator*

connected to a 50 Ω microstrip line. Fig. 3 shows the device mounting configuration. An antipodal fin-line microstrip to waveguide transition was interfaced with the 50 Ω microstrip line for frequency and power determination. This transition is a frequency-scaled version of the type described in Reference 5. Since the purpose of this work is to demonstrate the potential of the GaAs FET device operation around 100 GHz, no effort has been made to minimise the circuit losses. For a given gate feedback inductance, the device can be made to oscillate over the frequency range of 70 to 110 GHz with tuning in the drain circuit. The optimum drain bias was 4 V with a drain current of 15 to 20 mA. The nominal output power ranges from a few milliwatts in the 70 to 80 GHz range to about 0·1 mW at the maximum observed frequency of 110 GHz. With further improvements in the device mounting and circuit implementation technique, it is believed that an output power on the order 10 mW can be achieved at around 100 GHz.

Fig. 3 *Oscillator configuration*

In conclusion, the operation of a three-terminal device (GaAs FET) at a frequency as high as 110 GHz is demonstrated for the first time. With further improvement in the device and circuit implementation technique, the output power can be further improved. The device and circuit designs are such that it also will be suitable for monolithic integration for millimetre-wave EW and communication applications at around 100 GHz.

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MODE SELECTIVITY IN DFB LASERS WITH CLEAVED FACETS

Indexing terms: Lasers and laser applications, Semiconductor lasers

The mode selectivity of distributed feedback lasers with cleaved facets is examined for various positions of the grating relative to the facets. The expected yield of single-mode lasers is calculated for several values of the coupling coefficient.

Introduction: In order to take full advantage of the low loss in optical fibres in the 1·55 μm region a light source with a narrow spectral linewidth is required. A possible candidate is a semiconductor laser incorporating a grating in order to provide distributed feedback (DFB). Although the DFB favours modes near the Bragg wavelength, a laser with nonreflecting mirrors may be multimoded since one mode on each side of the stopband will have the same threshold gain. The resulting spectrum is then determined by the spectral gain which will shift with temperature or under modulation. In a DFB laser with reflecting mirrors (i.e. cleaved facets) the situation is more complicated since the threshold for the various modes depends on the position of the facet relative to the grating ('facet phase'). Various schemes have been proposed in order to bypass this problem:

(i) use a phase shift in the grating[1,2]

(ii) use a structure where the gratings have been partly removed[3]

(iii) employ a tuning section[4]

(iv) adjust the thickness of the facet coating for each laser.[5]

These schemes all complicate the fabrication, and in the following we therefore examine the mode selectivity of devices with cleaved facets in order to assess how serious the problem is.

Analysis and results: The strength of the distributed feedback depends on the product of the coupling coefficient κ and the length of the grating L. A good second-order grating has $\kappa \sim 100\,\text{cm}^{-1}$, and for $L \sim 300\,\mu\text{m}$ this gives $\kappa L \sim 3$. Higher values can be obtained for larger values of L. In theory a higher value of κ can be obtained by using a first-order grating, but this requires a more complicated processing technology. An analysis of various published results has shown that the reported first-order gratings do not have higher values of κ than those obtained by good second-order gratings.

We consider DFB lasers with one or two cleaved facets. In order to simplify the analysis we assume the maximum gain to occur close to the Bragg wavelength, and hence the spectral properties are mainly determined by the threshold gain of the first few modes on each side of the stopband. For given magnitudes and phases of the facet reflection coefficients we find, using the formulas from Reference 6, the difference in threshold gain for the two modes with the lowest thresholds. This calculation is performed for a number of facet phases and we define the 'yield' as the percentage of cases where the difference in threshold gain exceeds a given value. (A possible difference in the radiation loss[7] for the various modes is neglected.)

An analysis along the same lines was reported in Reference 8. In Reference 8 the mode selectivity for DFB lasers with one cleaved facet was given in terms of the threshold currents. For the case of two cleaved facets, results for the variation of the threshold current for the dominating mode due to various