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Experimental Demonstration of Resonant Tunneling Super Regenerative Detectors Detecting High Order Harmonic Signals

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Abstract

A super regenerative detector using a resonant tunneling diode (RTD) oscillator was fabricated and investigated for ultrahigh frequency detectors. This has various advantages, such as circuit simplicity, easy design, and low power consumption. It was demonstrated that the detector can detect very high order harmonic frequency of the oscillator's fundamental frequency.

1. Introduction

A resonant tunneling diode (RTD) is one of the most promising THz devices. An oscillator based on negative differential resistance is a most straightforward application of the RTDs. Fundamental oscillations over 1 THz have already been demonstrated in recent years [1,2,3]. Most recently, we have proposed a novel super regenerative detector using an RTD oscillator [4]. It is based on the response of the RTD oscillator to high order harmonics of the oscillation frequency. In this paper we report on the experimental demonstration of the resonant tunneling super regenerative detector detecting high order harmonic signals.

2. Operation principle

Fig 1 shows the basic configuration of the super regenerative detector we proposed [4]. It consists of an RTD oscillator with an input port, and a bias (pulse) supplying circuit. Input signal is fed into the circuit via the input capacitor $\mathrm{C_{IN}}$. To operate the circuit as a super regenerative detector a periodic bias voltage, as shown in Fig. 2 (a) for example, is applied to the bias node. We chose the V_a to bias the RTD in a upper positive differential resistance (PDR) region, while the V_b is to bias the RTD in the negative differential resistance (NDR) region. The oscillation stops when the bias voltage is V_a while the oscillation begins when the bias voltage is V_b.

The time variation of voltage applying to the RTD, V_{RTD}, obtained by circuit simulation [4], is shown in Fig. 2 (b). As shown in the figure, oscillation begins at a certain time, t_s, after the bias voltage falls down to V_b. When the sinusoidal input signal, whose frequency is the same as the free running frequency, is fed to the circuit, the oscillation begins earlier as shown in the Fig. 2 (c). The oscillation start time, t_s varies depending on the input signal amplitude. Therefore, one can determine the input signal amplitude by measuring the t_s. Our proposal is extending the input frequency to high order harmonic frequency of the free running one. This has great advantages, such as circuit simplicity, easy design, and low power consumption.

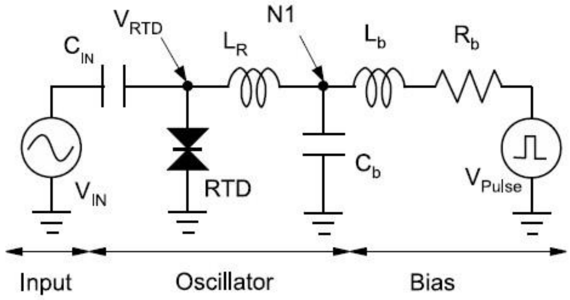

Fig.1 Basic circuit configuration of the super regenerative detector loaded with RTD oscillator.

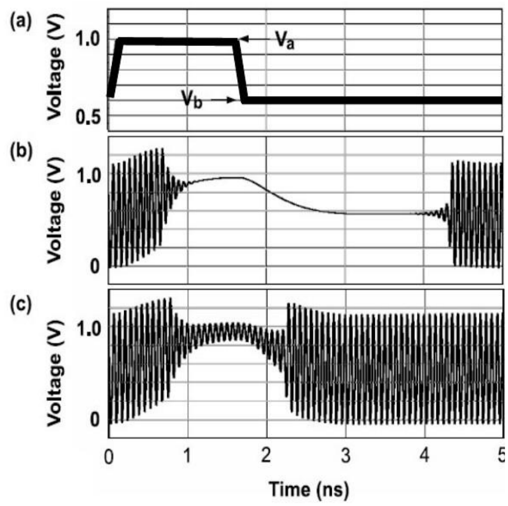

Fig.2 An example of the bias voltage and oscillation waveform of RTD super regenerative detector shown in Fig.1 obtained from circuit simulation.

3. Experiment results

We fabricated the core of the detector circuits with InGaAs/AlAs epitaxial layers grown on an InP substrate employing conventional photolithography and lift-off process. Fig 3 shows the photograph of the fabricated circuit. It consists of an RTD, an input capacitor, and an inductor. The RTD area was $7.2\mu m^2$. The experimental configuration to demonstrate super regenerative detection is shown in Fig 4. We used pulse generator for the bias voltage, which was synchronized to the 50GHz CW generator by 10 MHz time base connection.

First we tested the circuits with fundamental frequency inputs. The input and output signals were fed and monitored via circulator. Fig.5 shows examples of the output waveforms. The upper figure shows the output waveform without input signal. The oscillation begins at a certain time after we bias the RTD in the NDR region. The fundamental frequency of this oscillator was 1.53GHz. The bottom figure shows the output waveform when we input a 2GHz, -30dBm signal. We used 2GHz input signal because the band width of the circulator we used was 2-4GHz. The oscillation start time t_{s1} is earlier than t_{s0}, in spite of small signal amplitude.

Next we tested the circuit with much higher frequency input. Here, we used power splitter in place of the circulator. Fig.6 shows the output waveforms with no input signal (upper figure) and with 50GHz, -13.5dBm input signal (bottom figure). As shown in this figure, the oscillation begins earlier when the 50GHz input signal is fed to the circuit. This demonstrates that a very high frequency of 32th order harmonic can be clearly detected by the circuit. It is noted that no input signal was shown in the waveform because the bandwidth of the oscilloscope was 4GHz.

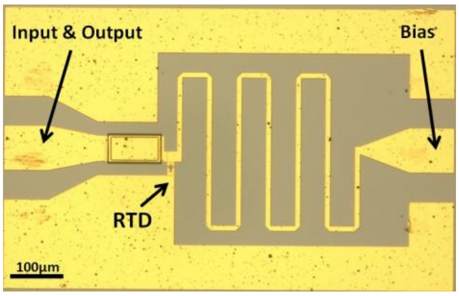

Fig.3 Photograph of the fabricated oscillator load with an RTD.

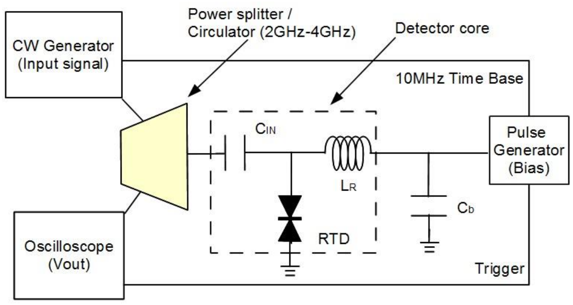

Fig.4 Experimental configuration of the real measurement. .

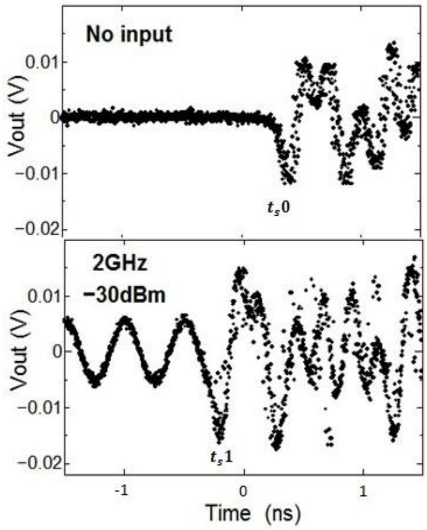

Fig. 5 Output waveforms of the RTD super regenerative detector using circulator for 2GHz signals.

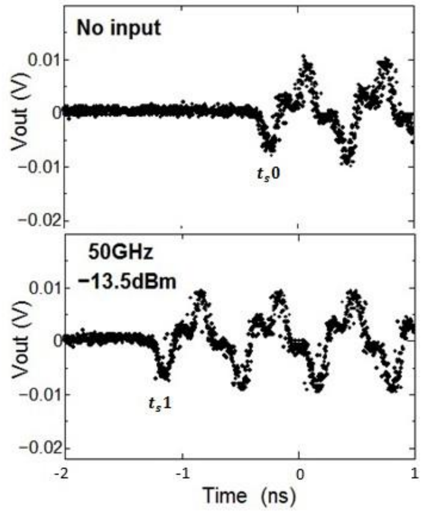

Fig.6 Output waveforms of the RTD super regenerative detector using power splitter for 4GHz signals.

4. **Conclusion**

We have fabricated and tested the super regenerative detector using an RTD. Operation of the super regenerative detector for very high order harmonic input was demonstrated, which indicates that this super regenerative detector is promising for THz signal detection.

Reference

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