Terahertz-Wave Amplitude-Modulated Radar Based on a Resonant-Tunneling-Diode Oscillator

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Terahertz electromagnetic waves have a frequency in the order of 1 THz, which places them between millimeter waves and infrared radiation and gives them the property of being able to pass through many materials. Besides having started being used in non-invasive product inspection, terahertz waves are expected to find application in safety and homeland security scenarios, such as vehicle anti-collision systems and body scanners, where distance measurement (ranging) is necessary.

One emerging type of terahertz-wave source is the resonant-tunneling-diode (RTD) oscillator, a solid-state, compact device that works at room temperature and has very easy-to-meet power requirements. It can generate continuous terahertz-wave outputs below 1 mW at frequencies up to 2 THz, depending on fabrication parameters. We believe these qualities give RTD oscillators the potential of becoming the terahertz-wave source of choice for many future applications. Here we present recent advances in achieving a radar functionality based on RTD oscillators, an improvement on the results we reported in Ref. 1.

The radar we propose relies on the amplitude-modulated continuous-wave (AMCW) radar technique, which benefits from the ability of the RTD oscillator of being easily modulated in amplitude by simply adding a sinusoidal signal to its bias voltage. When the modulated terahertz beam is allowed to propagate to the target and then arrive back at a detector, the modulation signal can be reconstructed and its phase measured using an oscilloscope to reveal information on the propagation distance. Additionally, if more than one modulation frequency is used, the distance ambiguity caused by the periodical nature of the sinusoidal signal can be removed and an absolute distance measurement becomes possible.

For the results in Ref. 1, we used an oscilloscope to measure the phase of the detected signal and achieved a ranging error of ±0.6 mm, for an RTD emission frequency of 522 GHz and modulation at 5 and 6 GHz.

We have now replaced the oscilloscope with a phase measurement setup based on a hybrid coupler, which produces two 90° shifted copies of the modulation signal, and two mixers whose outputs are the sine and the cosine of the detected signal phase, as shown in Fig. 1. This method allows an even smaller ranging error, currently ±0.12 mm, due in part to low-pass filtering the mixers' outputs to below 50 Hz. We expect further error reduction by improving the correction algorithms, reducing the noise, and selecting better measurement parameters.

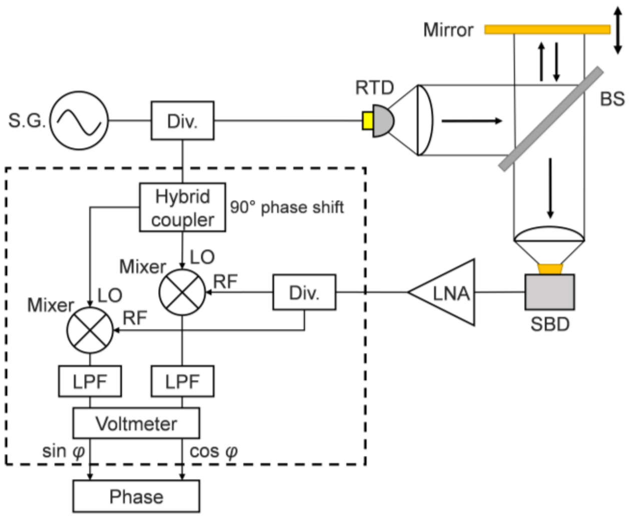

Fig. 1. Schematic of the experimental setup. S.G.: signal generator; Div.: divider; BS: beamsplitter; LNA: low-noise amplifier; SBD: Schottky-barrier-diode detector; LPF: low-pass filter. The part in the dashed rectangle replaces the oscilloscope.

[1] A. Dobroiu, R. Wakasugi, Y. Shirakawa, S. Suzuki, and M. Asada, "Absolute and precise terahertz-wave radar based on an amplitude-modulated resonant-tunneling-diode oscillator," *Photonics* 2018, 5, 52.