A 1.7–1.9 THz Local Oscillator Source

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***Abstract*—We report on the design and performance of a ×2 × 3 × 3 frequency multiplier chain to the 1.7–1.9 THz band. GaAs-based planar Schottky diodes are utilized in each stage. A W-band power amplifier, driven by a commercially available synthesizer, was used to pump the chain with 100 mW of input power. The peak measured output power at room temperature is 3 μW at 1740 GHz. When cooled to 120 K, the chain provides more than 1.5 μW from 1730 to 1875 GHz and produced a peak of 15 μW at 1746 GHz.**

***Index Terms*—Frequency multiplier, local oscillator, Schottky diode, THz technology, varactor.**

I. Introduction

An IMPORTANT goal of the astrophysics community is to perform a systematic survey of the ionized carbon fine-structure line at 1900.5 GHz to gain a better understanding of the chemistry and energy balance of the interstellar medium. However, the viability of such a measurement is strongly dependent on the availability and deployability of compact solid-state local oscillators at 1.9 THz. Though much progress has been made recently on generating millimeter and submillimeter wave power [1]–[3], obtaining sufficient power levels at 1.9 THz to pump heterodyne mixers remains a considerable challenge. In this letter, we report on recent results from a fully solid-state LO chain that have been achieved by cascading three multiplier stages. The output power from this broadband tunerless source ought to be sufficient to pump HEB mixers based on recent results at a slightly lower frequency [4].

II. Frequency Multiplier Designs

The first multiplier in the chain uses a six-anode balanced doubler chip that produces power in the design band of 184–212 GHz. Details of similar doublers have been presented before [5]. The room temperature output power from the first stage is in the 9–29 mW range with 100 mW of input power, with the doubler working better at the lower end of the band.

The second stage multiplier is a balanced tripler based on a lower frequency tripler described in [1]. The circuit and diode chip are shown in Fig. 1.

At the input frequency the diodes are in series with a short-circuited line, which provides the correct input reactance. This stub is grounded using beam leads on the far side of the output waveguide, which also provide dc return for the bias. The output waveguide is cutoff at the input frequency, so no additional filtering is needed at this frequency, but the line crossing the waveguide has very high impedance and so the waveguide must have quite reduced height in order to avoid adding excessive input inductance.

At the output frequency, two radial stubs provide short circuits at either diode, and ensure that little power couples back to the input. The diodes couple to the output waveguide via the wide suspended line, which also provides impedance matching. The narrow lines connecting to the diodes provide the required output inductance. Additional impedance matching is provided by a step transformer up to full height waveguide, and by a fixed backshort in the waveguide. The diode loop has nearly optimum second harmonic inductance at midband without producing excess inductance at the output frequency.

The final stage of the LO chain is a balanced tripler made with membrane [6] technology. It is a split-block waveguide design using two Schottky planar varactor diodes in an antiparallel configuration at the RF frequency. Each anode is nominally 0.4×0.8 μm (epilayer doping 5×10^{17} cm^{-3}).

The waveguide block includes a 1.8-THz diagonal feed-horn machined in two symmetrical parts. The dimensions of the output waveguide were chosen to cutoff any signal below 1415 GHz. This was important to prevent second harmonic leakage. The circuit is integrated on a 3 μm thick frameless GaAs membrane located between the input waveguide and the output waveguide, inside a $46 \times 25 \times 123$ μm channel. Four 1 μm thick gold beam-leads, located on either side of the membrane, suspend the chip above the bottom half of the channel. Two of them provide the required dc and RF connections for the diodes. This tripler design along with the expected performance was described in detail elsewhere [7]. The picture of the completed chip inside the waveguide block is shown in Fig. 2. A close-up of the anode area is also shown in Fig. 2. The two diodes are positioned on each side of a high impedance line. They are connected in series at dc. One has its anode grounded to one side of the channel by a first beam-lead, the other has its cathode grounded to the other side of the channel by a second beam-lead. Due to the symmetry of the field at the fundamental frequency (quasi-TEM mode), the diodes appear in an antiparallel configuration at RF. The second harmonic is trapped in a virtual loop and cannot propagate in other parts of

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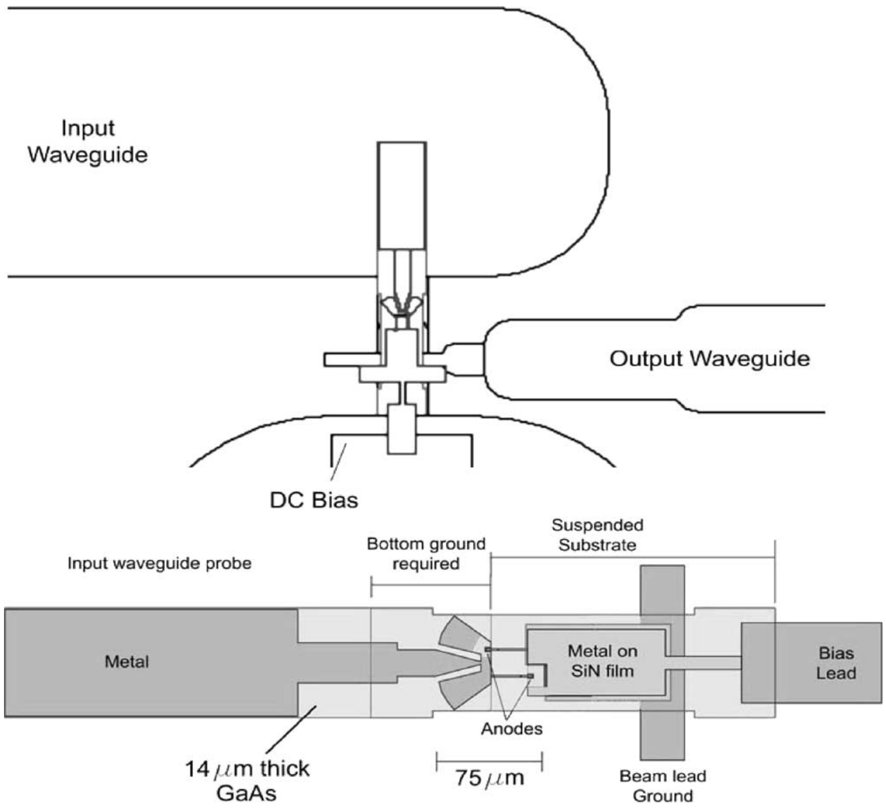

Fig. 1. Cross section through the 600-GHz tripler (top) and a detail of the diode (bottom).

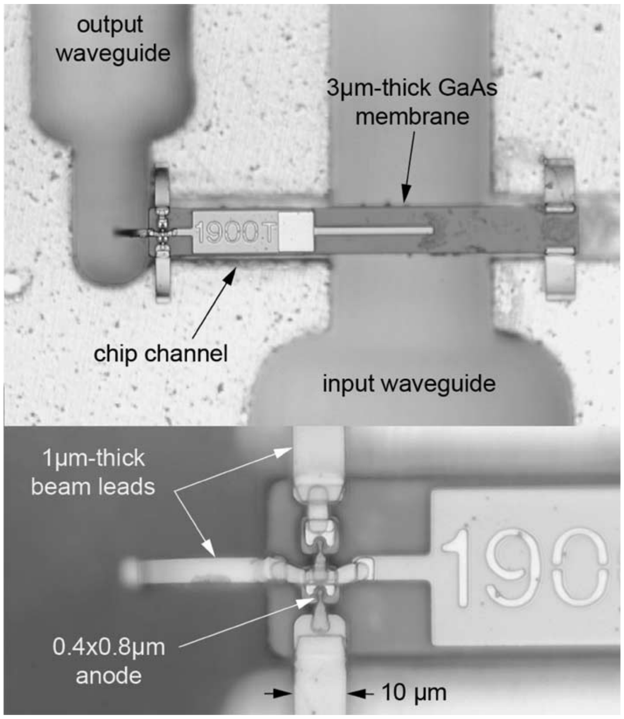

Fig. 2. The 1.9 THz balanced tripler chip in its wave guide structure (top). Detail of the anode area (bottom).

the circuit. This topology offers the advantage of a very small phase shift between the two anodes and the possibility to tune the matching at the idler frequency by adjusting the length of the beam-leads that ground the diodes. By using a mesa size of 7 $\mu\mathrm{m} \times 7$ $\mu\mathrm{m}$, we were able to place the device in a 46 $\mu\mathrm{m} \times 25$ $\mu\mathrm{m}$ channel, which is important to prevent higher order modes from propagating inside the channel.

III. POWER MEASUREMENTS

A commercial synthesizer with sextupler head was used to drive a MMIC-based W-band power amplifier [8]. Although this amplifier can provide more than 200 mW from 89 to 106 GHz, the W-band power was kept constant at 100 mW for the measurements presented here to avoid damaging the second stage multiplier.

The output power from the first stage doubler was measured with an Erickson calorimeter [9] that provides a broadband match at the output frequency. The power produced by the second stage multiplier (the 600 GHz tripler) was measured by attaching an external Picket–Potter horn directly to the tripler output flange and measuring the power with a Thomas Keating meter. A loss of 0.7 dB was assumed for the horn. Measuring the output power quasioptically allowed us to cool the $\times 2 \times 3$ chain to estimate the input power to the final stage tripler. The measured results at 120 K are shown in Fig. 3. The input power to the first tripler is relatively flat, and the structure in the output spectrum of the $\times 2 \times 3$ chain comes from the interaction between the multipliers.

Measuring the output power at 1.8 THz with any certainty is a tedious and difficult undertaking. A Golay cell with a diamond window was used as the primary detector based on its speed, sensitivity, and flat frequency response. The Golay was first calibrated against the Thomas Keating meter. A nitrogen-purged

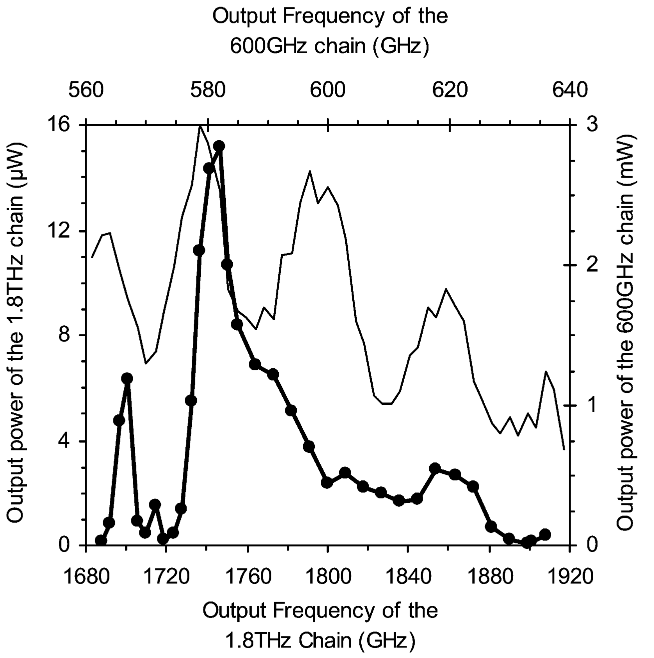

Fig. 3. Performance of the 1.8-THz chain (dark line with dots) along with the performance of the ×2 × 3 chain to 600 GHz (lighter line) are shown at 120 K. The input power to the first doubler was nominally 100 mW.

Plexiglas enclosure was used to reduce RF losses due to water absorption, and the beam path in air was minimized to only 2 cm. No corrections to the data were made for any atmospheric losses. Low-loss 1.0-THz high-pass and 2.0-THz low-pass filters were used to check that no out-of-band radiation biased the measurements.

An output power of 3 μW and estimated conversion efficiency of 0.2% were measured at room temperature at 1740 GHz. When cooled to 120 K, the chain covers the band 1730–1875 GHz with an output power of at least 1.5 μW. A maximum of 15 μW and estimated conversion efficiency of 0.6% were measured at 1746 GHz (see Fig. 3).

IV. CONCLUSION

An all solid-state, compact, robust and space-qualifiable local oscillator for 1.7–1.9 THz has been described. The LO chain consists of three cascaded frequency multipliers $(\times 2 \times 3 \times 3)$ and produced a peak power of 15 μW at 120 K. It is believed that this performance can be improved by further optimizing each stage.

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