OPTICAL MEASUREMENTS OF MICROWAVE GRID OSCILLATOR POWER COMBINERS

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Abstract – **A unique electrooptic sampling technique is used to measure the potential distribution on a 5.8 GHz 25-HEMT grid oscillator power combiner built on a GaAs electrooptic substrate. The grid oscillator is a two-dimensional planar array of HEMT oscillators, backed by a metal mirror that provides feedback and unidirectional radiation. From the measured potential distribution, the current distribution along the radiating leads and bias lines is found. No edge effects were observed on a square grid that is smaller than a free-space wavelength on the side. It was found that each unit cell in the grid can operate independently and that the bias lines provide the boundary conditions necessary for oscillation. Knowing the exact current distribution is important for designing the output power of such quasi-optical combiners.**

Quasi-optical oscillator power combining is a technique for coherently adding the output powers of a large number of devices into a narrow radiated beam. So far, the largest number of devices that have been combined was in a 5 GHz 100-MESFET planar grid oscillator [1], in which the transistors were used as negative resistance devices with radiating gate and drain leads. A similar oscillator with gate feedback was also built at Ku band [2]. In grid oscillators, transistors load a grid with a period that is small compared to a wavelength. The grid is fabricated on a dielectric substrate and backed by a metal mirror that ensures positive feedback and locked oscillation. A transmission line model was used to predict the oscillation frequency of these devices, but the output power cannot be predicted from this model. In this model, the current distribution along the radiating leads was assumed to be uniform. Here we present the actual current distribution obtained from electrooptic sampling measurements. We expect that these results will enable us to design the output power of these devices.

The current distribution along the radiating leads, as well as along the bias lines, is found from measurements of the potential distribution. The potential distribution is measured with respect to the bottom side of the substrate using a unique electrooptic sampling technique [3]. The output of this measurement is a complex number proportional to the integral of the vertical field component through the substrate, as shown in Figure 1. The surface charge distribution can be found from the measured voltage distribution using a static Green's function for the structure in one cross section:

$$G(r) = \frac{1}{4\pi\epsilon_0\epsilon_r}\left[\frac{1-\beta}{r} - \frac{1-\beta^2}{\sqrt{r^2+d^2}} + \frac{\beta(1+\beta^2)}{\sqrt{r^2+(2d)^2}} - \dots\right]$$

where $\beta = (1-\epsilon_r)/(1+\epsilon_r) \simeq 0.85$ for GaAs. Using the static Green's function is justified by the fact that the measured voltage distribution has a standing wave form. After obtaining the charge distribution from a moment method solution, the surface current along the metal leads can then be found as

$$J(r) = -\frac{\delta}{\delta t}\int_{r_0}^{r} \sigma(r')\mathrm{d}r',$$

where r_0 is a point where the charge is equal to zero and $\sigma(r)$ is the surface charge distribution.

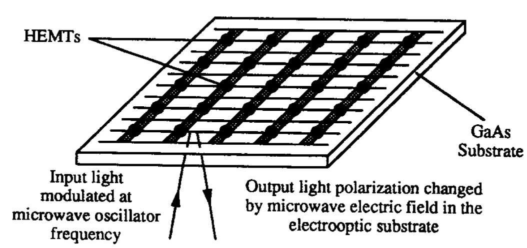

Figure 1. Electrooptic sampling of the grid oscillator built on a GaAs electrooptic substrate.

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A 25-HEMT grid oscillator with a 5 mm period was built on a 0.5 mm thick GaAs electrooptic substrate using Fujitsu FHX35X HEMTs. Using the model presented in [1], the grid was designed to lock around a 5.89 GHz frequency that corresponds to a multiple of the pulse repetition rate of the laser in the sampling setup. The chip devices were epoxied onto the gold plated grid leads, and the gate, drain and source pads were bonded to the leads. A sketch of the grid is shown in Figure 2, where the vertical leads are the gate and drain radiating leads, and the horizontal ones are the source leads and the gate and drain bias lines. This grid oscillated between 4.5 and 7 GHz, depending on the bias point and the mirror position. For the sampling measurements, an operating point of 5.89 GHz was chosen, and the grid was quasi-optically injection-locked to a synthesized source at the closest harmonic of the laser repetition rate. The data was then calibrated [3], and the resulting measured potential distribution along a radiating column, as indicated in Figure 1, is shown in Figure 3. The measured phase jumps by roughly π when going through each transistor, and is periodic along the radiating leads. The charge distribution is calculated from a fit to the potential distribution,

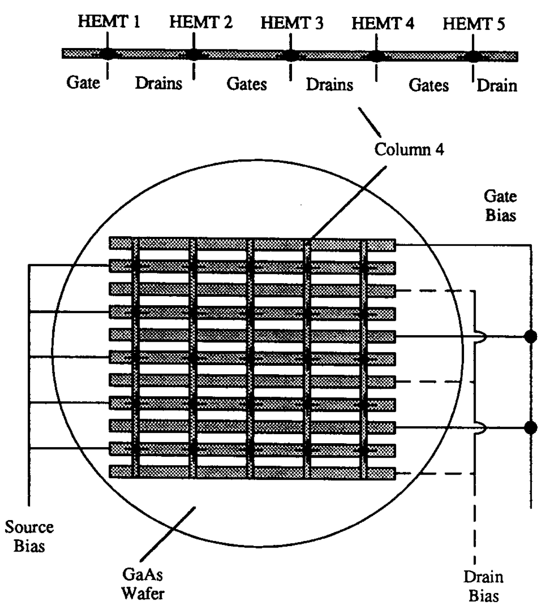

Figure 2. The 25-HEMT grid oscillator. A radiating column is shown in more detail. The results of optical sampling measurements on this column are shown in Figure 3.

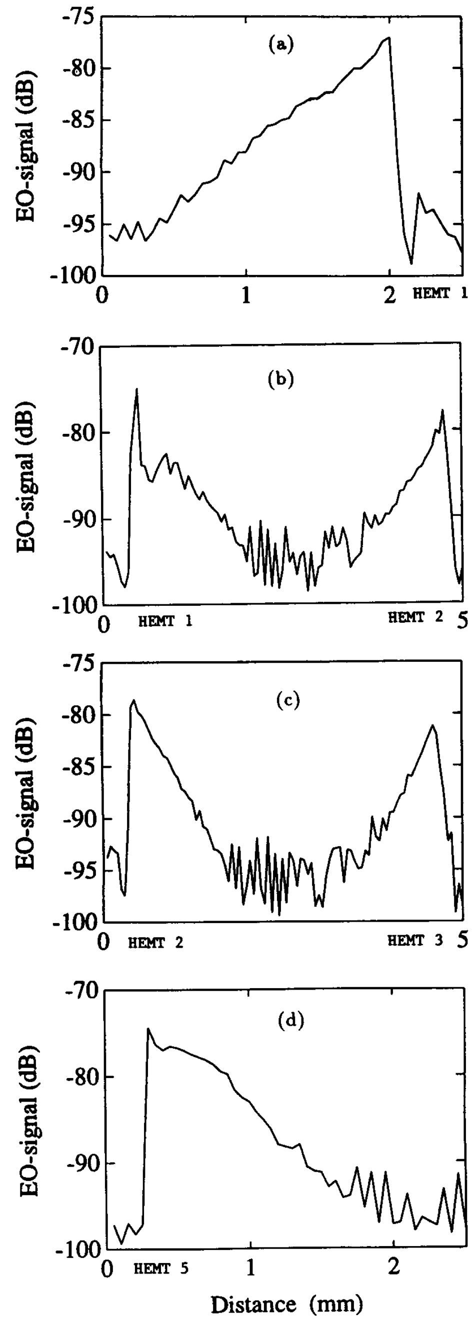

Figure 3. The measured potential distribution along a radiating column: (a) along first gate lead, (b) between HEMT1 and HEMT2 along their drain leads, (c) between HEMT2 and HEMT3 along their gate leads, and (d) along the last drain lead. The spacing between devices is 5 mm, and no measurements could be made directly at the HEMTs due to the metalization of the back side of the chips.

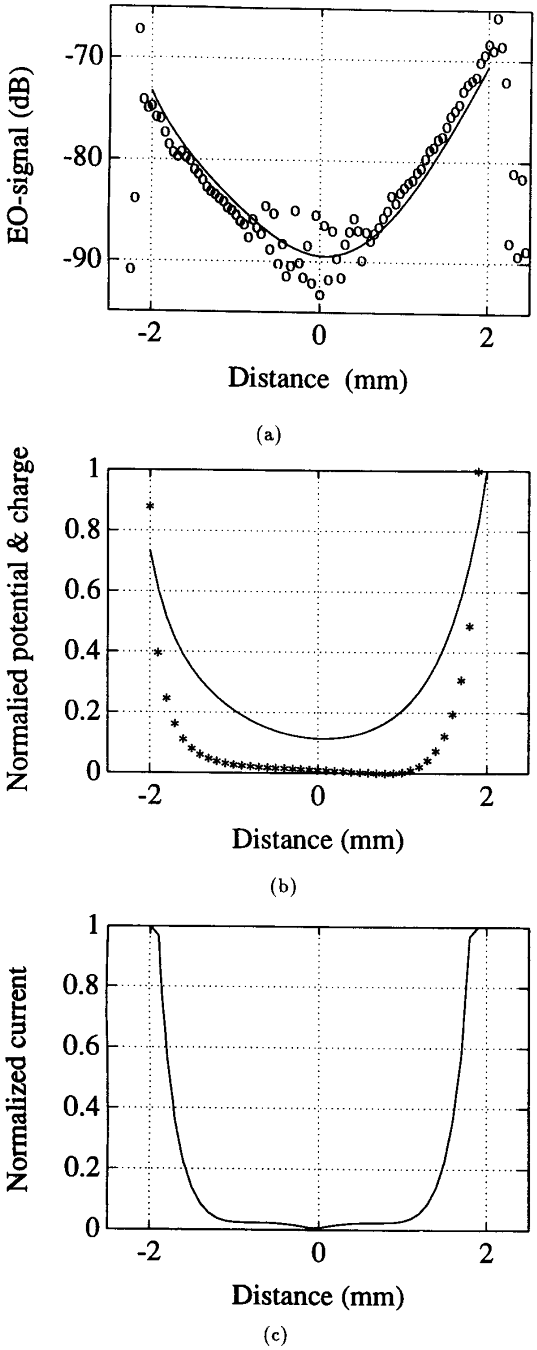

Figure 4. (a) Fitted potential distribution along a radiating lead, shown in solid line on a dB scale. (b) Potential distribution shown in linear scale with solid line and calculated charge distribution, shown in dotted line. (c) Calculated current distribution along two adjacent drain leads.

Figure 4(a) and (b). The resulting current distribution is calculated by integrating the charge distribution, and is shown in Figure 4(c). This measured current distribution is quite different from the uniform one assumed in the transmission line models [1,2].

The electrooptic sampling measurements also show that there is very little current flowing in the source leads and none flowing in the gate and drain bias lines, which can be seen from the measured potential distribution shown in Figure 5. In addition, the

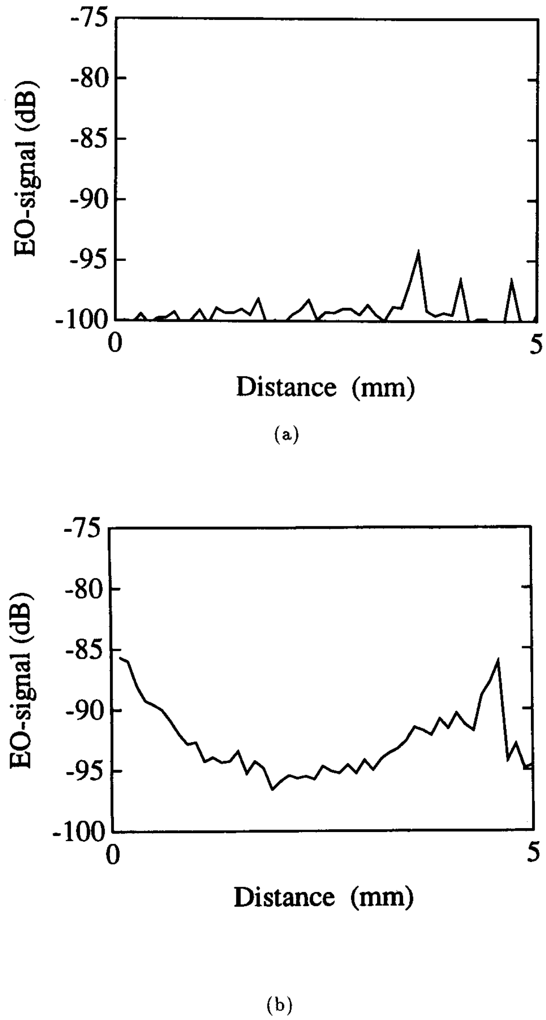

Figure 5. Measured potential distribution along two source leads (a) and gate bias lines (b). The maximum value of the source potential is much smaller than those of the gates and drains.

distribution along two adjacent radiating gate leads is essentially the same as along the drain leads. Surprisingly, the measured potential distribution across the whole grid shows no edge effects. This leads to the interesting conclusion that each transistor is working independently, and that the current distribution is determined by the geometry of the grid. This was confirmed by measurements in a single unit cell, with only one device biased and operating. A two-dimensional plot of the measured potential distribution across a unit cell with three devices in one row operating is shown in Figure 6. The radiation pattern of the whole grid oscillator depends on the exact current distribution on the leads. Once the radiation pattern of the grid is well known, the grid output power can be designed by calibrating the current amplitude in a single unit cell with a given active device.

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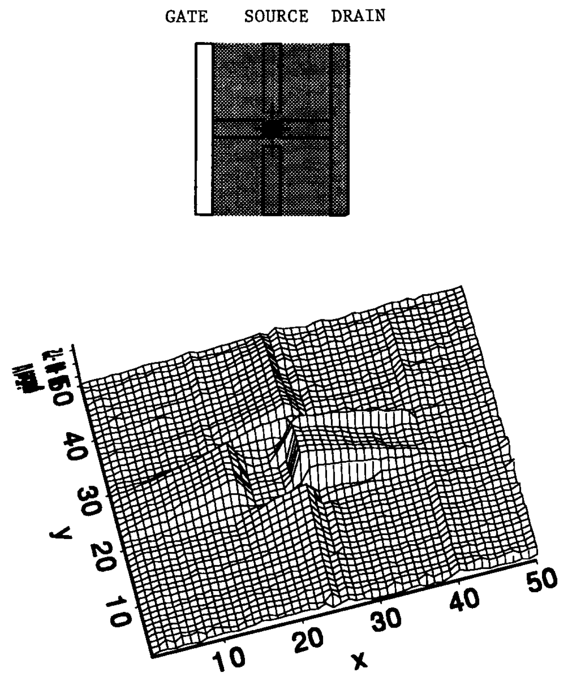

Figure 6. Measured two-dimensional potential distribution across a single unit cell operating in a row with three HEMTs biased. The shaded region in the unit cell shows the measured area .