A Voltage Tunable 35 GHz Monolithic GaAs FECTED Oscillator

K. Lübke, H. Scheiber, and H. Thim

Abstract—**Monolithically integrated FECTED-oscillators have been fabricated with high yield, high reliability and precise frequency control. With unoptimized circuits 12 mW with 1.4% efficiency in cw-operation and 25 mW with 2% efficiency in pulsed operation have been obtained. These results represent the highest power output and efficiency of monolithic TED and FET oscillator in this frequency range.**

I. Introduction

It HAS RECENTLY been demonstrated [1]–[3] that planar field effect controlled transferred electron devices ("FECTED's") are capable of producing several tens of milliwatts at *ka*-band frequencies with efficiencies of a few percent and are attractive candidates for applications at higher frequencies as they are not subject to the transit-time ($1/f^2$) limitation conventional TED and FET oscillators are suffering from. This advantage is a result of the reduced electron injection at the cathode contact of a planar transferred electron device. The electron injection is controlled by a negatively biased Schottky gate that prevents Gunn domain formation. The usual transit-time ("Gunn") oscillations are thus suppressed.

Instead, a stationary high field domain forms in the gate-drain region that exhibits a *frequency-independent* negative differential resistance. The FECTED is thus inherently a broad band device and has indeed been operated over a fairly wide range of frequencies [1]. However, in these experiments unpredictable bonding wire inductancies made it impossible to design an oscillator for a desired frequency and kept reproducibility low. In order to overcome these problems monolithically integrated FECTED oscillators have been fabricated. The results obtained with oscillators will be reported in this letter.

II. Device/Circuit Structure

Fig. 1 shows a cross sectional view of the active element (FECTED) used in the MMIC version. It consists of a 0.9 μm thick MOCVD-grown active *n*-layer ($N_D = 5 \times 10^{16}$ cm^{-3}), a Schottky drain contact, an ohmic source contact and a 0.5 μm long Schottky gate with an integrated 10 pF capacitor to source. The device width is 400 μm.

Fig. 2 shows a photograph of a 5 × 5 mm^2 monolithic oscillator chip. The circuit is similar to the microstrip version used previously [1] with one exception: the dielectric resonator used in the hybrid version has been replaced by two sections of transmission lines symmetrically connected to the drain contact of the FECTED [4]. The length of these two bars ("*Y*" section) has been chosen such that they provide inductive impedances to the drain contact. The oscillation frequency is that frequency at which these inductances compensated the device capacitance. Of course, this is valid only if the two other (mushroom-like) resonating elements provide ground potential to both gate and source at the same frequency. The length of these two shorted transmission lines is λ/2 at 35 GHz.

Manuscript received October 18, 1990. This work was supported in part by the Austrian Science Foundation (FWF) and in part by the U.S. Government through its European Research Office.

The authors are with Johannes Kepler Universität Linz, Institut fur Mikroelektronik, Abteilung Elektronische Bauelemente, A-4040 Linz, Austria.

IEEE Log Number 9041649.

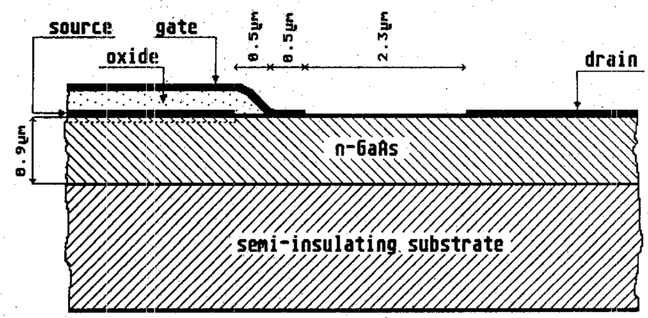

Fig. 1. Cross sectional view of the FECTED.

Experimental Results

FECTED oscillators monolithically integrated with circuits of the type shown in Fig. 2 have produced output power levels as high as 25 mW with 2% efficiency and 12 mW with 1.4% efficiency in cw operation. The devices have been tuned over 1 GHz by varying the negative gate voltage. Fig. 3 shows output power, efficiency and gate voltage plotted against frequency. As can be seen from these plots the frequency of operation varies linearly with gate voltage over a few hundred megahertz. Fig. 4 shows several spectral characteristics measured at three different frequencies. As expected the line width decreases with increasing frequency. However, a comparison with spectral characteristics obtained with discrete dielectric resonator loaded FECTED oscillators /1/ /2/ /3/ shows that the MMIC oscillator version is noisier due to the lower quality factor of the MMIC resonators.

It should be emphasized that all devices fabricated from one batch yielded identical results demonstrating that yield is high when monolithic integration is employed.

IV. Conclusion

Monlithically integrated FECTED-oscillators have been fabricated with high yield, high reliability and precise frequency control which is primarily a consequence of eliminating bonding wires used in hybrid circuits. With unoptimized circuits 12 mW with 1.4% efficiency in cw-operation and 25 mW with 2% efficiency with 1 μs long drain voltage pulses have been obtained. These results represent the highest power output and efficiency of a monolithic TED and FET oscillator in this frequency range. Higher efficiencies should be obtainable with improved coupling circuitry. Of course, FECTED oscillator

1051-8207/91/0200-0035$01.00

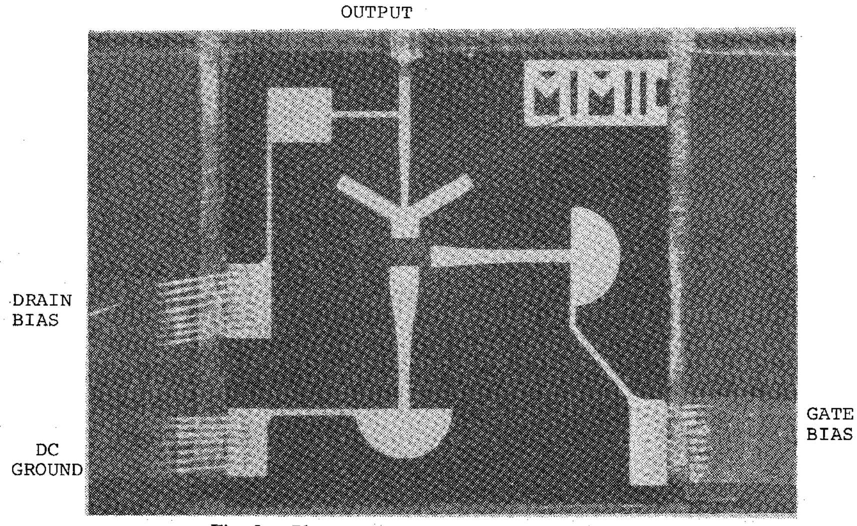

Fig. 2. Photograph of an MMIC FECTED oscillator.

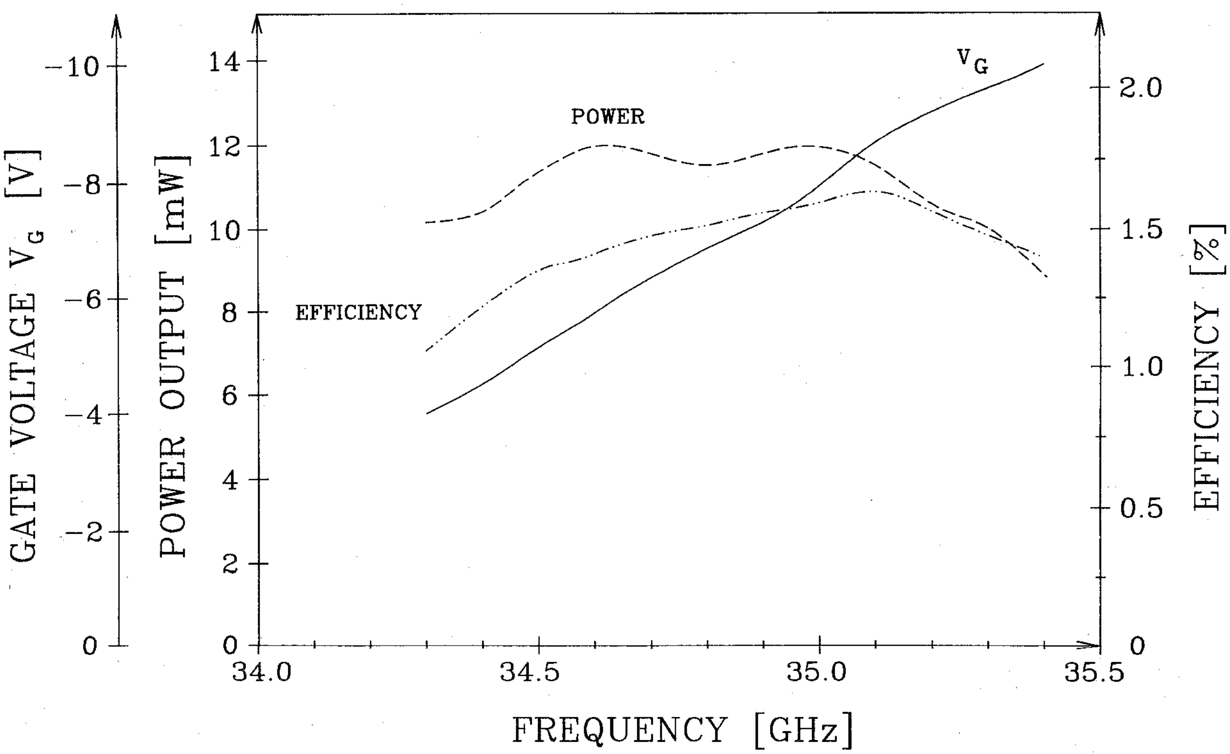

Fig. 3. Output power, efficiency and gate voltage verus frequency of a cw operated MMIC FECTED oscillator.

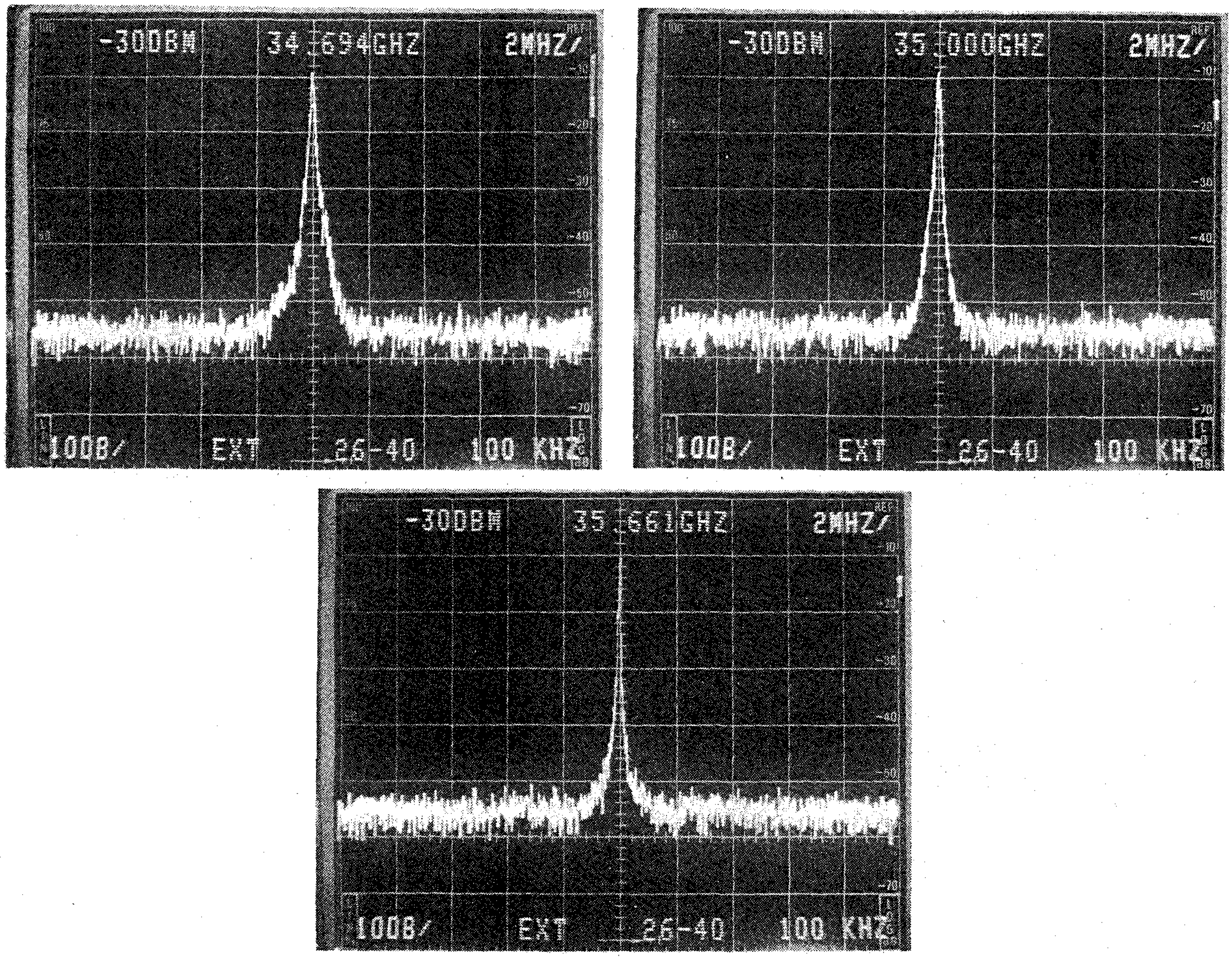

Fig. 4. Spectral characteristics of an MMIC FECTED oscillator.

efficiencies are lower than those obtainable with transistor oscillators at least at lower frequencies but they are presumably comparable at higher frequencies (above perhaps 50 GHz) as circuit matching of a two-terminal device is certainly easier. Also FECTED's do not need extremely small gate dimensions like FETs since FECTED's are not subject to the transit-time limitation.

Acknowledgment

The authors want to thank G. Hofmann, J. Katzenmayer, and G. Roithmayr for fabricating the devices and G. Hofmann for performing the RF measurements.

References

[1] H. Scheiber, K. Lübke, C. Diskus, and H. Thim, "An IC-compatible 45 mW ka-band GaAs TEO," *Electron. Lett.*, vol. 25, pp. 223–334, 1988.

[2] K. Lübke, H. Scheiber, D. Grützmacher, C. Diskus, and H. Thim, "MIMIC-compatible 55 mW InP and GaAs 30–40 GHz field controlled TE oscillators," *IEEE MTT-S Digest*, pp. 729–730, 1989.

[3] H. Scheiber, K. Lübke, D. Grützmacher, C. Diskus, and H. Thim, "MIMIC-compatible GaAs and InP field effect controlled transferred electron (FECTED) oscillators," *IEEE Trans. Microwave Theory Tech.*, vol. 37, No. 12, pp. 2093–2098, 1989.

[4] S. C. Binari, R. E. Neidert, and K. E. Meissner, "Monolithic and discrete mm-wave InP lateral transferred electron oscillators," *IEEE MTT-S Digest*, pp. 683–686, 1988.