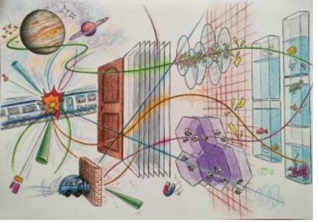
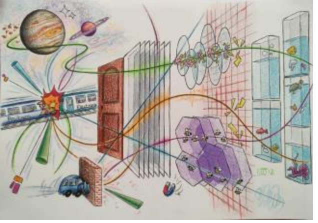


DRD3

WG5: New characterization techniques and facilities of common interest
Development of a new tool: Two Photon Absorption - TCT

Marcos Fernández García
IFCA-Santander & CERN-SSD guest scientist



New characterization techniques

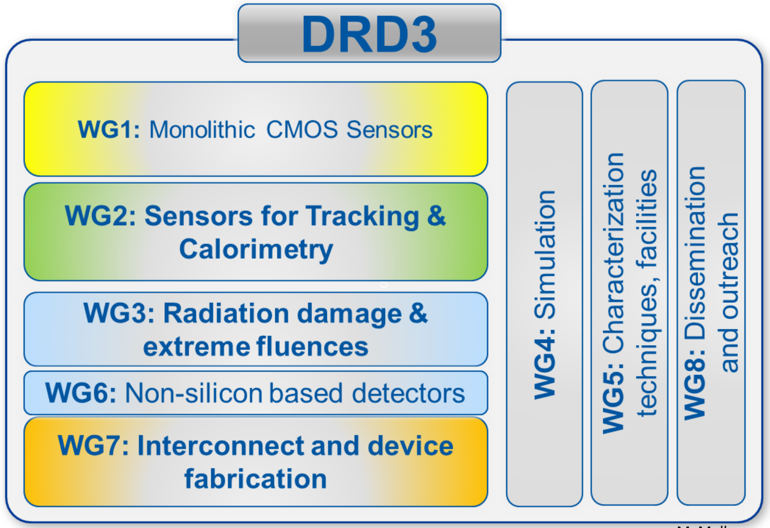
The development of new semiconductor characterization techniques is a priority for future detector developments. These techniques should enable high-resolution imaging and defect spectroscopy of semiconductor materials, as well as advanced characterization of charge transport properties.

Two Photon Absorption – TCT is an example of these characterization techniques:

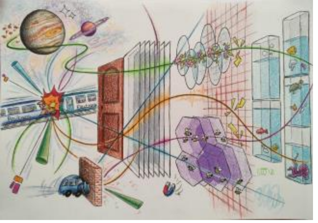
- Benefited from RD50 common fund both during development and measurement campaigns.
- It also received financial support (laser procurement) from CERN Knowledge Transfer fund (2017).

TPA-TCT is now available to the community:

- Used within RD50 and RD42 collaborations.
- Laser is a commercial tool (Si bandgap) .
- As a characterization tool, it is transversal to several WGs(1,2,3,4,6,8)
- Expertise in the technique built up by different groups



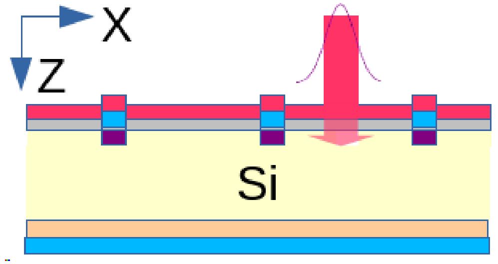
M. Moll



Development of TCT as characterization tool

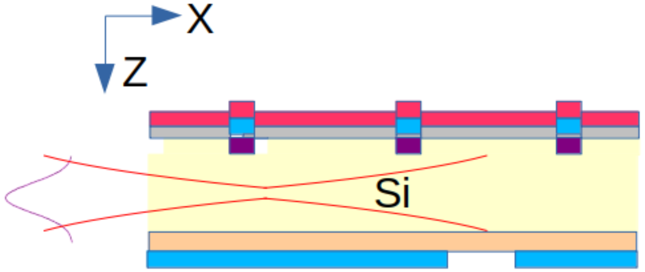
DRD3

Study of non-equilibrium charge carriers in semiconductors (TCT=Transient Current Technique) started in the **90's** (Fretwurst, Li, Eremin, Verbitskaya…) [1].



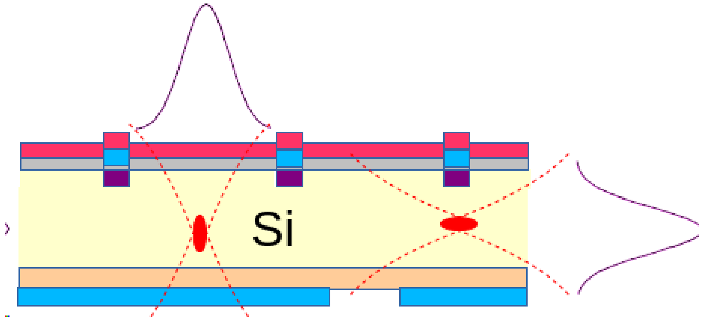
Single Photon-TCT
2D resolution (XY)
e-h separation

2009 G. Kramberger et al. develop **edge** laser illumination -> depth profiling added to TCT [2].



Single-Photon TCT
2D resolution (ZY)
Allows profiling (Q(z), v_{drift}(z),…)

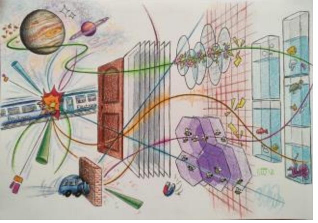
2013 First **T**wo **P**hoton **A**bsorption-TCT measurement in silicon and diamond (IFCA, CERN, UPV, US)



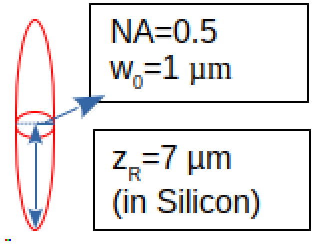
Two Photon TCT
True 3D resolution

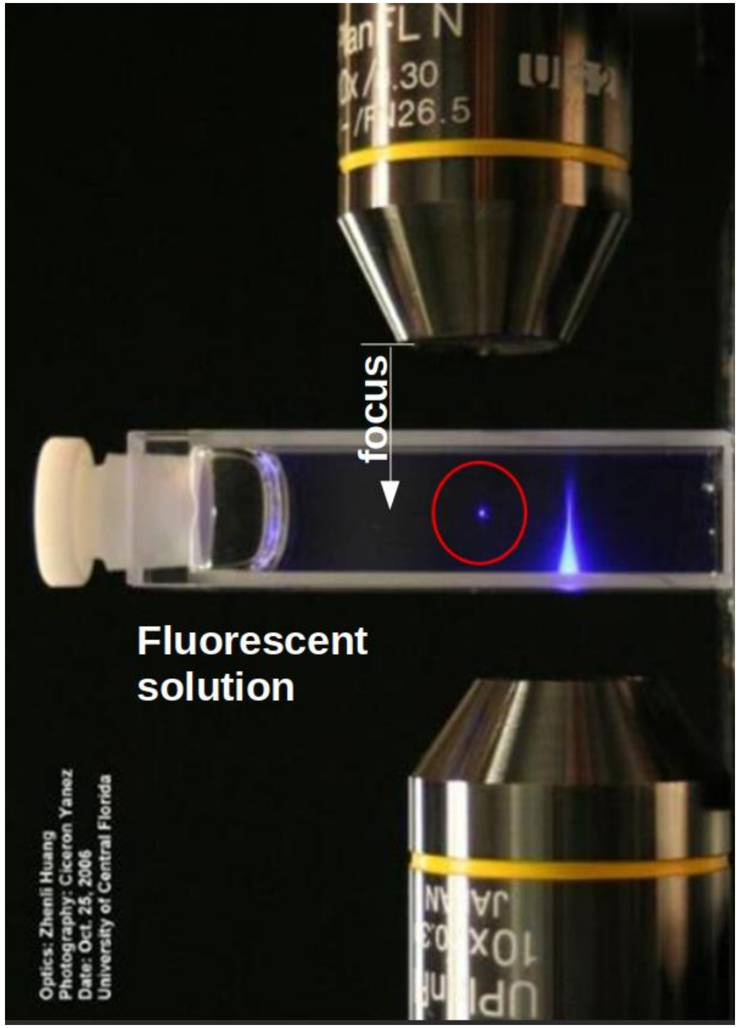
TCT has been/is a workhorse for characterization of detectors for the **RD48-RD50** collaborations.

[1] Review: M. Zavrtanik, 2nd TCT workshop
[2] doi: 10.1109/NSSMIC.2009.5402213.

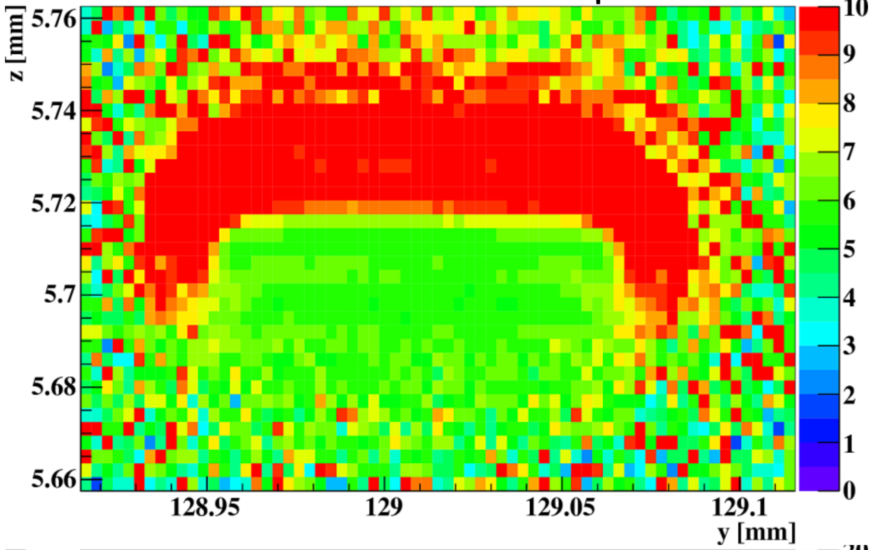


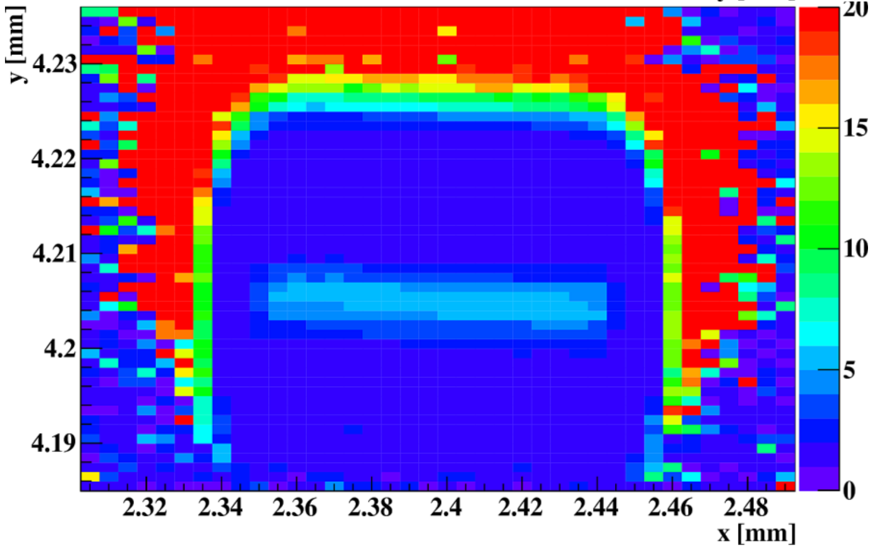
Two Photon Absorption TCT





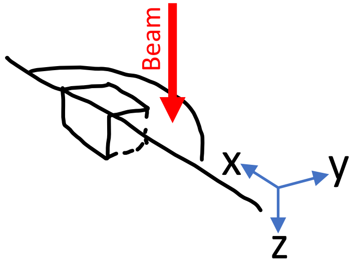
HVCMOS ams H18 HV process





SPA-TCT:
2D resolution

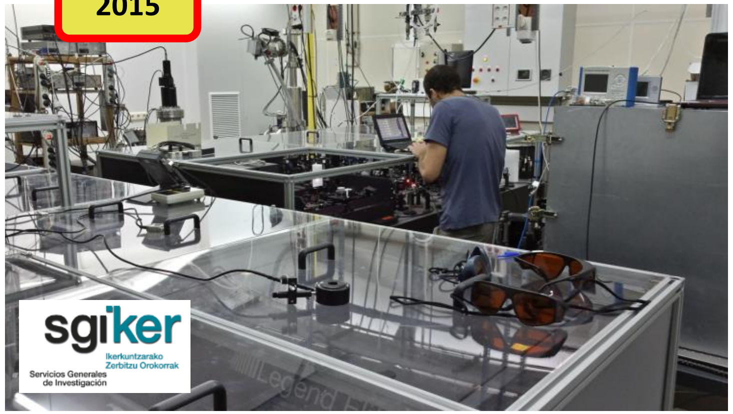
TPA-TCT:
3D resolution along beam propagation direction (Z).



RD50 and CERN-KT support

- TPA-TCT developed within RD50. Access to demonstrator fs-laser facility and measurement campaigns supported by **RD-50 common fund**.

2015



A non-destructive laser application for quality control & radiation studies in semiconductor devices

2017

The project aims to develop a method and platform to extract doping and electric field profiles within semiconductor devices by non-destructive femtosecond laser induced Two-Photon Absorption. Several fields could benefit from this development, amongst them Quality Control & Assurance of semiconductor devices, E-Field and Charge Collection Efficiency mapping of photosensors, and radiation damage studies for high-energy physics detectors.

This project is a collaboration between CERN and the Instituto de Física de Cantabria (CSIC-UC).

KEY FACTS

A non-destructive laser application for quality control & radiation studies in semiconductor devices

Submission Year
2017

Budget
120 kCHF

Timeline
2017 -

Funding Opportunities
CERN Knowledge Transfer fund

CONTACT PERSON

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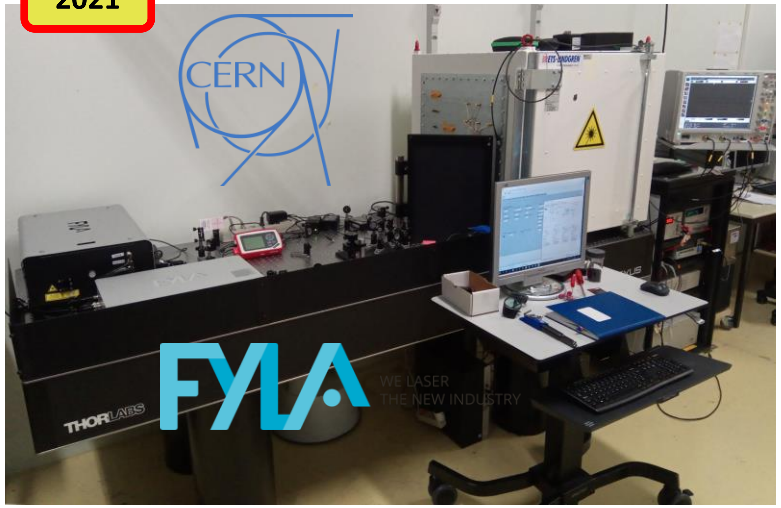
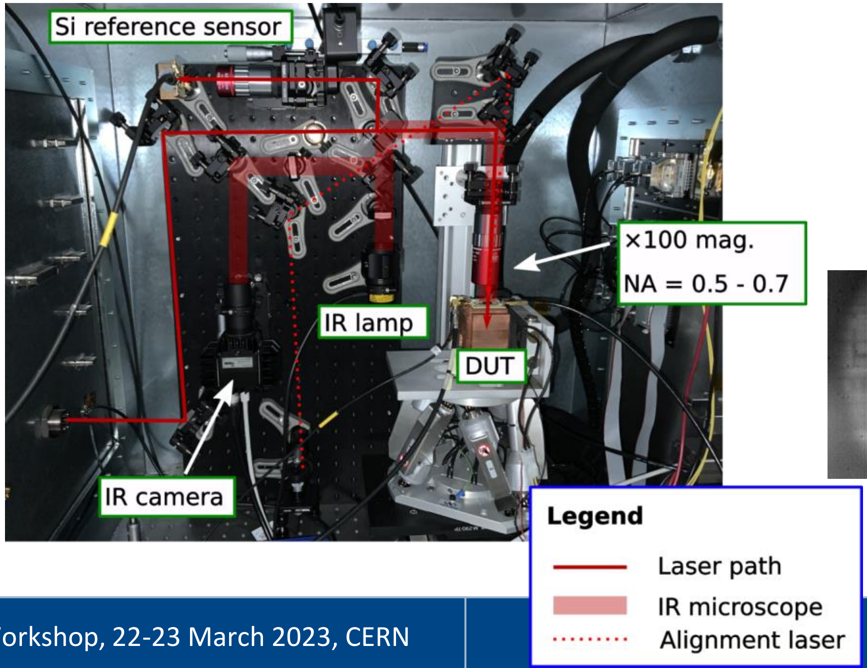
Aurelie.pezous@cern.ch

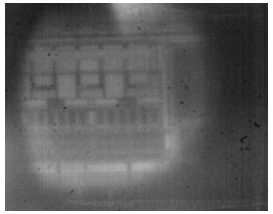
- TPA-TCT laser **procurement** via CERN-Knowledge Transfer contract.

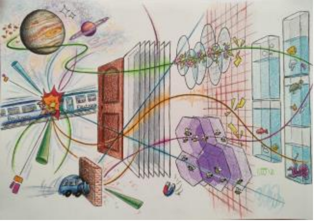
2021

M. Wiehe, [10.1109/TNS.2020.3044489](10.1109/TNS.2020.3044489)

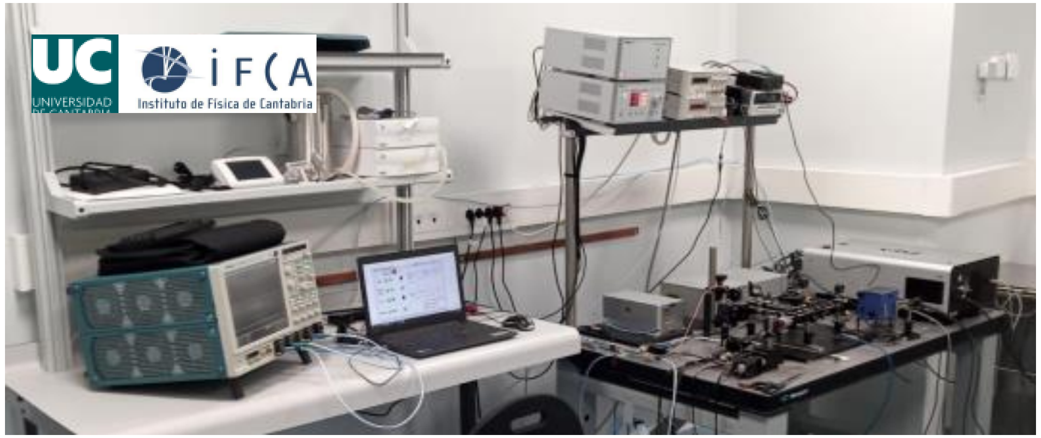


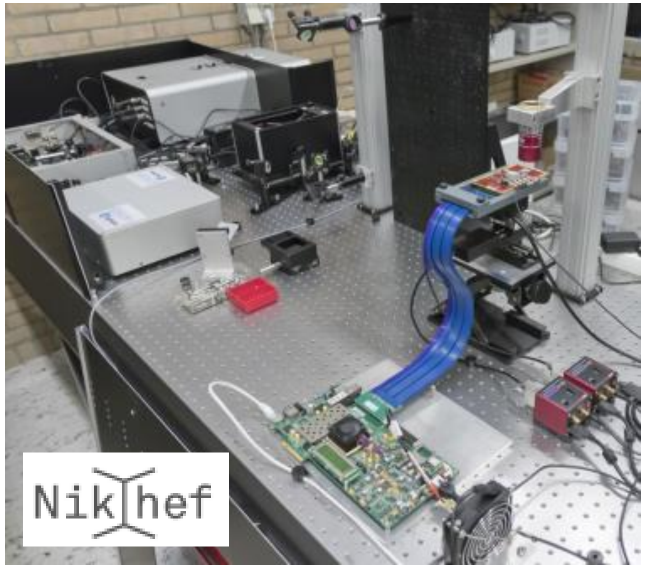


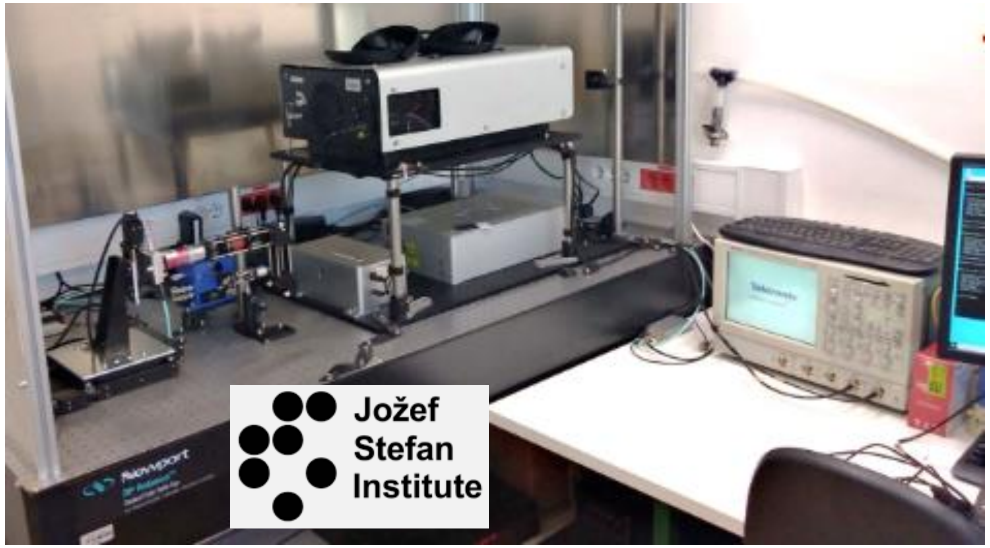


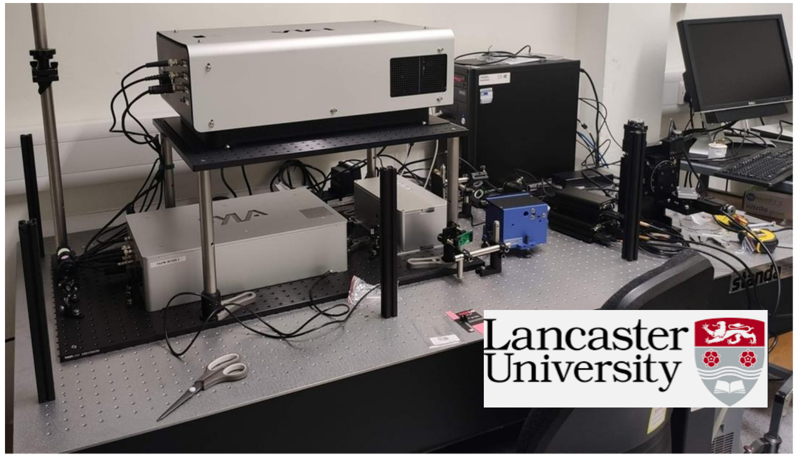


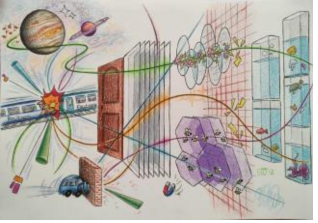
Customized systems built by the community



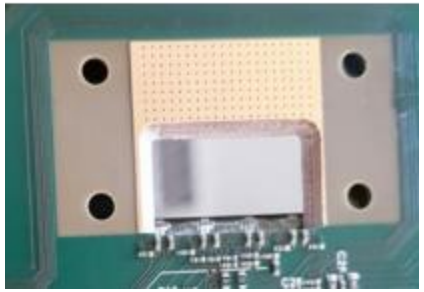


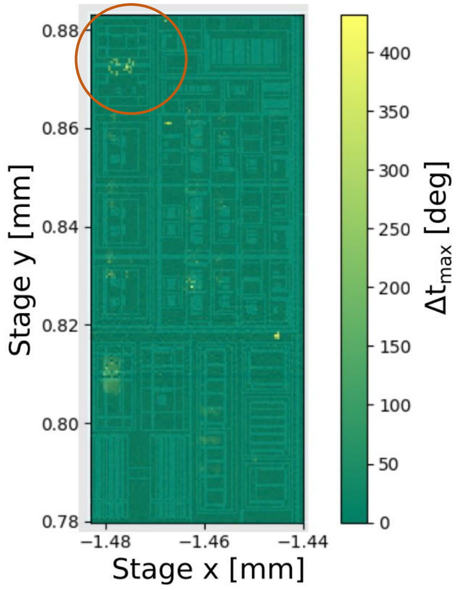






System flexibility: beyond bulk studies



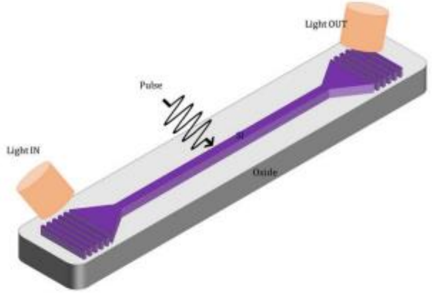


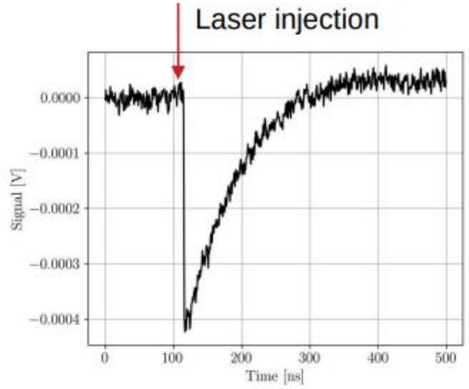
Laser settings:
Pulse energy 1.2nJ
Repetition rate 10Hz
Spatial resolution: 1 µm

RD53B: Single **E**vent **E**ffects found during heavy-ion testing on specific transistors. Used TPA-TCT back side injection to find sensitive elements→ Fixed in new version

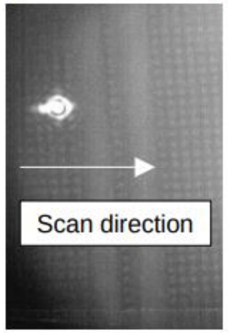
J. Lalic, S.Pape

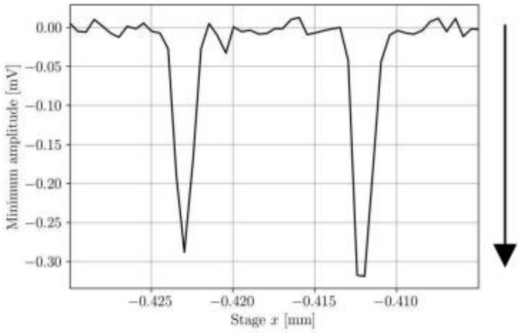
High speed optical links (CERN EP-R&D WP6):
Benchmark of carrier recombination lifetime in Si-waveguides. Inject charge using TPA-TCT → Free carriers absorb light that passes trough the waveguide → Transient behaviour as free carriers recombine:



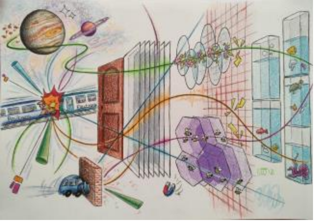


Optical waveguides



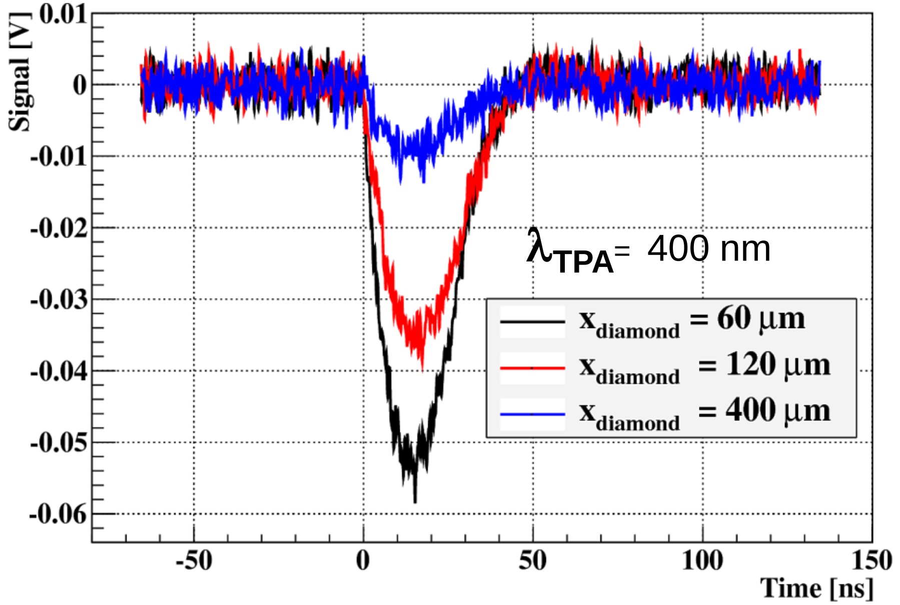


A. Pandey, S. Scarcella, S. Pape



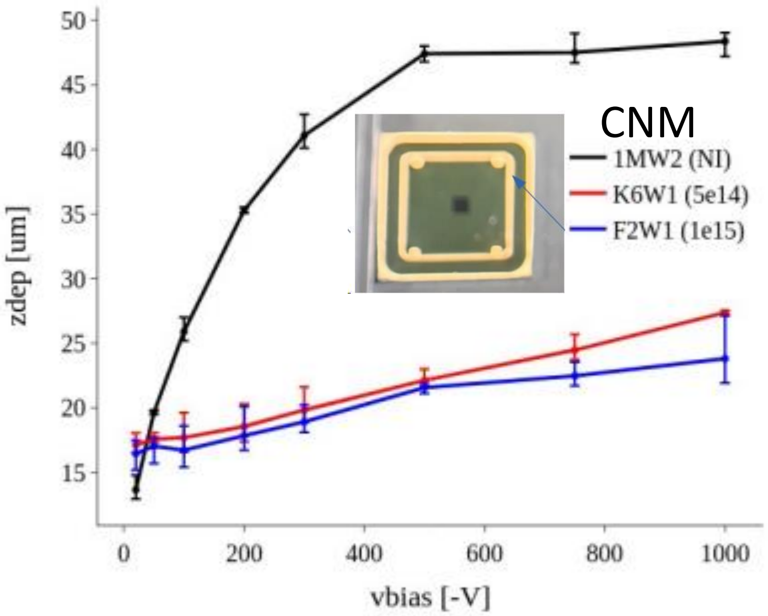
Beyond silicon

TPA-TCT also used to study other materials. It has been demonstrated in **diamond** (RD42) and **SiC** (RD50), using 400 nm fs laser.



2016: proof of principle of TPA-TCT in **diamond** with 400 nm TPA at SGIKER (Bilbao).

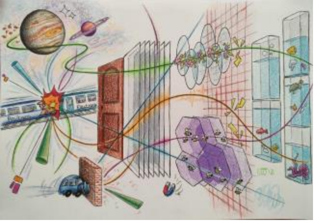
See as well C. Dorfer, https://doi.org/10.1063/1.5090850



2022: TPA-TCT in **SiC** with 400 nm TPA at SGIKER (UPV, Bilbao).

C.Quintana, 41st RD50 meeting

Envisaged improvements/updates



DRD3

Hardware-wise

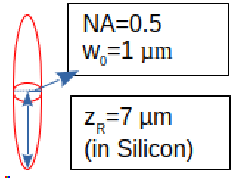
❶

FYLA is working in a fully fibered laser, tunable pulse duration: 100-1000 fs

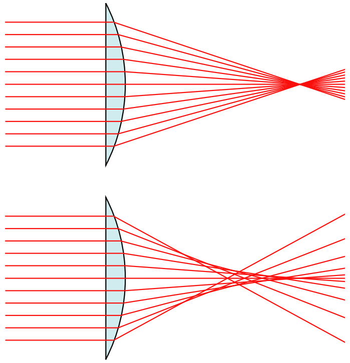
Their goal is to provide a "turn-key" TPA-TCT solution, including mechanics and software.

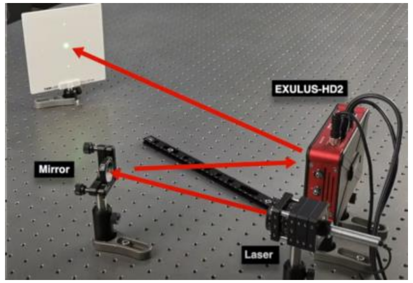
❷

Radiation hardness demands thin detectors (≤ 50 µm). Longitudinal resolution in TPA is improved using objectives with NA>0.5 (=TPA baseline) .



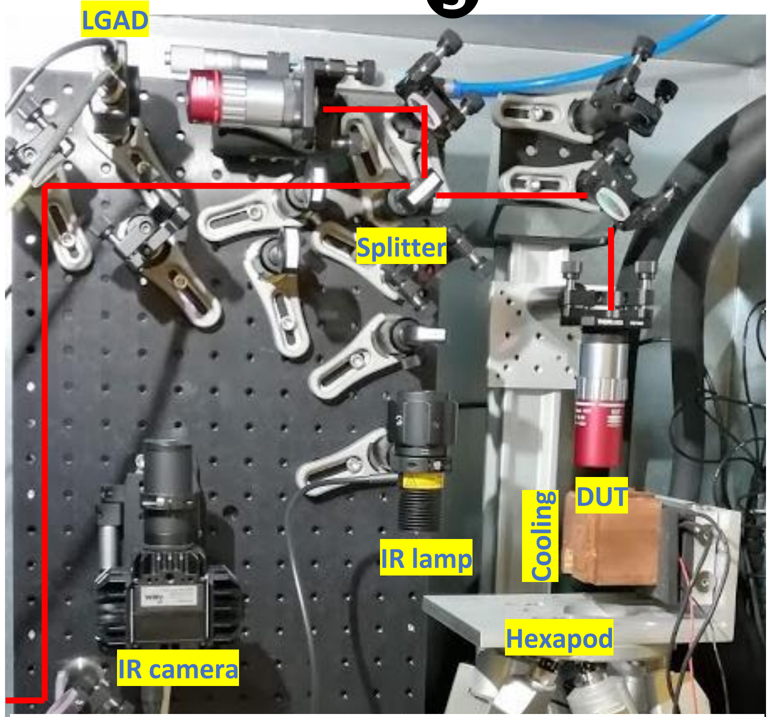
In thick devices (> 70 µm), very high NA (>0.5) leads to spherical aberration (SA) of the focus, degrading TPA measurement.



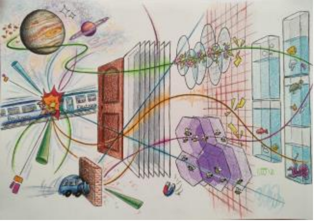


This effect can be compensated using Spatial Light Modulators (~25k€).

❸



Timing measurements with TPA can be easily achieved splitting the beam before the objective. An LGAD placed on a **monitoring branch** can be used as time reference for jitter calculation.

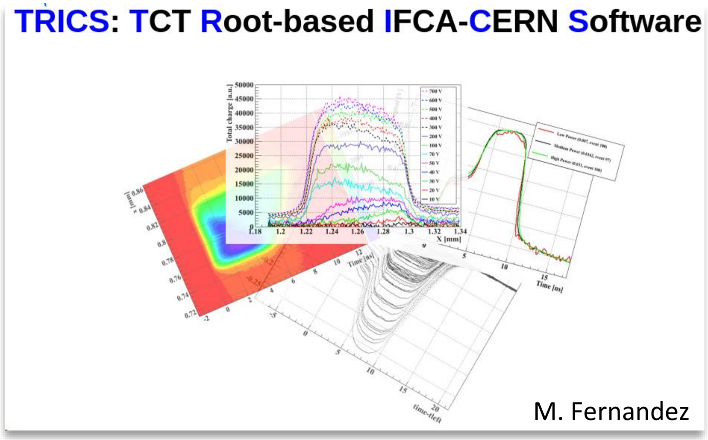


Envisaged updates

Software-wise

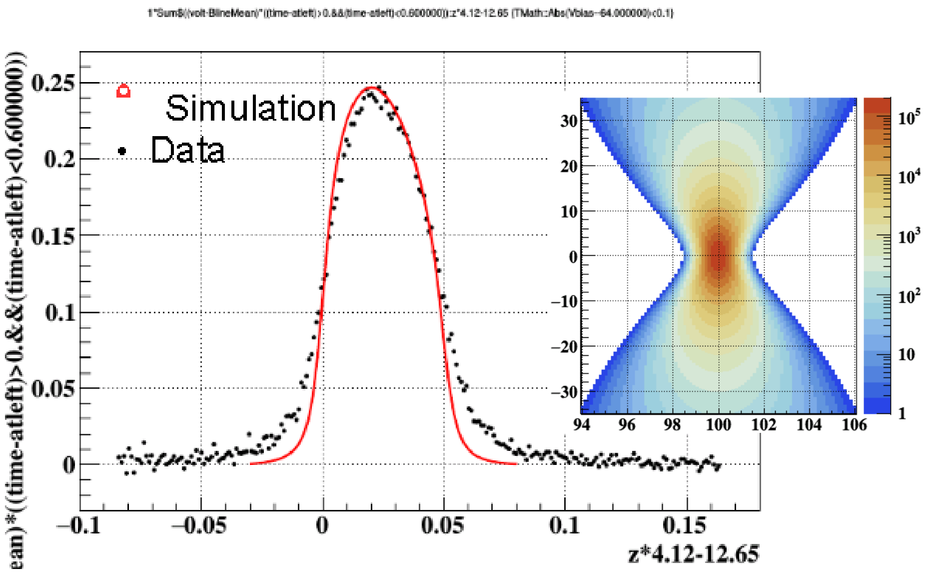
❶

Analysis package:
1) ROOT based (1D, 2D plotting)
2) Includes SPA subtraction methods for irradiated detectors



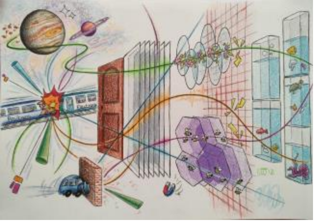
❷

TRACS simulation package:
1) For diodes and microstrips
2) Fast Poisson solver. It accepts arbitrary illumination patterns



❸

Online user forum and organization of hands-on workshop on TPA-technique



Milestones & deliverables (2024-26)

DRD3

- Deliverable: reduction of excitation “voxel” dimensions (longitudinal ≤3.5 µm in Si)
  - Using high NA objectives and Spatial Light Modulators (~2 years)
  - Extension of TPA setup with timing reference (this year)

- FYLA:
  - Step 1: All fiber laser, tunable pulse length (1 year)
  - Step 2: Full TPA-TCT system “turn-key” (~2 years)

- Build-up of user community:
  - Organization of tutorials and hands-on workshops (also within WG8).
  - Online User forum (technical support for hw&sw).