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Echo-less Photoconductive Switches for High-Resolution Terahertz Time-domain Spectroscopy

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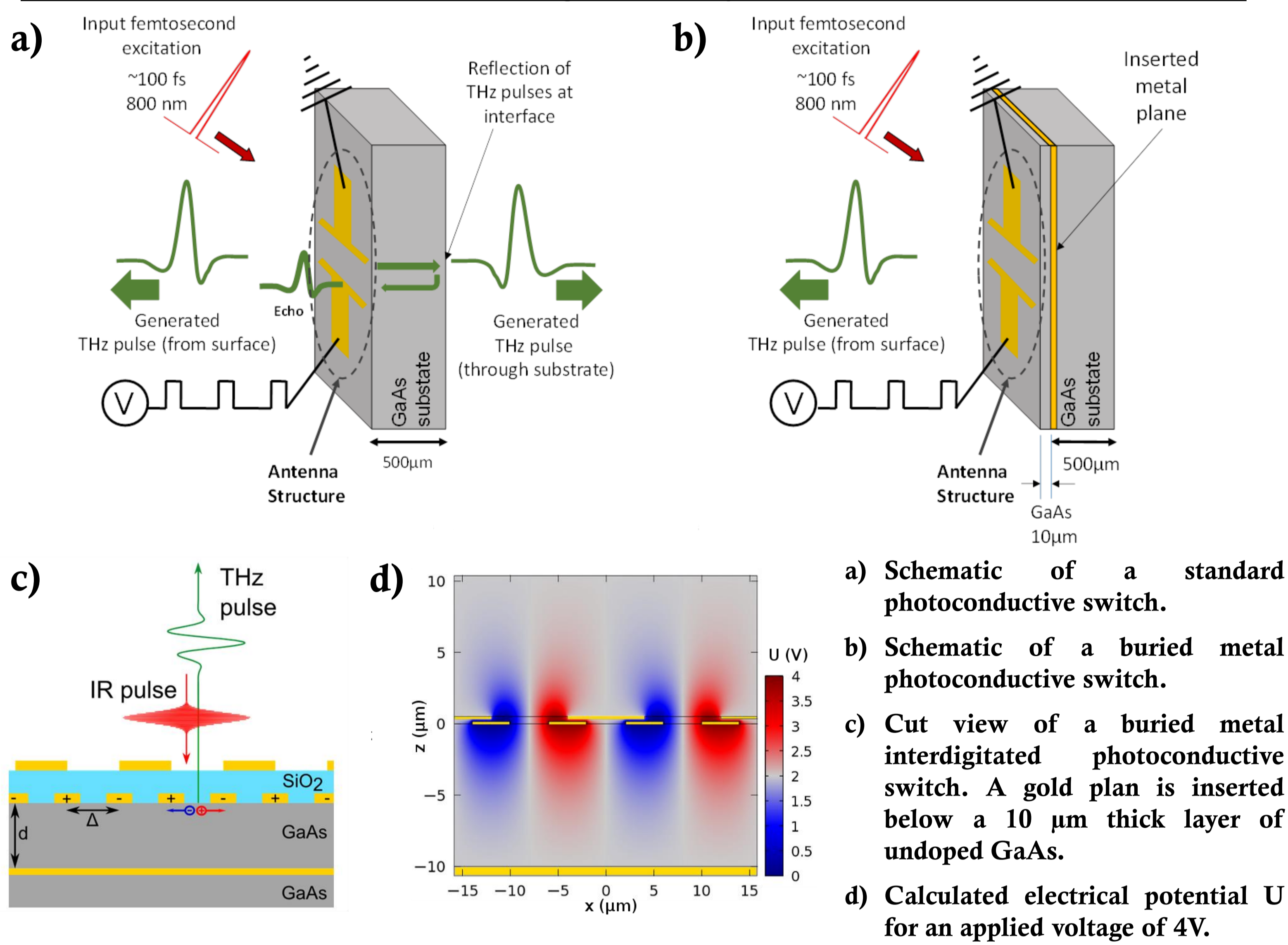
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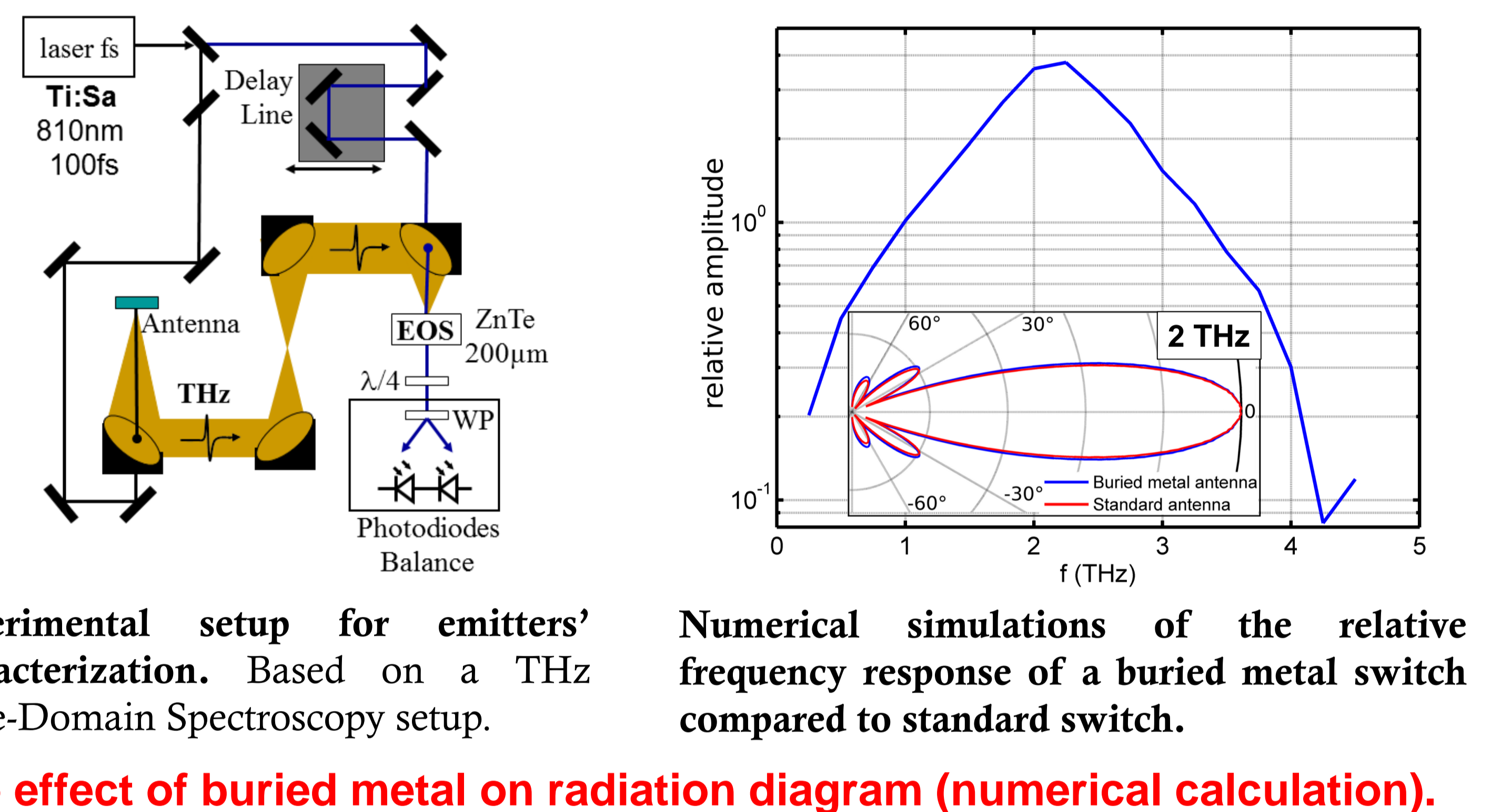
Overview

Interdigitated photoconductive (iPC) switches are powerful and convenient devices for time-resolved spectroscopy, with the ability to operate both as sources and detectors of terahertz (THz) frequency pulses. However, reflection of the emitted or detected radiation within the device substrate itself can lead to echoes that inherently limits the spectroscopic resolution achievable from their use in time-domain spectroscopy (TDS) systems. We demonstrate a design of iPC switches for THz pulse emission and detection that suppresses such unwanted echoes and provides high-resolution in frequency. As a proof-of-principle, the 2_{12} - 2_{21} and the 1_{01} - 2_{12} rotational lines of water vapor have been spectrally resolved, demonstrating a spectral resolution below 10 GHz.

1. A buried metal interdigitated photoconductive switch



2. Experimental characterization as emitter



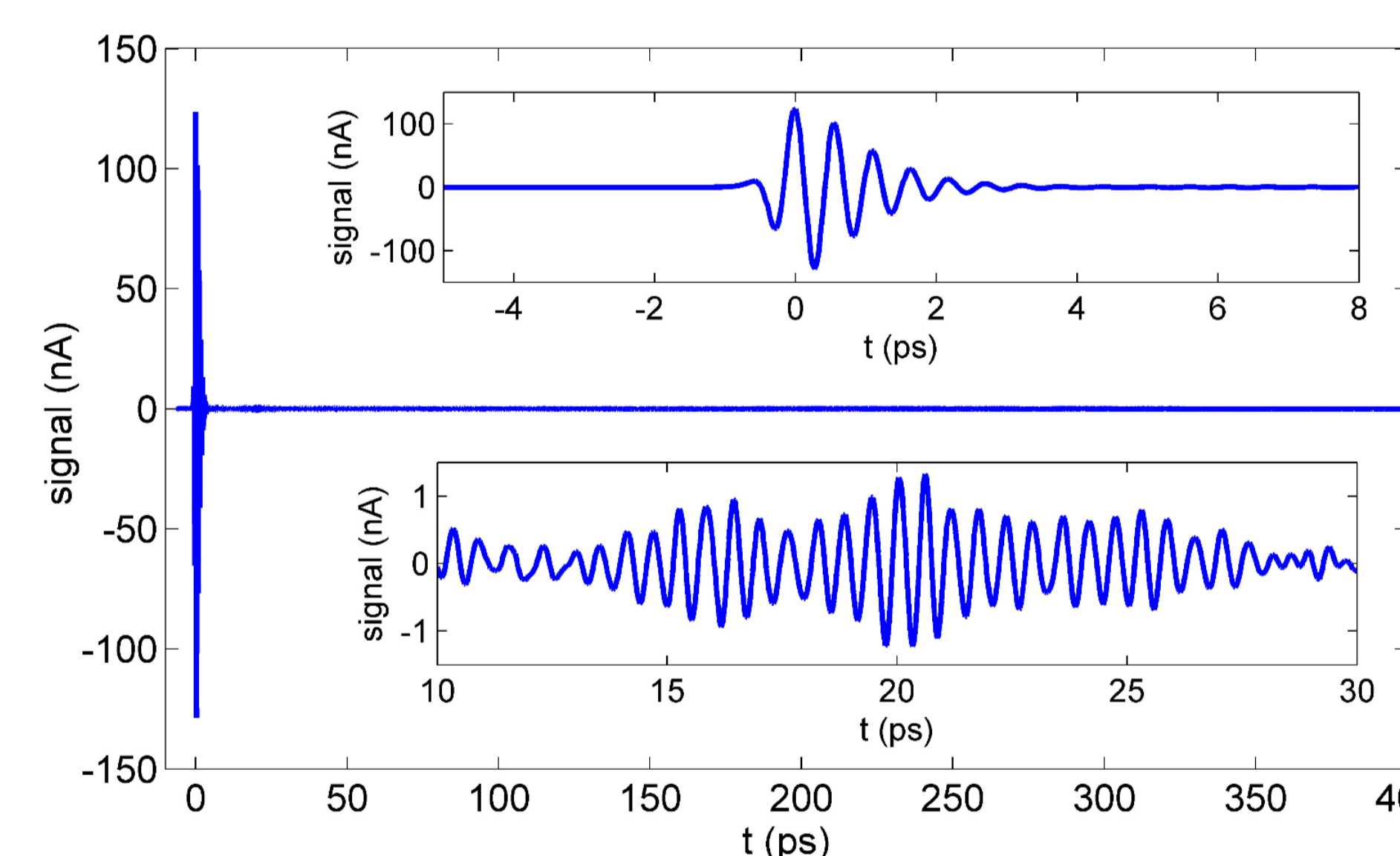
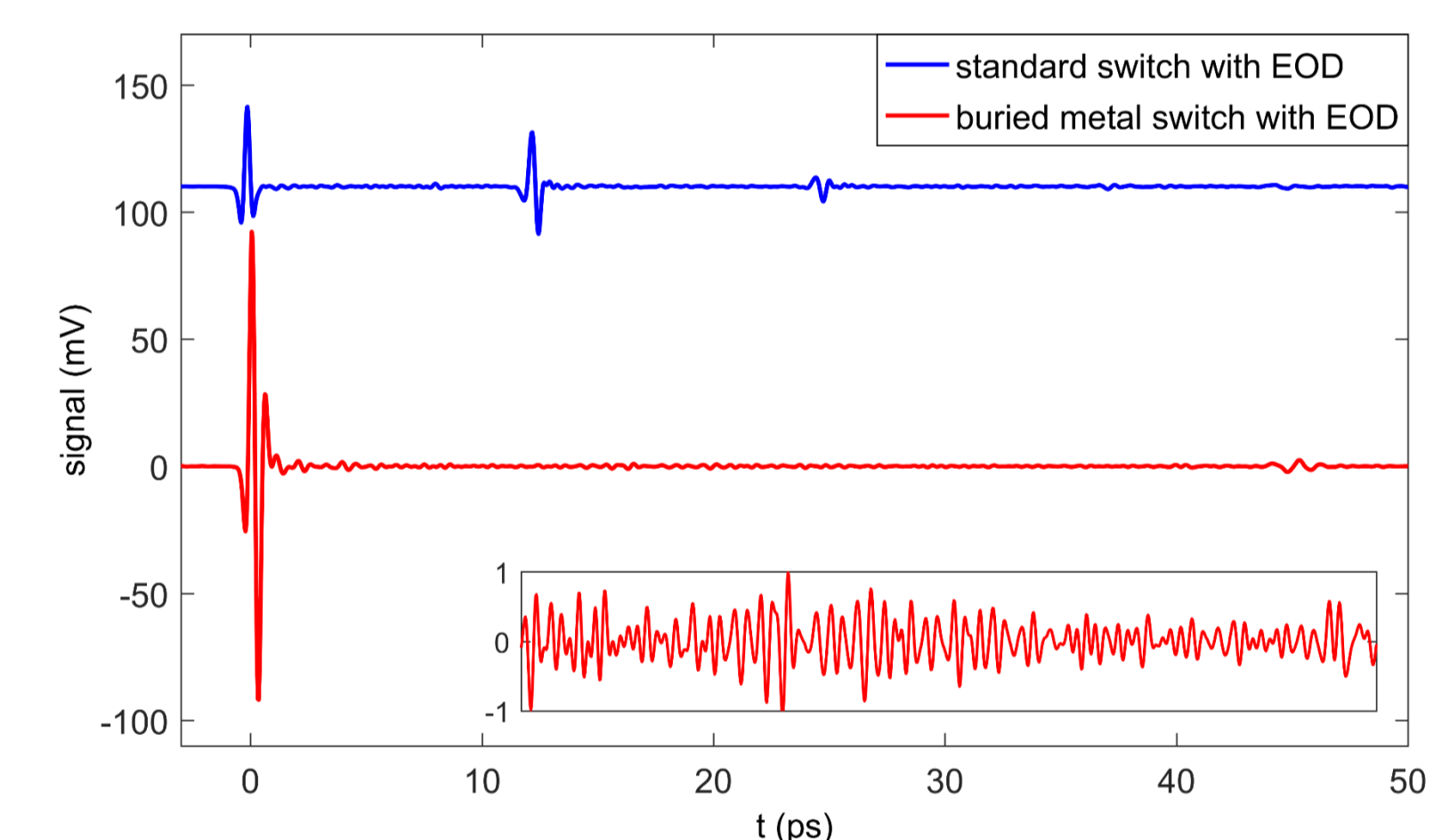
4. Time traces and echo suppression

1) Detection with ZnTe EOD crystal (200 μm thick)

Resolution limited only by echo in detection crystal (42 ps time window).

THz power concentrated in a single pulse: higher peak amplitude for a given polarisation bias electrical field.

$$E_{\text{bias}} = 10 \text{ kV/cm}$$

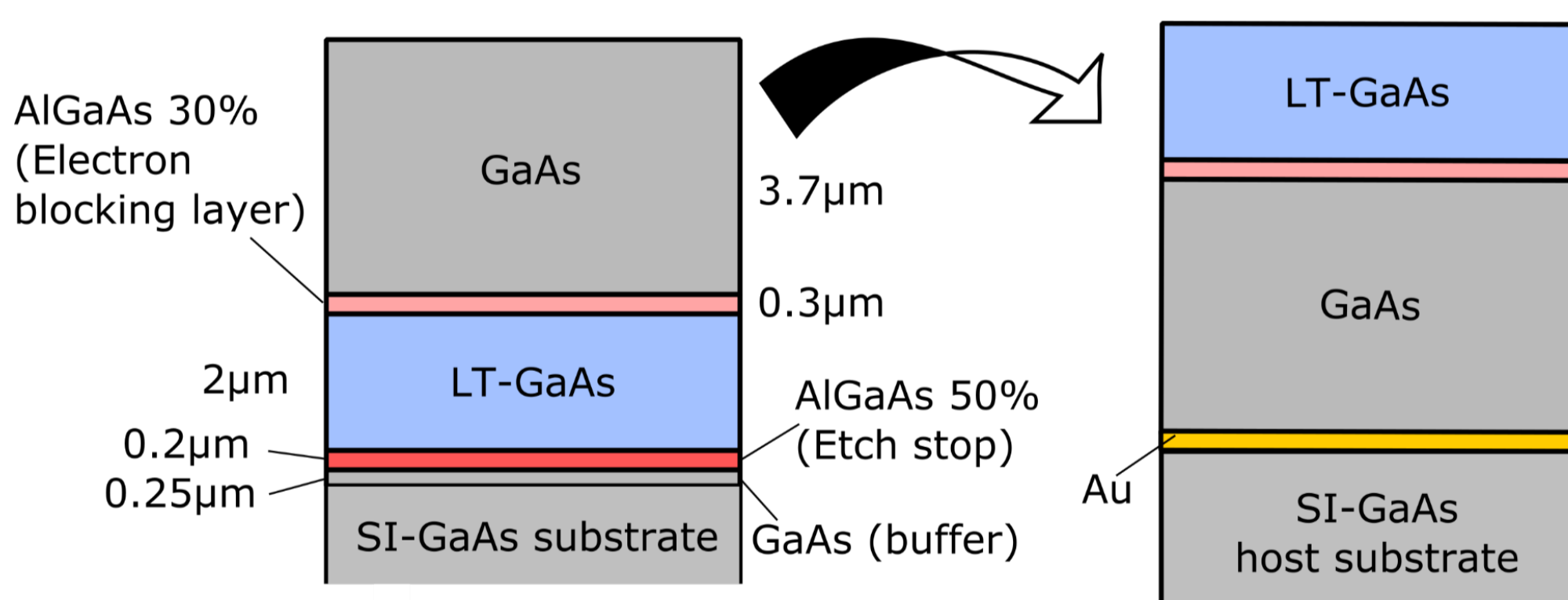


2) Detection with a buried metal plane LT-GaAs photoconductive switch

Resolution limited only by delay line length and probe beam alignment stability during scan.

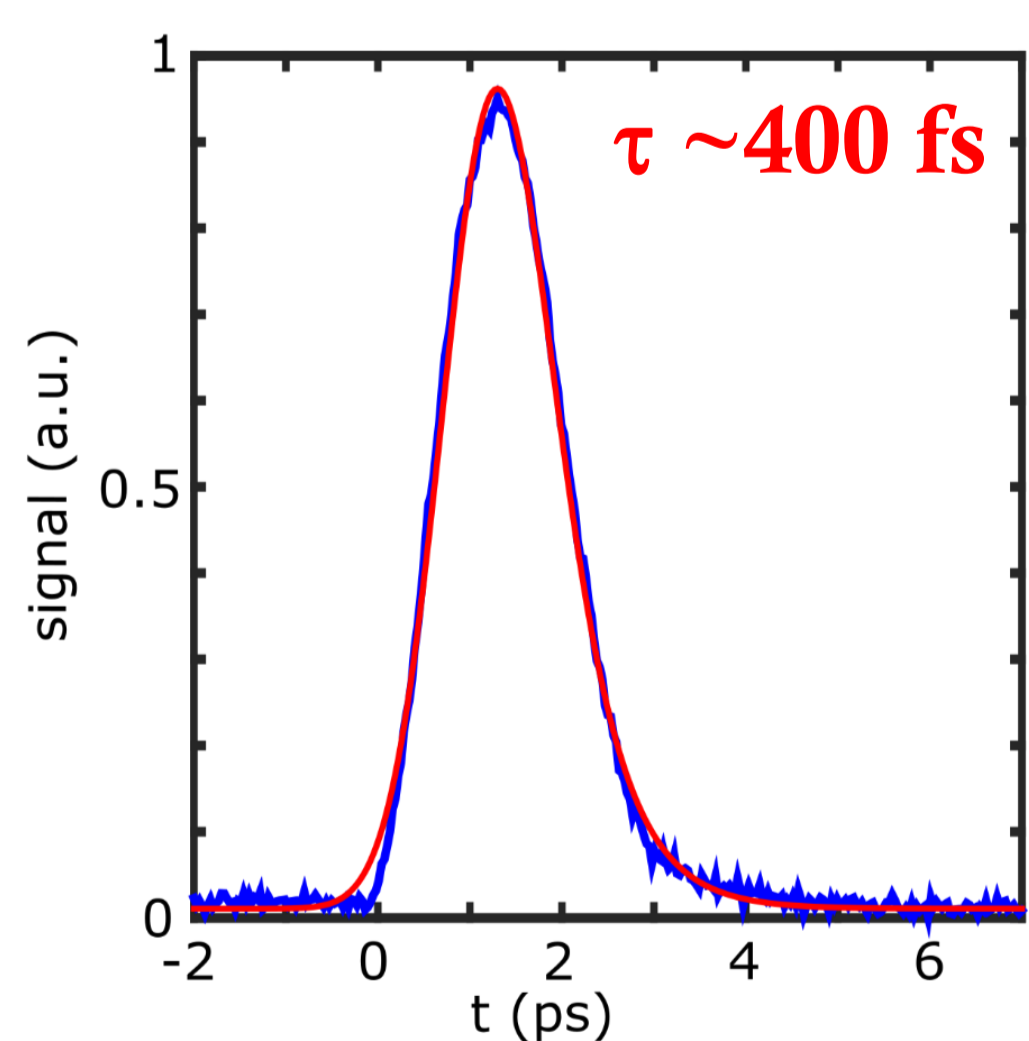
With standard delay lines, few ns time windows might be achieved, resulting in sub-GHz resolution.

3. LT-GaAs layer for switches as detectors



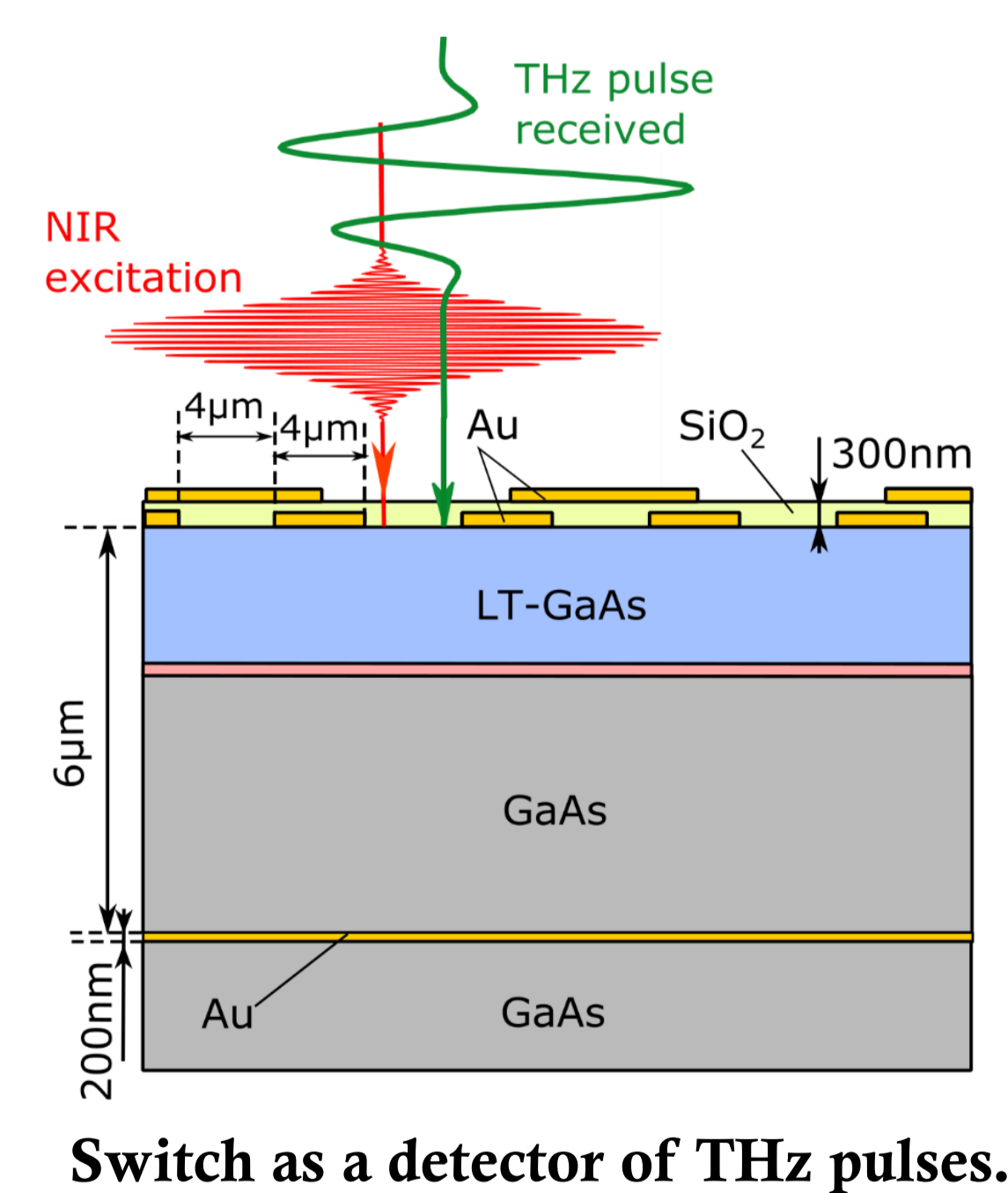
Pre-photolithography sample. The MBE grown sample is wafer bonded to a gold-coated host SI GaAs substrate. The substrate and the AlGaAs (50%) layer of the MBE grown wafer are removed, exposing the LT-GaAs active region with the echo-blocking metal plane 6 μm below the surface.

Measurement of carrier lifetime in the LT-GaAs active layer (optical pump – THz probe technique).



Blue line: variation of THz reflectivity of LT-GaAs layer after a 100fs – 800nm excitation optical pulse at t=0ps.

Red line: Numerical fit $s(t) = s_0 \text{erf}\left(\frac{1}{\sqrt{2}\delta t}\left(t - \frac{\delta t^2}{\tau}\right)^2\right) e^{-t/\tau}$

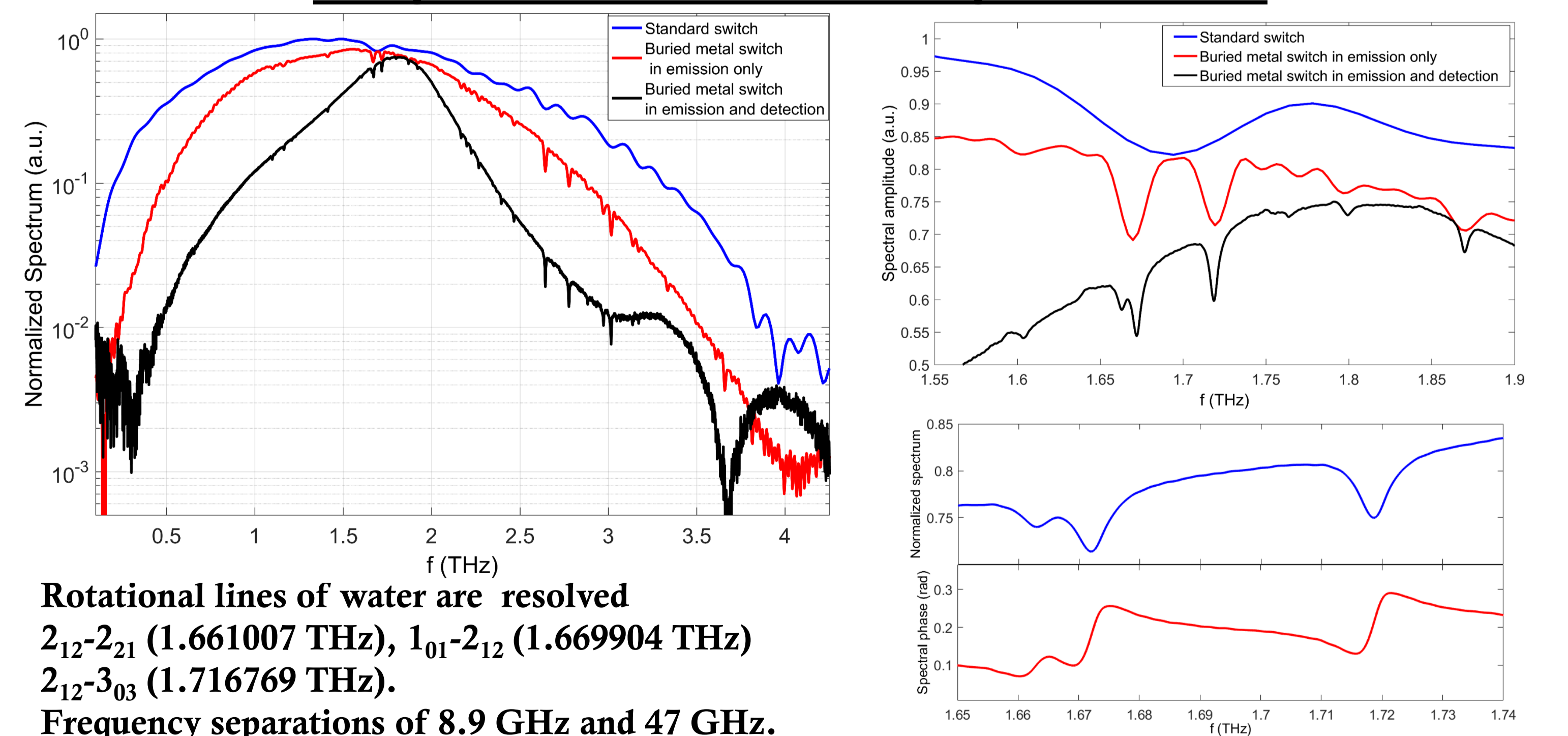


Conclusions:

- THz pulse generation and detection with echo suppression.
- High-resolution in the spectral window 500 GHz – 3.5 THz experimentally demonstrated.
- Demonstration of 9 GHz spectral resolution from 2_{12} - 2_{21} and 1_{01} - 2_{12} water vapour rotational lines measurement.
- Perspectives :

better understanding of spectral properties, including influence of the distance between electrodes and the buried metal plane.

5. Spectral resolution improvement



K. Maussang, et al., *Monolithic echo-less photoconductive switches as a high-resolution detector for terahertz time-domain spectroscopy*, Appl. Phys. Lett. 110, 141102 (2017), doi:10.1063/1.4979536

K. Maussang, et al., *Echo-free Interdigitated Photoconductive Antenna for High-Resolution Terahertz Time-domain Spectroscopy*, IEEE Trans. Thz Sci. Technol., 6, 20-25 (2016), doi:10.1109/TTHZ.2015.2504794

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