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A Wide-Range Variable-Frequency Resonant Tunneling Diode Oscillator Based on a Novel MEMS Phase Shifter

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Abstract

A resonant tunneling diode oscillator having a wide frequency variation range was proposed based on a novel MEMS phase shifter, which exploits the change of the signal propagation velocity according to the movable ground plane. Basic operation was demonstrated with a prototype device. It showed a wide frequency change of about 100 %.

1. Introduction

A resonant tunneling diode (RTD) oscillator is one of the most promising candidates for THz signal sources. Fundamental oscillations over 1.9 THz have already been demonstrated [1]. In addition to the THz sources, the RTD oscillators can be a basis for various sensors [2]. Such applications often need control of the output frequency in a wide frequency range. For example, RTD oscillators having a wide frequency sweeping range can be used for THz spectroscopy. A variable capacitance diode can be used for such oscillators to control the resonant frequency. However, it is difficult to obtain wide frequency range due to the limited capacitance variation.

In this paper we propose a novel variable frequency RTD oscillator having a wide frequency range, based on the MEMS phase shifter we proposed recently [3]. Experimental demonstration of the basic operation is also shown with a simple prototype device.

2. A resonator based on a novel MEMS phase shifter

Here, we use a shorted coplanar waveguide (CPW) stab as a resonator. The resonant frequency of this resonator can be controlled by the MEMS phase shifter we proposed recently [3]. Figure 1 shows the basic concept of the variable frequency resonator. It has a movable ground plane on the CPW resonator. The distance between the CPW and the ground plane determines the signal propagation velocity, and hence the resonant frequency.

The operating principle of this phase shifter is explained by the inductance reduction when the ground plane is approaching to the CPW. The magnetic field around the signal line of the CPW is blocked by the ground plane, which reduces the inductance. This situation is shown in the Fig. 2, where the magnetic field distributions for two ground plane positions obtained by simulation are shown. This reduction is much larger than the increase in the capacitance between the ground plane and the CPW. Consequently, lower ground plane position makes higher signal propagation velocity. It should be noted that the dependence of the signal propagation velocity on the ground plane position is opposite to that of the conventional distributed MEMS transmission line (DMTL) phase shifters, where the velocity decreases when the bridges on the CPW approach to the signal line.

This phase shifter has various advantages beyond the DMTL phase shifter. First, this is made of a very simple structure, and its operation frequency is not limited by the Bragg frequency. Moreover, analog phase control is possible, if the ground plane position can be controlled continuously. It is possible, for example, by using a comb drive

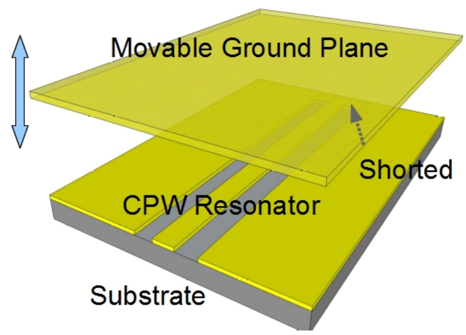

Fig. 1 Basic configuration of the CPW resonator with a controllable resonant frequency.

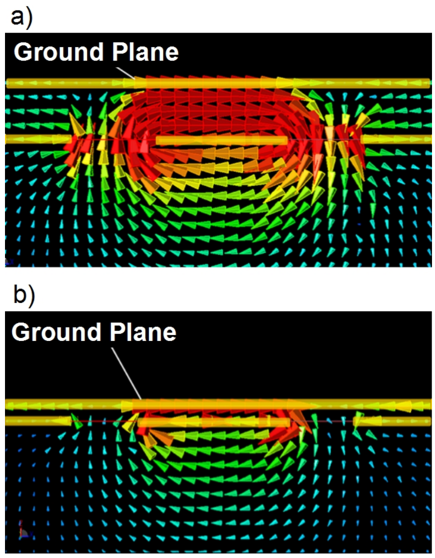

Fig. 2 Magnetic field distributions for two ground plane positions obtained by electromagnetic simulation.

actuator. With such mechanisms, this resonator can sweep the resonant frequency continuously, which is advantageous for various applications.

3. Experiments

The RTD shows negative differential resistance (NDR) in a very wide frequency range from dc to higher than 1 THz. This indicates that the combination of the RTD and the resonator discussed above can be a variable frequency oscillator with a very wide frequency range. To demonstrate this possibility, we fabricated the RTD oscillator having a shorted CPW resonator as shown in the Fig. 3. The circuit was fabricated with InGaAs/AlAs epitaxial layers grown on an InP substrate using conventional photolithography and lift-off process. It has two identical CPW resonators and the bias stabilization resistor. The oscillation was monitored through the bias line using the bias T.

To demonstrate the effects of the movable ground plane, we fabricated the experimental equipment as shown in Fig. 4. The movable ground plane was attached to the micrometer head, so that the distance between the CPW and the ground plane can be controlled with a μm precision. The oscillator circuit was put on a print circuit board. The output port was connected to the SMA connector through the bonding wire. The oscillation frequency of the circuit was designed to be about 10 GHz, which was limited by the bandwidth of the SMA connector. The movable ground plane can be integrated using MEMS technology in future.

Figure 5 shows the experimental result of the oscillation frequency as a function of the ground plane position. Simulation results are also plotted in the figure. When the ground plane is far from the CPW, the oscillation frequency is around 10 GHz. The frequency increases when the ground plane approaching the CPW, and it reaches at about 20 GHz when the ground plane position is 1 um from the CPW. These frequencies are in good agreement with the simulation results. It should be noted that the large frequency change of nearly 100 % can be obtained with this oscillator, which is promising to various applications such as spectroscopy.

4. Conclusions

We have proposed the RTD oscillator having a wide frequency variation range based on a novel MEMS phase shifter. Basic operation was demonstrated with a prototype device.

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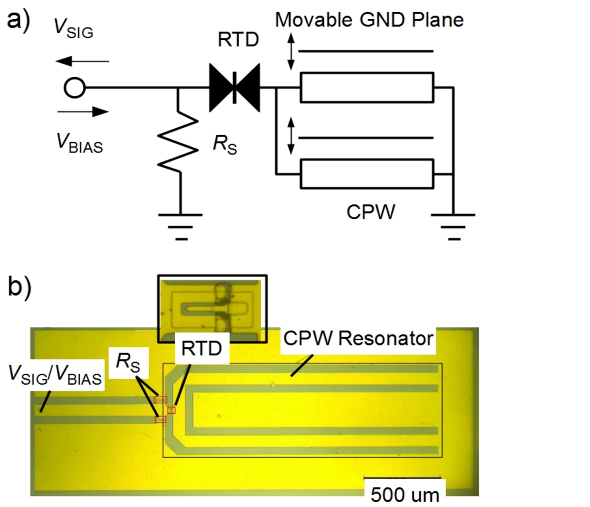

Fig. 3 Circuit and the microphotograph of the fabricated oscillator..

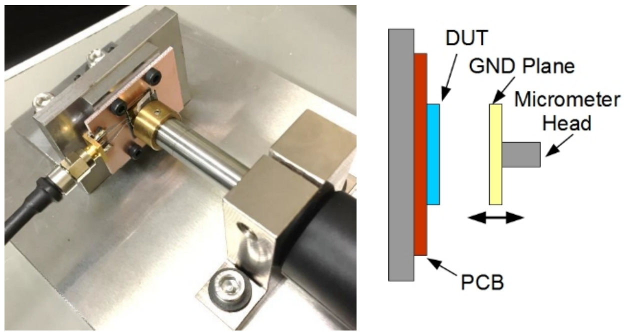

Fig.4 Experimental setup.

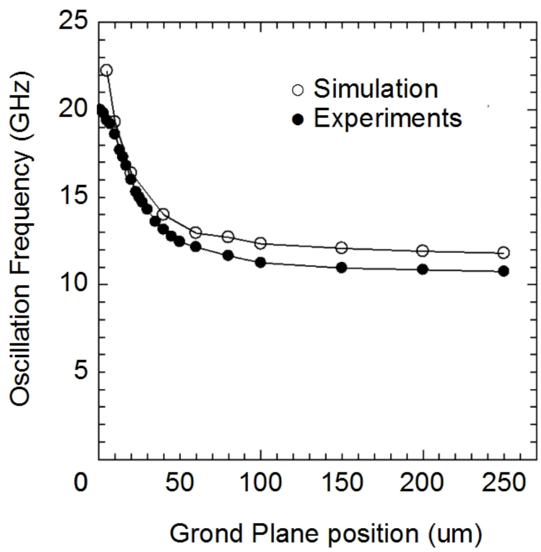

Fig. 5 Oscillation frequency as a function of the ground plane position.