Laser Excited Transient Current Pulse Shape Formation in (CdZn)Te Detectors

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Introduction:

The determination of electric field profile and charge collection efficiency belongs to important tasks in the semiconductor radiation detectors characterization. Transient Current Technique (TCT) is used as a standard method for this purpose [1,2,3]. Laser-induced transient current pulse (L-TCT) provides favorable signal to noise ratio in compare to non-synchronized sources (e.g. alpha particles). This fact is due to the possibility of direct oscilloscope triggering by the excitation pulse and exact focusing of the optical beam on a specific detector spot. Moreover, this approach also enables us the detector area mapping with point-to-point scanning beam. By using this technique even very low detector bias TCT electron signal can be recorded (down to 50V) so that mobility-lifetime product and electric field profile can be calculated for a very wide bias interval.

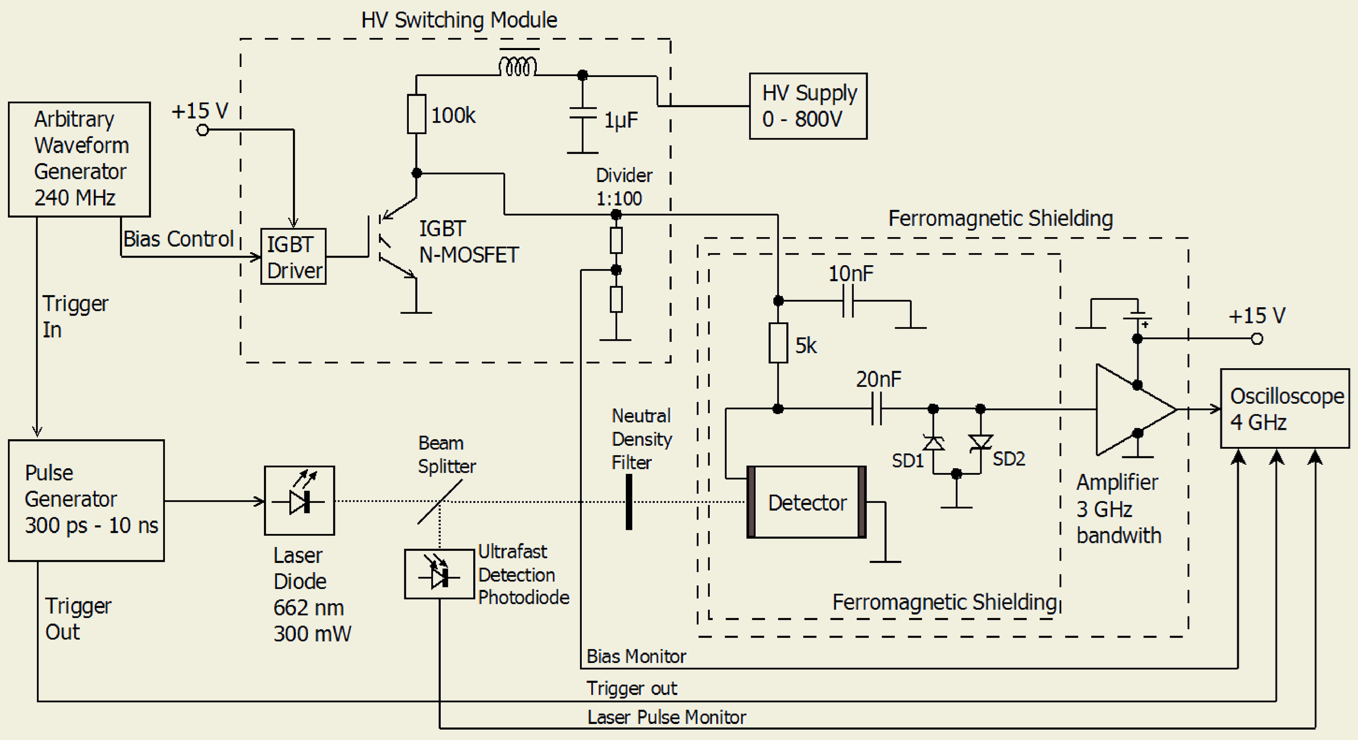

Fig. 1.: Block diagram of the laser excited TCT pulse detection electronics setup with the detector bias pulse switching.

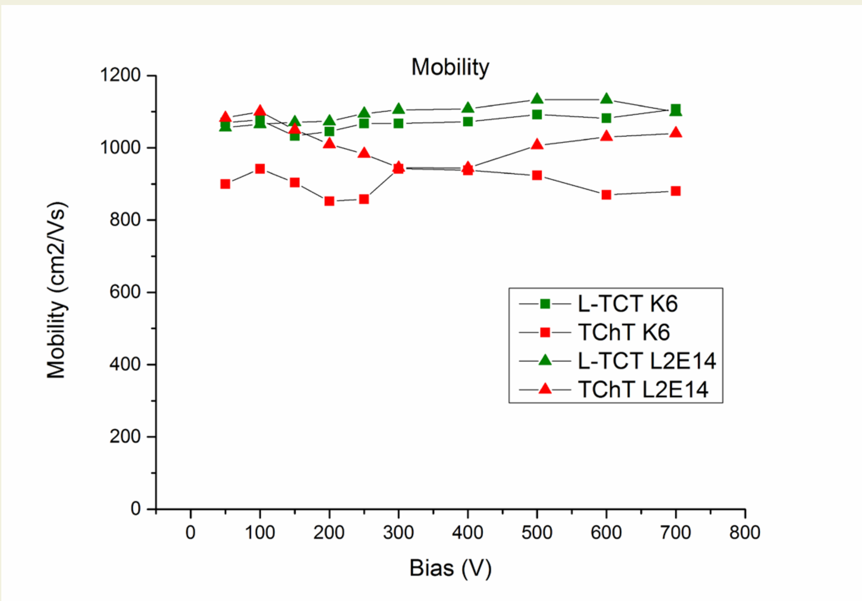

Fig. 2.: Bias dependece of the mobility for K6 and L2E14 CdZnTe detectors calculated from transient current and transient charge measurement.

Experimental setup:

Our L–TCT experimental setup (see Fig. 1.) is based on the direct high frequency amplification (up to 3GHz) of the AC coupled detector current pulse [1] and its shape is recorded by using ultrafast digital sampling oscilloscope (4GHz bandwidth, 40 Gs/s) for further processing. Short excitation optical pulses (> 4 ns) are generated by the laser diode (660 nm wavelength, 300mW pulse peak power) that is driven by the ultrafast pulse generator (300 ps to 10 ns) and by two channel digital high frequency arbitrary waveform generator as a master. Variable pulse repetition rate, its width and the laser pulse/bias time position can be set by using both generators. We use collimation optics to focus the laser beam onto the examined spot in the detector plane. Variable neutral density filter is included in the setup for continuous laser pulse intensity control. Oscilloscope trigger is directly synchronized with the pulse generator in order to overcome less sensitivity and high content of the additive noise component in L–TCT signal particularly for the low detector bias. Laser pulse shape can be directly visualized by using ultrafast GaAs photodetector (25 GHz bandwidth). Detected electron L–TCT pulse (see Fig.2 a,b) in wide detector bias range (50 V to 700 V) enables us to characterize the time resolved charge collection process in the detector volume [1] and to evaluate its internal electric field. The measurement also gives the possibility of time–resolved monitoring of the charge formation process. In case of relatively low internal charging [1] the relation between the mobility μ, the detector thickness L, voltage V and the risetime τ_r is given by:

$$\mu = L^2 / (\tau_r \cdot V)$$

Double exponential method and maximum slope method [4] were used to calculate the transit time for the transient current and transient charge measurement respectively. Two CdZnTe detectors with 12 % of Zn (K6, L=1.55 mm and L2E14, L=2.02 mm) were studied in this work.

Advantages: low voltage TCT measurement and the current waveform triggering; no plasma effect; tunable intensity, repetition frequency, width, time possition and wavelength of the optical pulse.

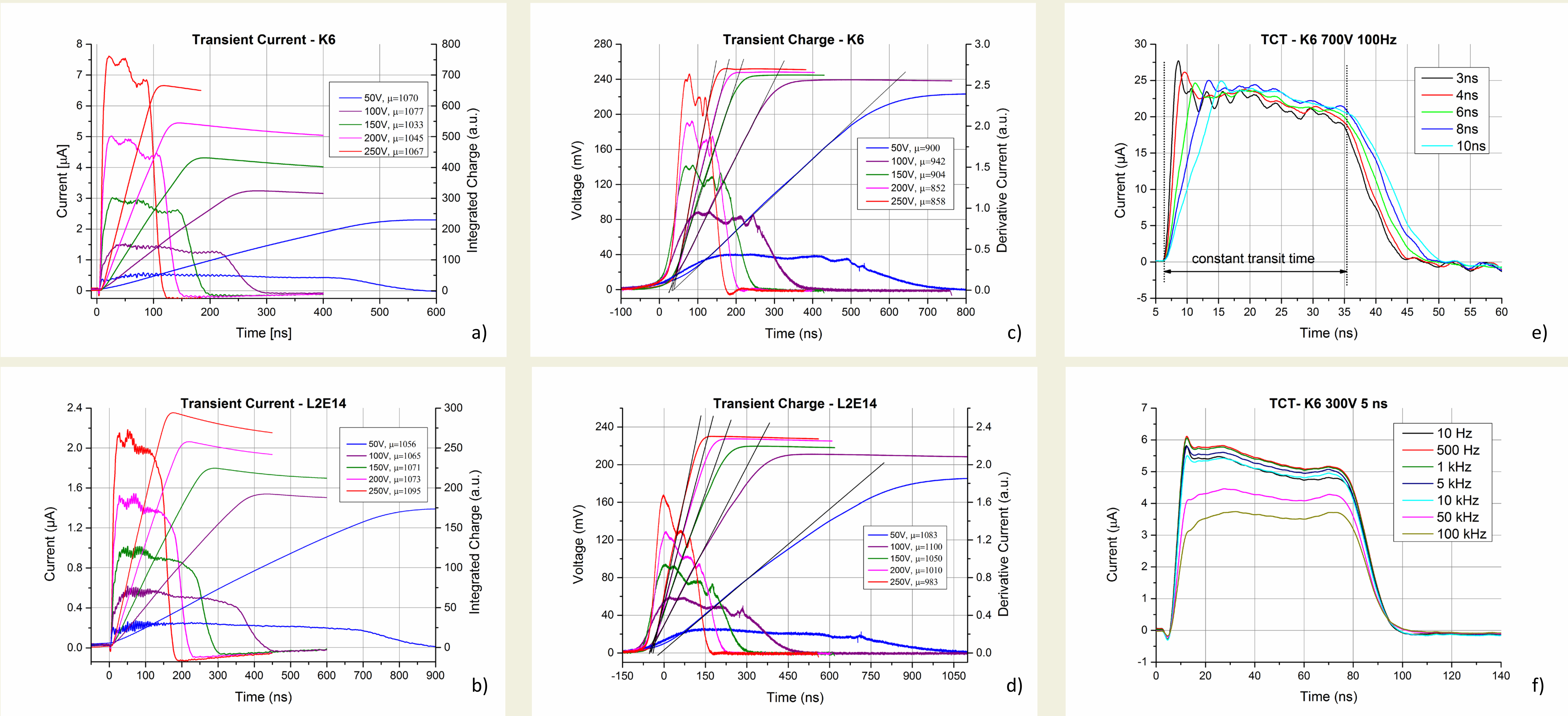

Fig. 3.: Transient current pulse (a, b) and transient charge (c, d) for K6 and L2E14 CdZnTe detectors and TCT pulse width and repetition frequency dependence (e, f)

Results:

- It was found, that laser induced TCT electron signal can be measured from 50 V to 700V bias very reliably (see Fig.3. a,b).
- In low voltages (50 to 250V) that are suitable for the mobility and the spatial charge density evaluation in TCT, calculated electron mobility is 1033–1095 cm^2/Vs for both samples. If compared to TChT measurement (858 to 942 cm^2/Vs, Fig.3.c,d), L-TCT appears to give more reliable mobility value even in 50 to 700 voltage interval (Fig. 2)
- Calculated transient time is independent in 3–10 ns optical pulse width (see Fig. 3.e)
- Stable and constant current waveforms are obtained when using 10 Hz–10kHz pulse repetition frequency interval (see Fig. 3.f). At high repetition frequency the space charge formed below the cathode limits the charge collection efficiency.

Reference:

[1] S. Uxa, E. Belas, R. Grill, P. Praus, and R. B. James, IEEE Trans. Nucl. Sci. **59**, 2402 (2012).
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[4] P. Praus, E. Belas, J. Franc, R. Grill, P. Höschl and J Pekárek, IEEE Trans. Nucl. Sci. **61**, 2333 (2014).

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