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A Resonant Tunneling Super Regenerative Detector with Input/Output Isolation and Improved Sensitivity

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Abstract

A super regenerative detector (SRD) using a resonant tunneling diode (RTD) oscillator featuring Input/Output (I/O) Isolation was designed for ultrahigh frequency detectors. A key is to detect higher frequency signals than the free running one. This permits us to implement the I/O isolation easily by incorporating a high pass filter at the input port. The circuits were fabricated with the RTDs on an InP substrate, and high frequency signal detection at 50 GHz was demonstrated with improved sensitivity.

1. Introduction

Recently, a resonant tunneling diode (RTD) has been attracting a great deal of attention for THz signal sources. Fundamental oscillations over 1 THz have already been demonstrated with RTD oscillators [1]. In addition to the THz sources, the RTD oscillators can be a basis for various sensors and detectors [2-6]. Among them, a super regenerative detector (SRD) [7] is an interesting application of the RTD oscillators [3]. Most recently, we have proposed a novel SRD using an RTD oscillator [4], and a fundamental operation was demonstrated with a simple circuit [5, 6]. It is based on the response of the RTD oscillator to higher frequency signals than the oscillation frequency. This has various advantages, such as circuit simplicity, easy design, and low power consumption. Employing the higher frequency input also has an additional advantage, that the input/output (I/O) isolation is easily implemented. The leakage of the oscillation power to the input port is a significant problem in the conventional SRDs. Moreover, the I/O isolation is difficult for two-terminal devices such as RTDs. In this paper we report on the design, fabrication and demonstration of the resonant tunneling SRD featuring the I/O isolation.

2. Design of the SRD

Figure 1 shows the basic configuration of the SRD. A key point is that the circuit is driven by a periodic pulse signal to stop oscillation periodically. The operation of the SRD is illustrated in Fig. 2. The SRD is based on the change of the oscillation start time after the circuit is biased in the oscillation condition. The oscillation start time changes depending on the power of the RF input. This permits us to detect the input signal. This phenomenon is explained by the initial condition difference in the oscillator circuit [7]. The oscillation can not start instantly, even when the circuit is biased in the oscillation condition. The oscillation is initiated by the fluctuations due to thermal or external noises. When the input RF signal is introduced, this signal replaces the fluctuations. Conventionally, the input signal frequency was identical to the free running oscillation frequency.

Recently, we proposed a resonant tunneling SRD, which detects much higher frequency than the free running one [4], and have demonstrated a basic operation [5, 6]. This technique has another advantage that the I/O isolation is easily implemented based on the difference in the input/output frequencies. Here, we newly designed a circuit shown in Fig. 3 to include the input port with I/O isolation, and to improve sensitivity. This circuit includes a high pass filter (HPF), which passes the input high frequency signal to the RTD oscillator and blocks the oscillation signal leakage to the input. This I/O isolation scheme based on frequency difference is effective not only for the SRD but also for various RTD circuits. The output signal was pulled out via small capacitance to avoid interference.

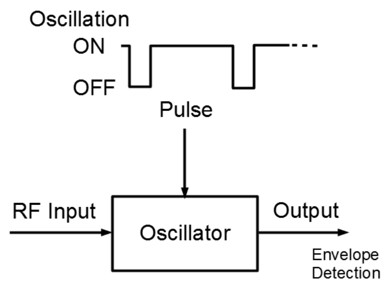

Fig. 1 Basic configuration of the SRD.

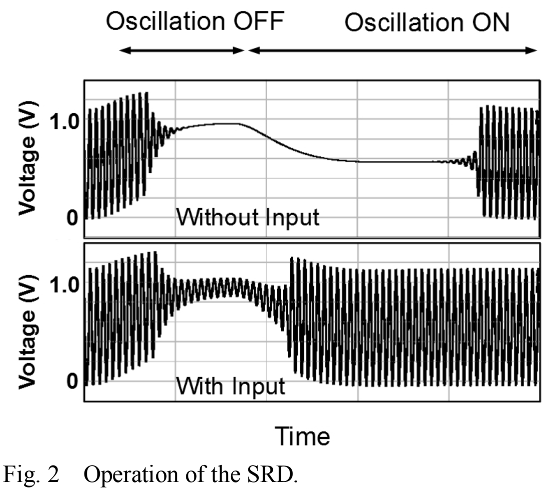

Fig. 2 Operation of the SRD.

3. Experiments

We fabricated the circuits with InGaAs/AlAs epitaxial layers grown on an InP substrate using conventional photolithography and lift-off process. The output buffer circuit was fabricated on a printed circuit board using a commercial heterojunction FET, and bonding wires were used for some inductors in Fig. 3 (L_o and L_{R2}). Figure 4 shows an microphotograph of the fabricated integrated circuit. Interdigital capacitors and meander (line) inductors were used on the chip. The input HPF was designed to have a cut off frequency of 50 GHz.

The experimental configuration is shown in Fig 5. We used a pulse generator for the bias voltage, which was synchronized to the RF generator by 10 MHz time base connection.

The free running frequency of the circuit was around 1 GHz depending on the length of the bonding wire, which is a part of the resonator. Figure 6 shows examples of the output waveforms of the circuit. In this figure, the arrows show the start of the oscillation. The bias voltage was 0.28 V with a periodic negative pulse, which stops the oscillation. The pulse height, width, and period were -0.25V, 20 ns, and 160 ns, respectively. The oscillation begins at a certain time after the pulse, as shown in the upper figure. The oscillation begins earlier, when the 50 GHz input signal is fed to the circuit as shown in the middle and lower figures. The difference of the delay time was as large as 30 ns, which is much larger than the previous report [5, 6]. This large difference indicates high sensitivity of the SRD.

4. Conclusions

We have designed and fabricated the super regenerative detector using an RTD. Input/output isolation was implemented based on frequency difference. Operation of the super regenerative detector for high frequency input was demonstrated.

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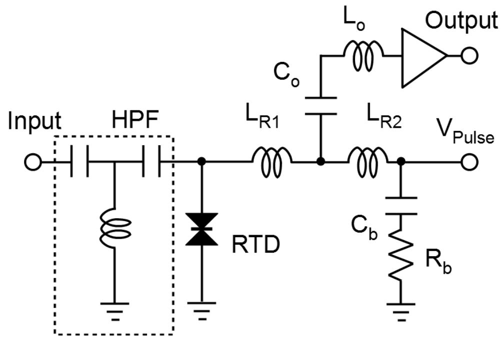

Fig. 3 Resonant tunneling SRD circuit featuring I/O isolation.

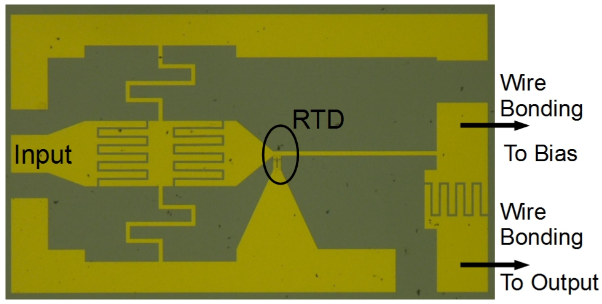

Fig. 4 Microphotograph of the fabricated circuits..

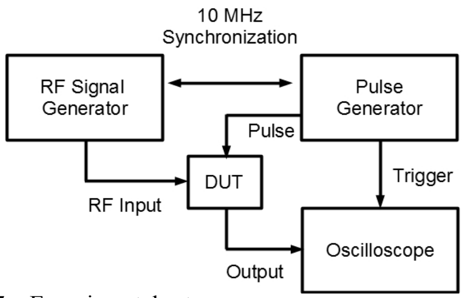

Fig. 5 Experimental setup.

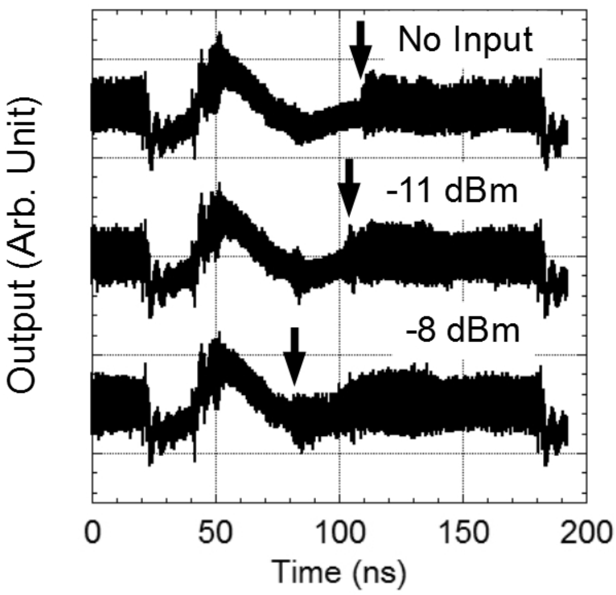

Fig. 6 Output waveforms of the fabricated circuit.