paper Mo-C1-3 - 26th Int. Conf. on Indium Phosphide and Related Materials (Montpellier, France, May 11-15, 2014)

A Sub-mW D-band 2nd Harmonic Oscillator Using InP-based Quantum-effect Tunneling Devices

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***Short-Abstract*— A compact D-band 2nd harmonic oscillator utilizing a push-push approach is demonstrated for the first time by using InP-based RTDs (resonant tunneling diodes). In order to achieve the low power operation, the NDC (negative differential conductance) characteristic at a low voltage of the RTD is used for RF signal generation. The implemented RTD-based oscillator by using an InP-based RTD MMIC technology operates at an oscillation frequency of 164.6 GHz. The total dc power consumption of the RTD oscillator is 0.4 mW, which is the lowest value reported up to date in the mm-wave D-band MMIC oscillators.**

I. Introduction

The InP-based RTD has attracted a great deal of interests in high frequency oscillator applications because of the excellent NDC characteristics and strong I-V nonlinearity. In our previous work, we demonstrated various RTD-based oscillators operating in the Ku-band [1], Ka-band [2], and 5.8 GHz ISM-band [3] with extremely low dc power consumption. The extremely low power performance of the RTD-based oscillators is attributed to the excellent inherent NDC characteristic of the RTD achieved at a low applied voltage. In recent year, the demands for the high-frequency oscillator operating at mm-wave have been increased because of its numerous applications such as high data rate wireless communications, spectroscopy, and imaging [4]-[6]. The RTD is one of the most promising electron devices for the high-frequency mm-wave oscillators [7] due to the very fast switching speed and small parasitic capacitance [8].

In this work, we demonstrate a low power RTD oscillator operating at the mm-wave D-band. In order to achieve the high frequency operation and low power consumption, the push-push principle is utilized for the RTD oscillator design. The designed RTD oscillator has been implemented by using an RTD MMIC (monolithic microwave integrated circuit) technology.

II. Operation Principle And Device Technology

Fig. 1 shows the circuit schematic diagram of the low power RTD oscillator, which is proposed by exploiting the low-power/high-frequency capabilities of the push-push topology [2]. The proposed RTD push-push oscillator consists of a LC resonator tank and two RTD devices which are used as the negative conductance cell of the oscillator. The two RTDs are biased at 0.45 V to compensate for the losses associated with the LC resonator tank. The CPW (coplanar waveguide) type transmission line is used as the inductor in the LC resonator to achieve high Q factor characteristic at the D-band. To operate the oscillator in a voltage controlled oscillation mode, two varactor diodes (C_{var}) are used as the capacitor in the LC resonator. At the center node between two CPW lines, the anti-phase fundamental frequency components cancel out, whereas the in-phase 2nd harmonic components sum up being extracted to the output port, based on the push-push principle [9]. The previous reported design theories of the tunneling-diode based oscillator [1] are considered to satisfy the oscillation condition under the proper push-push mode operation [2], [9].

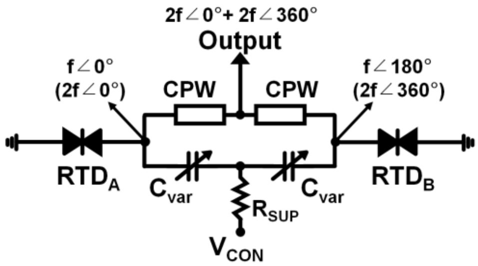

Fig.1. Schematic diagram of the RTD-based push-push type oscillator.

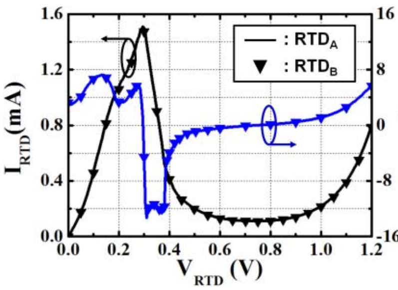

Fig.2. Measured dc I−V and differential conductance (g_d) characteristics of the fabricated RTDs.

An InP-based RTD MMIC technology has been used to fabricate the proposed RTD oscillator. The double-barrier quantum-well structure of RTD, stacked on the HBT layers, is composed of AlAs/InGaAs/InAs/InGaAs/AlAs layers. The detailed layer structure and the fabrication process have been described elsewhere [1]. As shown in the measured dc characteristics of the fabricated RTD with an emitter area of 1.6 × 1.6 μm^2 (Fig. 2), the RTD shows a peak voltage (V_P) of 0.3 V and a peak current (I_P) of 1.51 mA with a relatively high PVCR of 13.7 at room temperature. The RTD exhibits the negative conductance characteristics in a voltage range from 0.3 to 0.6 V.

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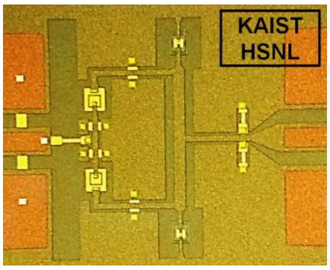

Fig.3. Microphotograph of the fabricated push-push mode RTD integrated circuit oscillator (chip size: 220×430 μm^2).

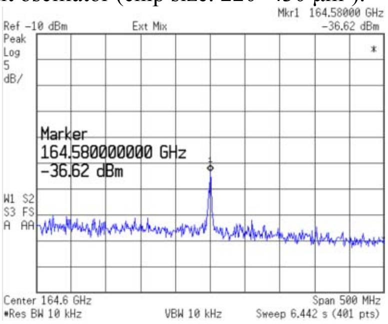

Fig.4. Measured output spectrum of the fabricated RTD oscillator.

III. Measurement And Discussion

Fig. 3 shows the microphotograph of the fabricated oscillator with a chip area of 220×430 μm^2 excluding the pads. The room temperature measurement of the fabricated RTD oscillator was performed on wafer. The RF output was probed using a GSG waveguide probe, and the DC voltages were supplied through the DC probes. The oscillation frequency and output spectrum of the RTD oscillator were measured using an Agilent E4407B spectrum analyzer and a QMA-DPD0000 D-band harmonic mixer. Fig. 4 shows the measured output spectrum of the fabricated RTD oscillator. The oscillation frequency was 164.6 GHz. The tuning range for the oscillation frequency was 2.7 GHz. The output power was measured using a D-band power sensor and an Erickson PM4 power meter. The RF output power of -36.5 dBm was obtained at the output port of the RTD oscillator under the supply voltage of 0.38 V with an RTD bias current of 1.05 mA. The corresponding dc power consumption of the oscillator was 0.4 mW. The obtained low power characteristics of the fabricated oscillator are mainly originated from the excellent NDC characteristics of the RTD obtained at the low bias voltage and current condition.

Table I shows the performance comparison of the fabricated RTD oscillator with other low-power oscillator ICs reported in the D-band frequency range. The results show that, compared to the conventional transistor-based D-band oscillators, the proposed RTD push-push oscillator operates at sub-mW low power consumption. The low power consumption of 0.4 mW is the lowest value reported up to date in the mm-wave D-band MMIC oscillators.

IV. Conclusion

A low power D-band 2nd harmonic RTD oscillator has been proposed and demonstrated based on an InP RTD MMIC technology. The fabricated oscillator showed the low power consumption of 0.4 mW at an oscillation frequency of 164.6 GHz. Compared to the reported conventional low power VCOs in the D-band, the RTD-based 2nd harmonic oscillator can be considered to be one of the best candidates for the low power practical mm-wave D-band applications.

TABLE I

Performance Comparison with Other Low-power Oscillator ICs Operating at The D-band.

	[10]	[11]	This work
Technology	65 nm CMOS	65 nm CMOS	**1.6 μm RTD**
f_{center} (GHz)	125	118.3	164.6
Supply Voltage (V)	1.0	1.0	**0.38**
Power Consumption (mW)	17	5.6	**0.4**

Acknowledgment

This research was supported by the Pioneer Research Center Program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning (grant number- 2012-0009594).

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