B05 – Towards femtosecond electron imaging of noisy terahertz electronics

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The ever-increasing demand for faster data transport, for example in 6G wireless communication, leads to a rising interest in terahertz electronics and circuitry. Signals at these frequencies are usually created by nonlinear harmonic conversion of conventional function generators, by femtosecond photoconductive switches or by optical rectification of laser pulses in a nonlinear crystal. First basic devices such as THz transistors, diodes, antennas, resonators, filters and related devices are already operational.

However, a fundamental barrier to the development of effective THz devices is the lack of diagnostics with sufficient bandwidth and noise level. By principle, diagnostics of state-of-the-art THz electronics is not possible by means of other electronics, for example by oscilloscopes, because any electronics cannot be faster than itself; in other words, it lacks the required bandwidth and time resolution.

Here, we explore a laser-optical approach to overcome this problem. We combine an electron microscope with nanometer resolution in space with a femtosecond laser that provides sub-picosecond or 10 THz resolution in the time and frequency domain, respectively. A crucial point of this new probing technique is the generation of femtosecond electron beam pulses to achieve terahertz resolution. These short electron pulse lengths can only be achieved by having only about one electron per pulse, otherwise the Coulomb forces between the electrons would elongate the pulse length [1,2]. A central part of our research is therefore the compression and diagnostics of the pulse length [3].

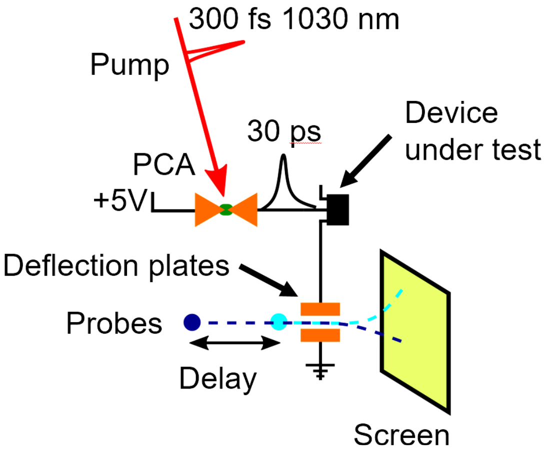

Fig. 1: *Concept with the photoconductive antenna for creating the THz signal, which goes through the DUT. The created signal is probed at the deflection plates by the electron pulse.*

Using these electron pulses, we demonstrate in a first proof-of-principle experiment how a contactless, impedance-free electron beam can probe basic THz circuitry in transmission with millivolt, femtosecond, and micrometer resolution. We also show that, in theory, this approach will be suitable to achieve petahertz and nanometer resolution when implemented in a commercial scanning or transmission electron microscope. Importantly, the concept is well suited for distinguishing correlated and statistical noise in coupled THz circuits by using double probe pulses and recording their noise statistics.

In the next step, we want to extend the concept to real-space imaging with the help of a commercial electron microscope. We currently work on the modification of a Zeiss EVO scanning electron microscope to reach femtosecond time resolution and sensitivity to instantaneous electric fields with help of voltage contrast. When this is achieved, we should become capable of imaging THz circuitry *in-operando* in a contact-free and non-distorting way.

References:

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