CERN related activities by the group of Photoelectric Phenomena at Vilnius University

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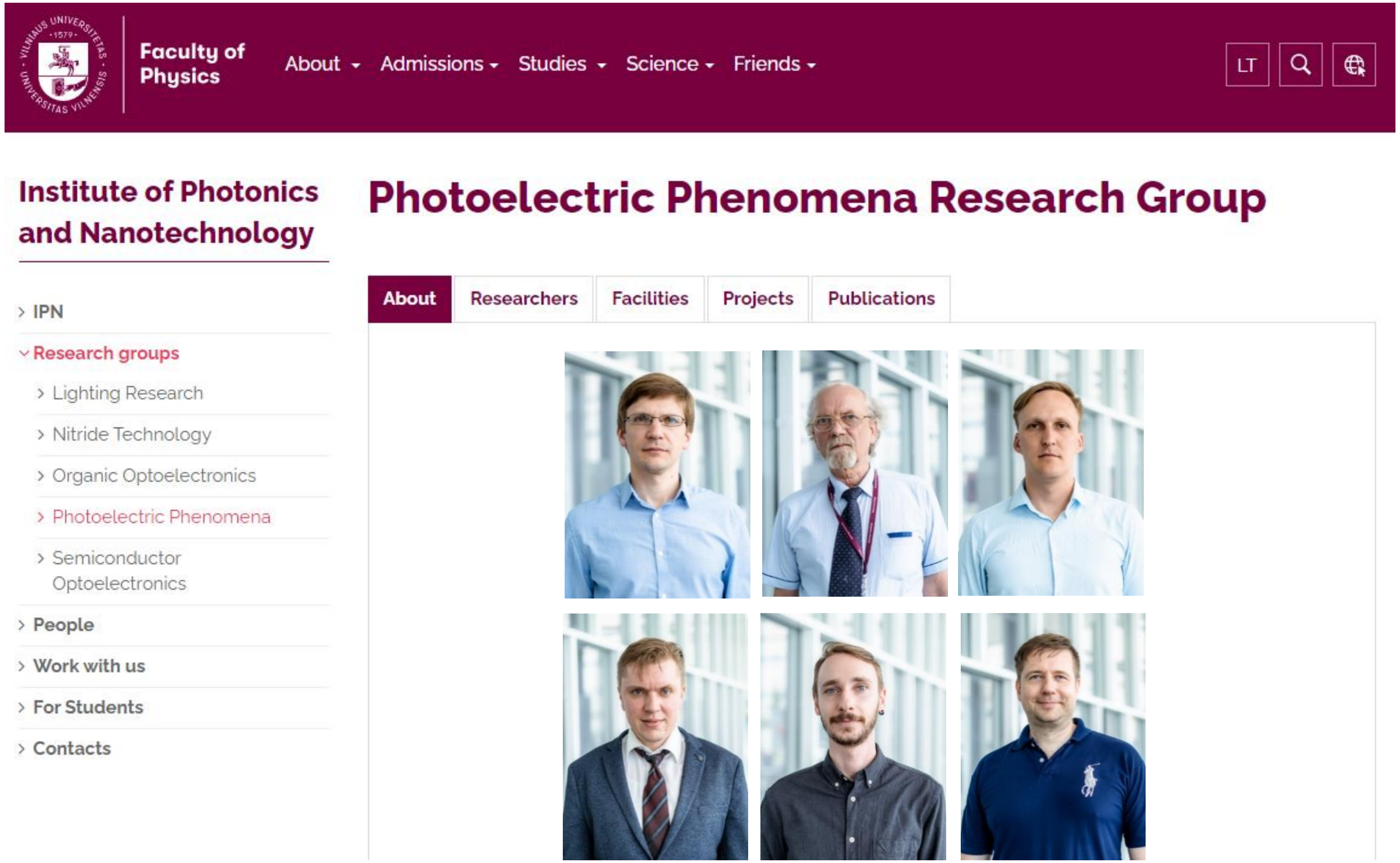
Outline

- Photoelectric Phenomena Research Group
- Major research activities
- Facilities
- Relations with CERN
- Some research results
- Summary

Photoelectric Phenomena Research Group



Group members:

- dr. T. Čeponis
- prof. E. Gaubas
- dr. V. Rumbauskas
- dr. J. Pavlov
- dr. L. Deveikis
- dr. A. Mekys
- PHD students ~ 1-2
- BC. students ~ 5
- Ms. students ~ 2

Major research activities

- Search of radiation hard materials and development of radiation tolerant sensor structures.

- Engineering of defects for development of radiation hard particle and photo sensors.

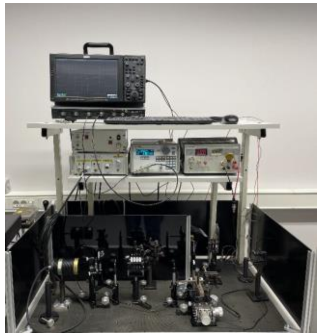
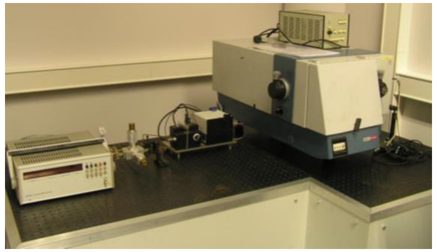
- Development of technologies and instrumentation for spectroscopy and contactless-remote dosimetry of the large fluences of high energy radiations.

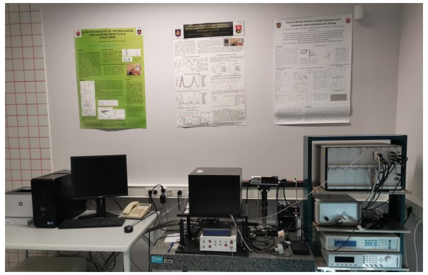
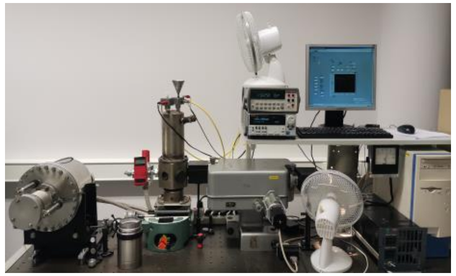
- Development of technologies and instruments for the remote in situ measurements in harsh irradiation environments.

- Development of advanced material characterization techniques and instruments.

Facilities



- Instrumentation for testing the electric characteristics of radiation detectors (Summit 11000 probe station, Keithley, Keysight SMUs and LRC meters)
- Instrumentation for profiling of carrier drift current transients (2 GHz Lecroy oscilloscope, PicoQant, Standa ps lasers, Particulars (Slovenia) TCT system is foreseen)
- Instrumentation for measurement of pulsed barrier capacitance transients (BELIV)
- EPR scanner BRUKER-E-SCAN
- Instrument for pulsed spectroscopy of thermal and photo-ionization VUTEG-6
- Instrument for steady-state photo-ionization spectroscopy
- Instrumentation for simultaneous spectroscopy of time-resolved luminescence and microwave-probed photoconductivity
- DLTS spectrometer HERA-DLTS System FT 1030
- Pulsed photo-ionization spectroscopy (fs and ns lasers equipped with optical parametric oscillators and differential frequency generators)

Relations with CERN

The CERN Experimental Programme

Grey Book database

Find in Greybook...

Welcome | Experiments & Projects | Teams | Participations | Countries

Research Programme

- LHC
- SPS
- PS
- AD
- ISOLDE Facility
- Irradiation Facility
- Neutrino Platform
- GRADE
- CTF3
- R&D
- Non-accelerator experiments

Research Activities

- Experiments and Projects under Study
- External Experiments
- Recognized Experiments
- Completed Experiments

RD50

Development of Radiation Hard Semiconductor Devices for Very High Luminosity Colliders

Synonym:
Research Programme: R&D
Approved: 30-05-2002
Beam:
Status: In-Progress

Overview | Teams | Participations

Spokesperson:	CASSE, Gianluigi MOLL, Michael
Contact person:	MOLL, Michael
Experimental Safety Officer (EXSO):	COSTANZI, Ruddy Alain
Experiment secretariat e-mail:	dt-secretariat@cern.ch

Number of Institutes:	66
Number of Countries:	25
Number of Participants:	238
Number of Authors:	191

Status History

Status	Start Date	End Date
Preparation	30-05-2002	25-01-2004
In-Progress	26-01-2004	

Relations with CERN

The CERN Experimental Programme
Grey Book database

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Research Programme

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- Neutrino Platform
- GRADE
- CTF3
- R&D
- Non-accelerator experiments
- Approved Studies for Future Projects

Research Activities

- Experiments and Projects under Study
- External Experiments
- Recognized Experiments
- Completed Experiments

Institute of Photonics and Nanotechnology

Overview | Experiments | Participations

Search criteria: [ ] Search

Name	Experiment Name	Author
Tomas CEPONIS	RD50	N
Laimonas DEVEIKIS	RD50	N
Eugenijus GAUBAS	RD50	Y
Jevgenij PAVLOV	RD50	N
Vytautas RUMBAUSKAS	RD50	N

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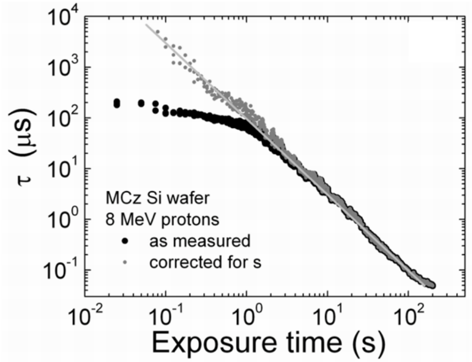
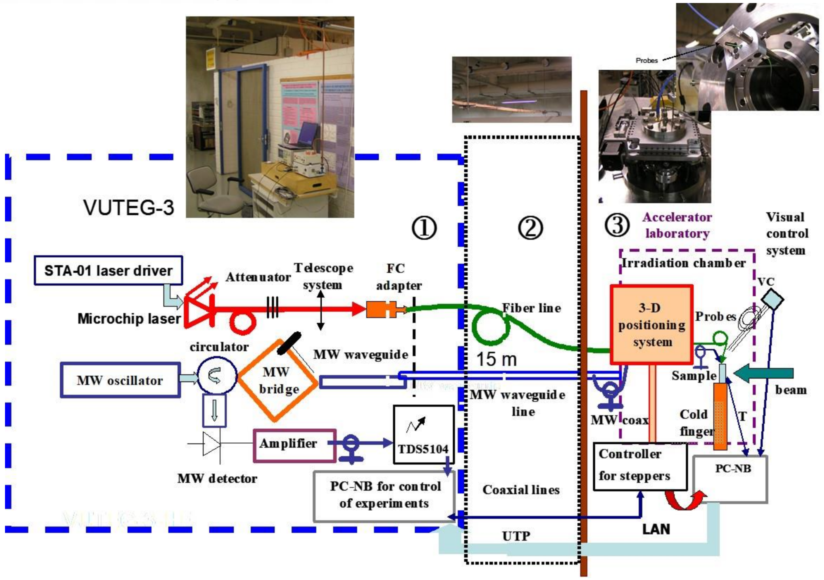
Technologies for the in situ monitoring of evolution of radiation defects

In situ control of evolution of the radiation defects introduced by 8 MeV protons at Helsinki University accelerator laboratory.

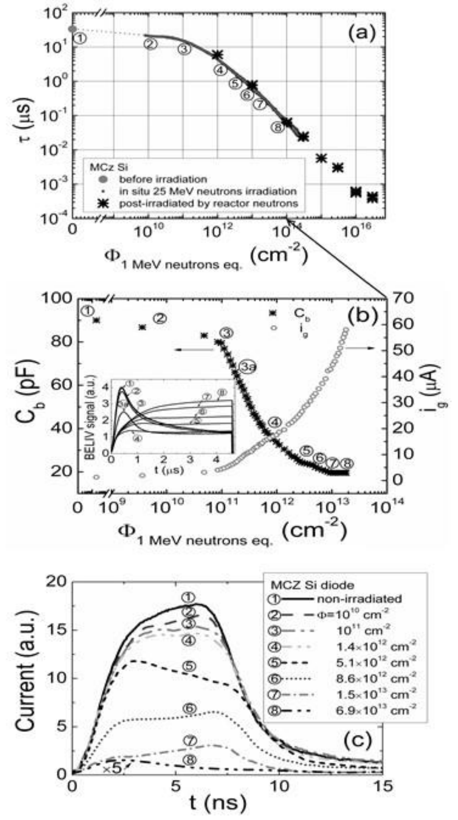




In situ variations of carrier recombination (a- MW-PC), of barrier capacitance (b-BELIV) and of detector response (c-TCT/ICDC) during irradiation by spallator neutrons.

Correlated evolution of the MW-PC, BELIV and ICDC characteristics during spallator neutrons irradiation:

transients registered every 10 ms, irradiation - bunches of 4 ns duration.



E. Gaubas, T. Ceponis, A. Jasiunas, A. Uleckas, J. Vaitkus, E. Cortina, and O. Militaru, *Correlated evolution of barrier capacitance charging, generation, and drift currents and of carrier lifetime in Si structures during 25 MeV neutrons irradiation*, Appl. Phys. Lett. **101** (2012) 232104.

Technologies and instruments for the radiation dose and flux measurements in a wide range

- Patented method and equipment for the measurements of high cumulative doses collected under ionizing irradiations.

URKUNDE | CERTIFICATE | CERTIFICAT

Europäisches Patent | European patent | Brevet européen

Es wird hiermit bescheinigt, dass für die in der Patentschrift beschriebene Erfindung ein europäisches Patent für die in der Patentschrift bezeichneten Vertragsstaaten erteilt worden ist.

It is hereby certified that a European patent has been granted in respect of the invention described in the patent specification for the Contracting States designated in the specification.

Il est certifié qu'un brevet européen a été délivré pour l'invention décrite dans le fascicule de brevet, pour les Etats contractants désignés dans le fascicule de brevet.

Europäisches Patent Nr. / European patent No. / Brevet européen n°: 3594723

Patentinhaber / Proprietor(s) of the patent / Titulaire(s) du brevet: Vilnius University, Universiteto g. 3, 01513 Vilnius/LT

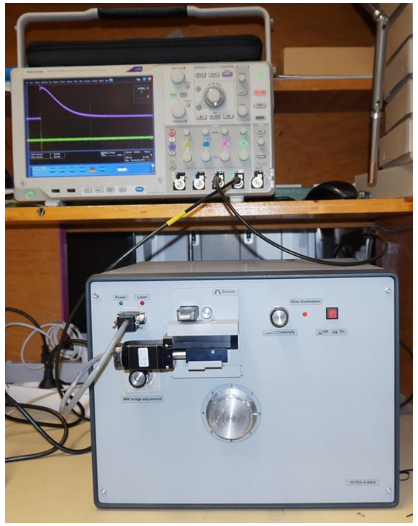
EU patent: E. Gaubas, T. Čeponis, et al, „DOUBLE RESPONSE IONIZING RADIATION DETECTOR AND MEASURING METHOD USING THE SAME“- App No.: 18213254.8, Patent No.: 3594723.

- Instrument and technology for dosimetry and fluxmetry of high energy electromagnetic and particle radiations.

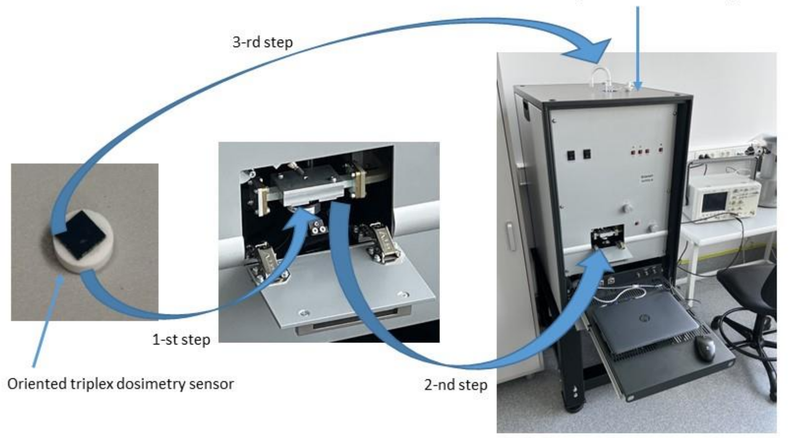
Particle identification, fluxmetry and dosimetry instrument „VUTEG-7“ (front view)

HYBRID MULTI-LAYER SENSOR AND METHOD FOR LARGE FLUENCE DOSIMETRY AND FLUXIMETRY, Authors: Eugenijus Gaubas, Tomas Čeponis, Laimonas Deveikis, Jevgenij Pavlov, Vytautas Rumbauskas. Application No. 21 165 145.0, submission date: 2021 03 26.

- Dosimeter VUTEG-5-AIDA has been installed at CERN in 2012 for the RD50 program and other CERN research. The dosimeter VUTEG-5-AIDA is devoted for dosimetric control of hot irradiation zones of large areas. This dosimeter is also equipped with precision scanning devices for evaluation of local fluence exposure. It can also be adapted for imaging of narrow irradiated beams.



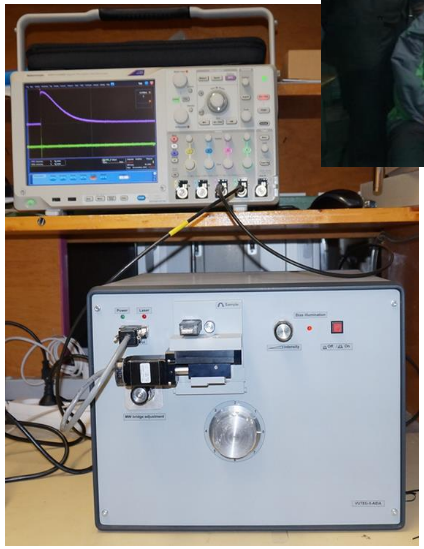
- The prototype system for the control of radiation doses in a wide range. This prototype system allows measuring low and very high fluences and to identify the spectrum of high energy radiations.



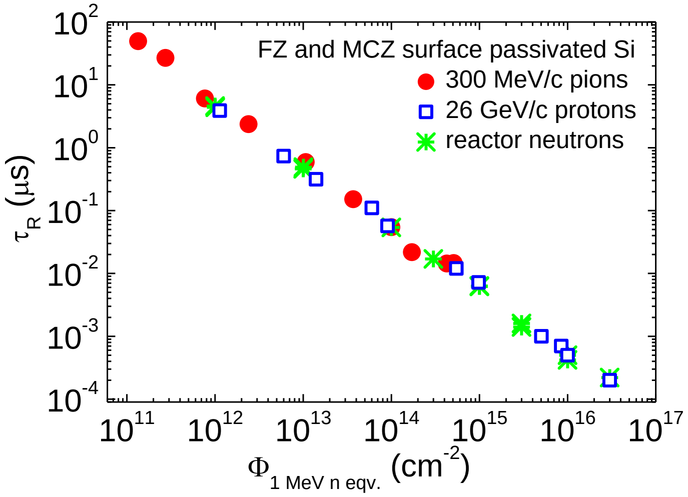
The oriented sensor is in succession set in PL as well as MW-PC opening and into the EPR insert of the tentative reader

E. Gaubas, T. Čeponis, L. Deveikis, J. Pavlov, V. Rumbauskas, Oriented triplex sensor and method of identification of the radiation source location and its dosimetry, EU patent application No. EP22171639.2, submission date: 2022 05 04.

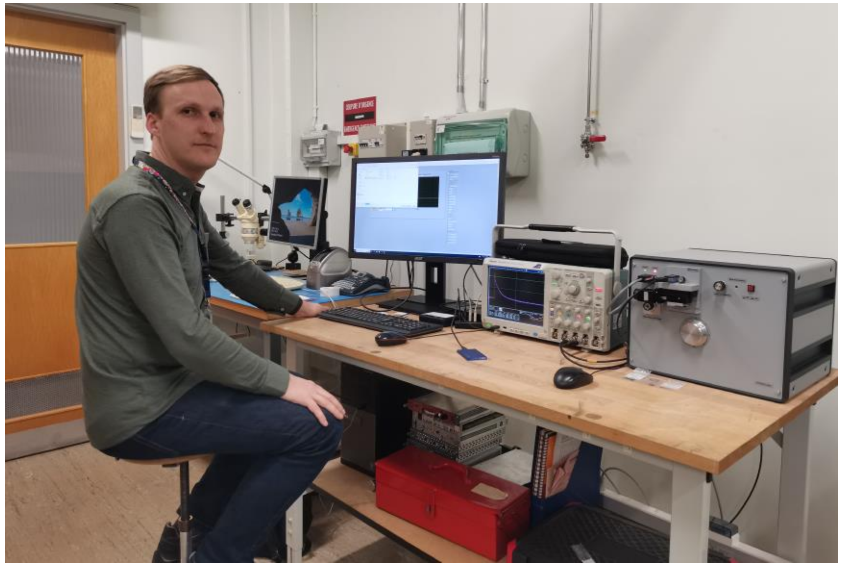
Multipurpose instrument VUTEG-5-AIDA installed at CERN



Instrument VUTEG-5-AIDA has been installed at CERN in 2012 for the RD50 program and other CERN research. The instrument VUTEG-5-AIDA is devoted for dosimetric control of hot irradiation zones of large areas. This dosimeter is also equipped with precision scanning devices for evaluation of local fluence exposure. It can also be adapted for imaging of narrow irradiation beams and for materials characterization.

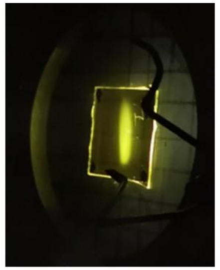


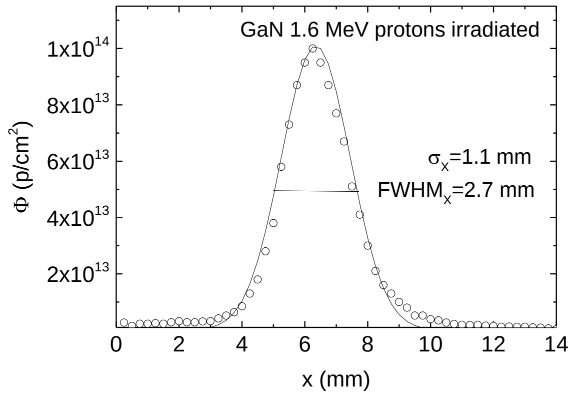
Carrier lifetime variations as a function of irradiation fluence in FZ and MCZ Si samples irradiated by different particles.

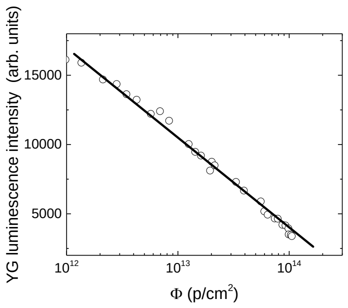


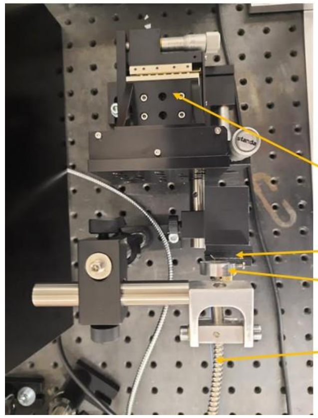
Dr. V. Rumbauskas is preparing instrument VUTEG-5-AIDA for CERN staff training in March 2023.

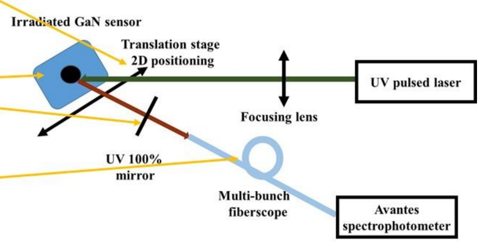
Technologies and instruments for particle beam profiling





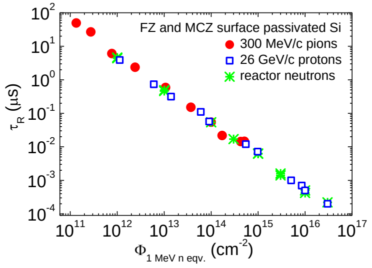


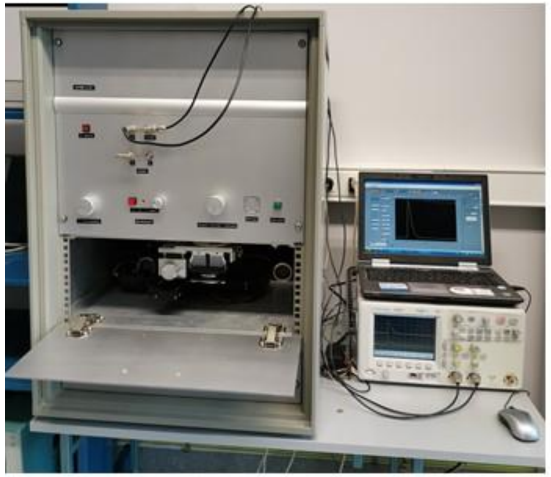


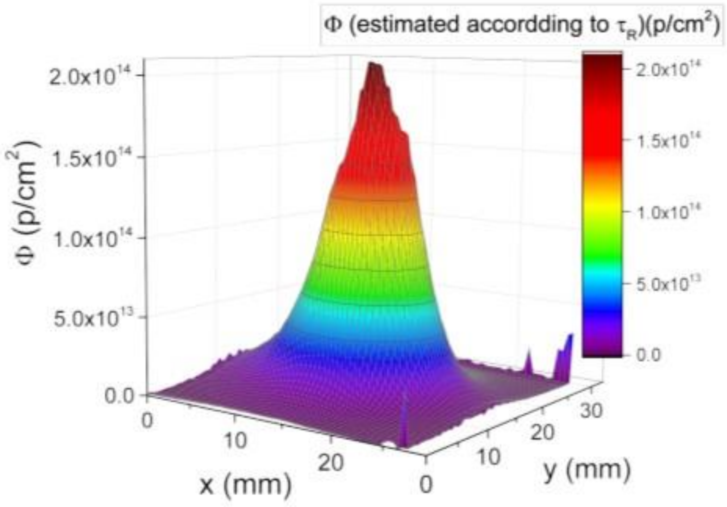


Recorded profile of 1.6 MeV proton beam.

The particle beam profiling techniques based on dosimetry of the hadron irradiated Si and GaN sensors have been developed. The fluence distribution profiles for high energy penetrative particles are recorded by carrier lifetime measurements within Si wafer. For beams of rather low energy particles, sensors with thin active layers are preferable. Then, the scintillation techniques are eligible to have recordable responses from thin sensor layers.



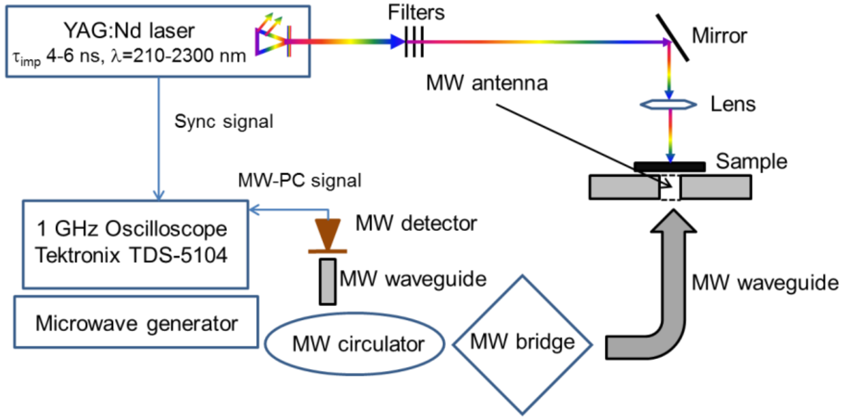




Recorded profile of 26 GeV/c proton beam.

- L. Deveikis, J.V. Vaitkus, T. Čeponis, M. Gaspariūnas, V. Kovalevskij, V. Rumbauskas, E. Gaubas, *Profiling of proton beams by fluence scanners*, Lith. J. Phys. **61** (2021) 75–83.
- T. Ceponis, L. Deveikis, E. Gaubas V. Rumbauskas, M. Moll, Particle beam profilers based on fluence dependent variations of carrier lifetime and scintillation intensity in Si and GaN materials, Presentation at RD50 workshop, CERN 2022-06.

Spectroscopy of defects in irradiated semiconductors



Sketch of the pulsed photo-ionization spectroscopy setup.

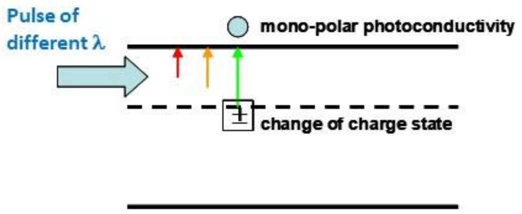


Illustration of monopolar photoconductivity.

	Activation energy (eV)	Γ	Defect type	Concentration (cm^{-3})	σ (cm^2)
GaN:Mn	E_{Mn-1}=1.40	0.05	Mn related	6×10^{18}	1×10^{-17}
	E_{Mn-2}=1.98	0.25	Mn related	5×10^{17}	1×10^{-16}
	E_{Mn-3}=2.40	0.15	Ga_I	5×10^{17}	4×10^{-16}
	E_{Mn-4}=2.97	0.25	Unidentified	4×10^{17}	7×10^{-16}
GaN:Mg	E_{Mg-1}=1.30	0.02	C_I related acceptors	1.5×10^{18}	8×10^{-18}
	E_{Mg-2}=1.75	0.18	Mg related	6×10^{17}	4×10^{-17}
	E_{Mg-3}=2.07	0.23	V_{Ga}	1.5×10^{17}	1×10^{-16}
	E_{Mg-4}=2.39	0.15	Ga_I	4×10^{16}	6×10^{-16}
	E_{Mg-5}=3.10	0.32	Mg related	2×10^{16}	2×10^{-15}
	E_{Mg-6}=3.30	0.20	V_N	7×10^{16}	3×10^{-15}

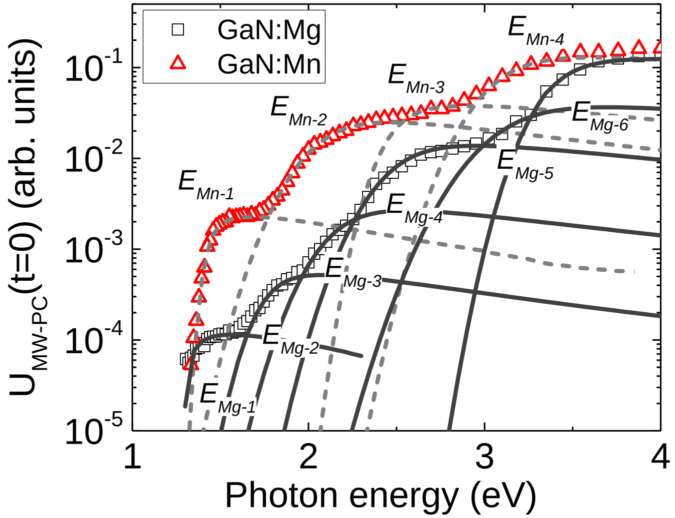
Kopylov-Pikhtin approach:

$$\sigma_{ph-e}(h\nu) \propto \int_0^\infty \frac{e^{-(E+E_{abs}-h\nu)^2/\Gamma^2}\sqrt{E}\,dE}{h\nu(E+E_{abs})^2}$$

$$\Gamma=\sqrt{2S}\nu_0\sqrt{2\coth(h\nu_0/k_BT)}$$

$$S = d_{FC}/h\nu_0$$

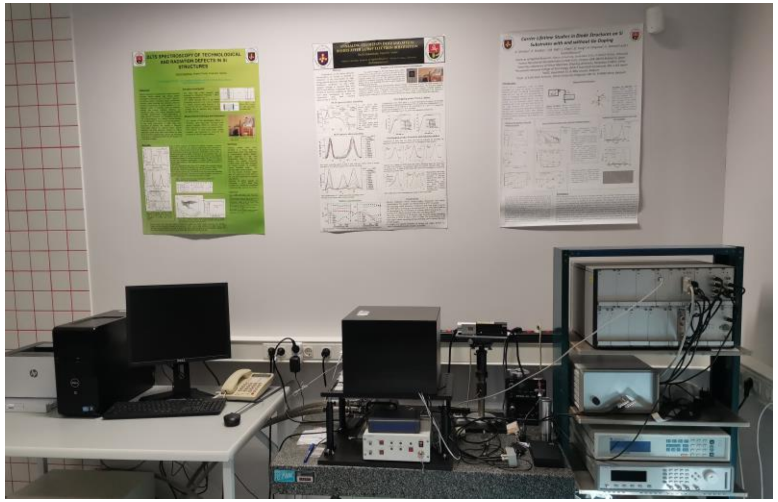
E – energy of states in the conduction band, E_{abs} – photo-ionization energy of the level, Γ– broadening parameter, S – Huang-Rhys factor, d_{FC}– *Franck-Condon* shift.

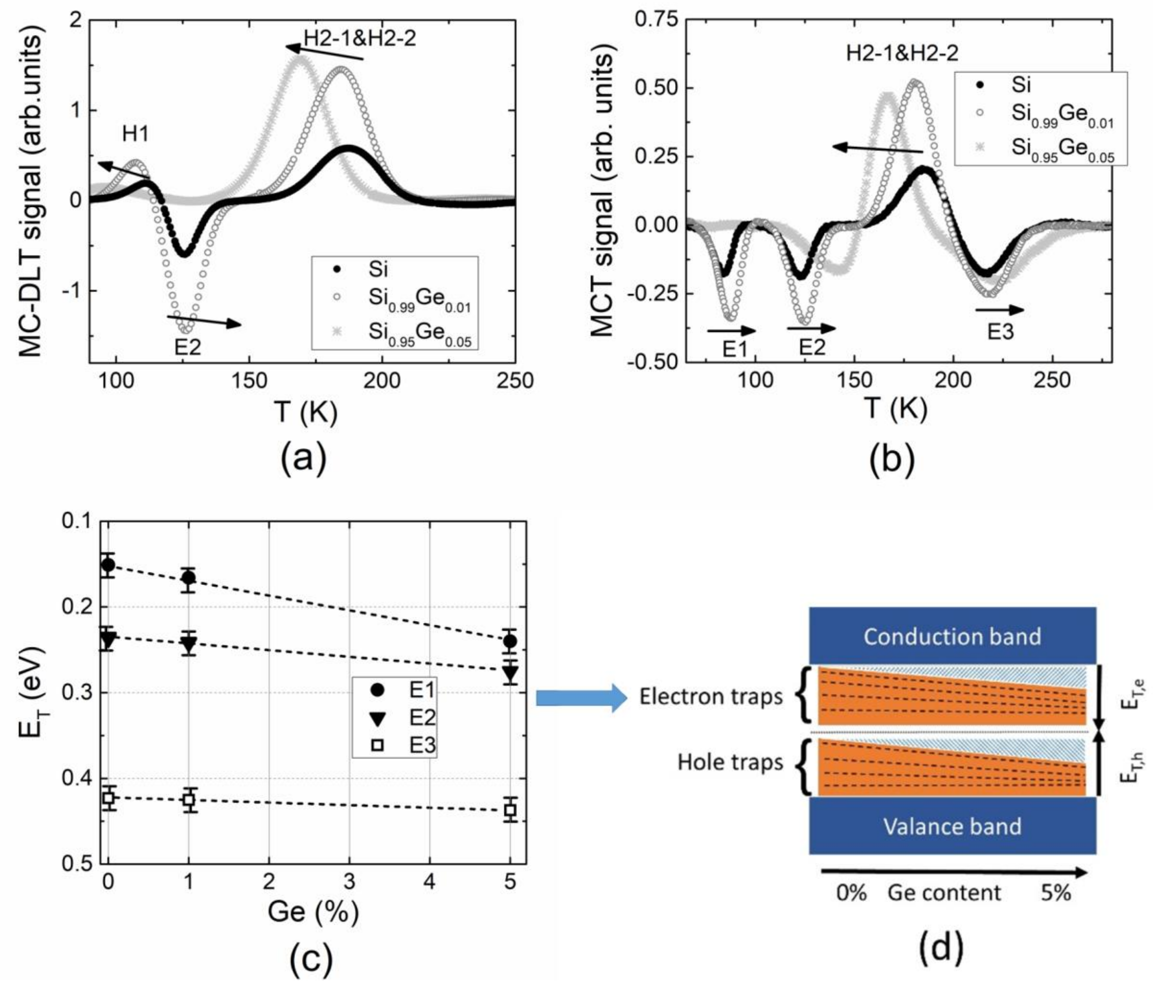


Experimentally obtained PPIS spectra in Mg and Mn doped pristine GaN samples and simulated energy level steps.

E. Gaubas, T. Čeponis, D. Meškauskaite, J. Mickevičius, J. Pavlov, V. Rumbauskas, R. Grigonis, M. Zajac, R. Kucharski, *Pulsed photo-ionization spectroscopy of traps in as-grown and neutron irradiated ammonothermally synthesized GaN*, Scientific Reports **9** (2019) 1473.

Spectroscopy of defects in irradiated sensors

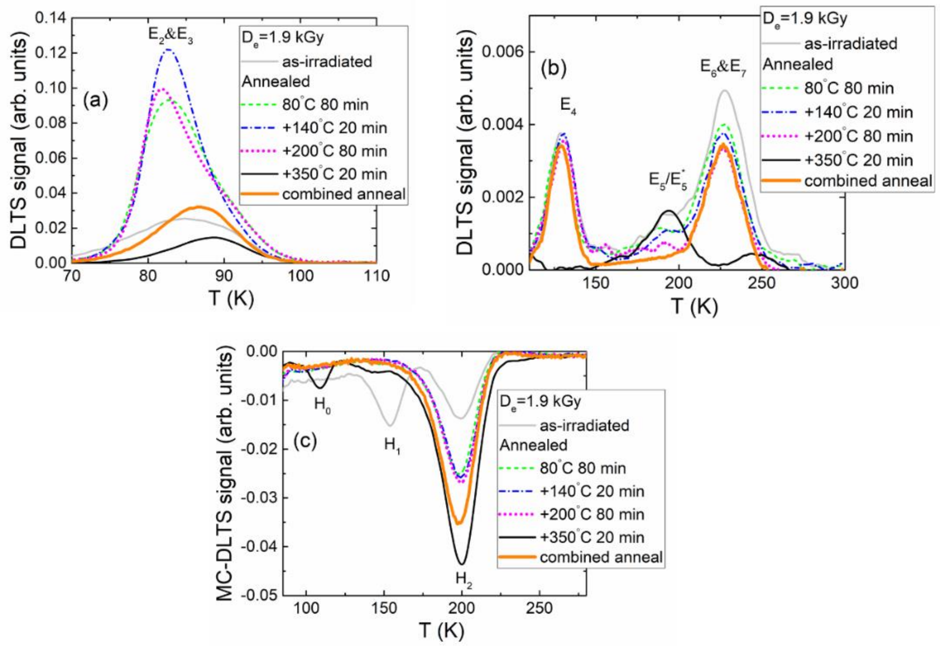




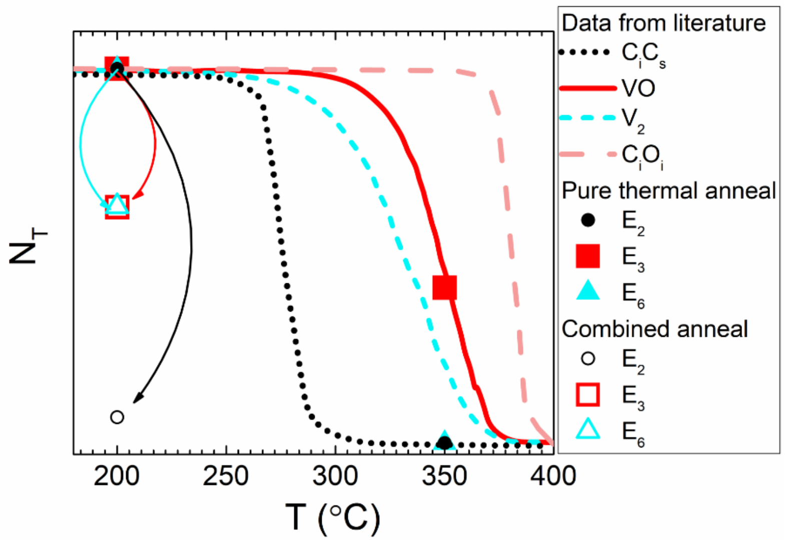
Comparison of MC-DLT (a) and MCT (b) spectra obtained in the 5.5 MeV electron-irradiated Si, $Si_{0.99}Ge_{0.01}$ and $Si_{0.95}Ge_{0.05}$ diodes; (c) The activation energy values (E_T) of the radiation-induced traps (E1–E3) of minority carriers as a function of Ge content; (d) A tentative scheme of the band gap variation in p-type $Si_{1-x}Ge_x$ material and related activation energy changes in the minority carrier traps depending on the Ge content.

- T. Ceponis, S. Lastovskii, L. Makarenko, J. Pavlov, K. Pukas, E. Gaubas, *Study of radiation-induced defects in p-type $Si_{1-x}Ge_x$ diodes before and after annealing*, Materials **13** (2020) 5684.
- J. Pavlov, T. Ceponis, K. Pukas, L. Makarenko, E. Gaubas, *5.5 MeV electron irradiation-induced transformation of minority carrier traps in p-type Si and $Si_{1-x}Ge_x$ alloys*, Materials **15** (2022) 1861.

Techniques for recovery of radiation damaged detectors



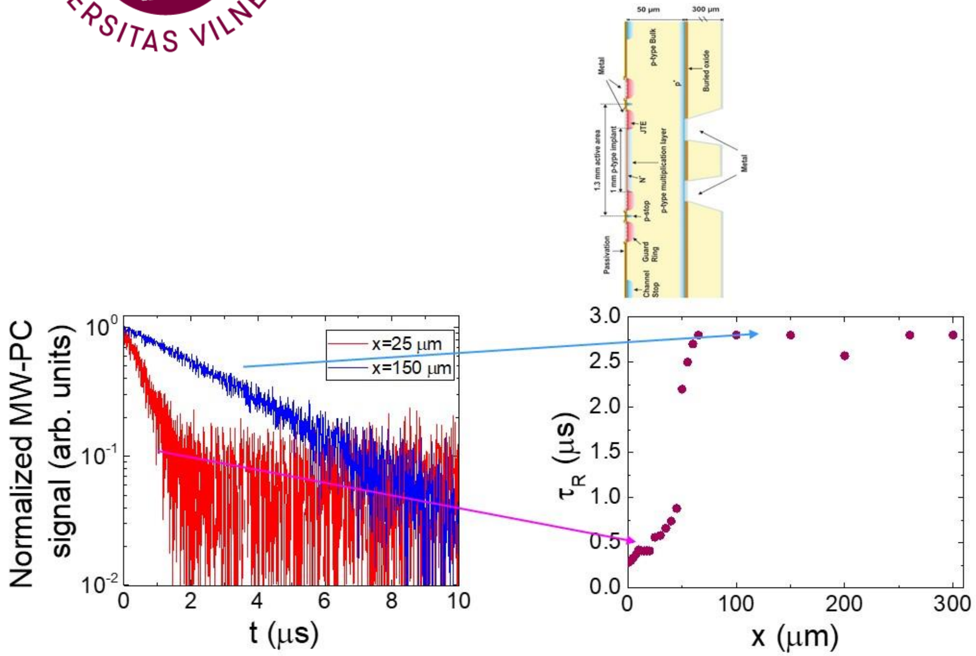
Thermal processing regime dependent variations of the deep-level transient (DLT) spectra of majority (a) and (b) and minority (c) carrier traps recorded on the pristine and electron irradiated Si PIN diodes.



Temperature ranges (according to literature data) where various carrier traps in Si materials can be isochronally 15-30 min annealed out (solid curves) are compared with the data obtained in this work using pure thermal (solid symbols) and combined furnace-laser (open symbols) anneal technology. It can be seen that the combined anneal leads to more efficient transformations of defects when compared with the pure thermal anneals by reaching the same temperature.

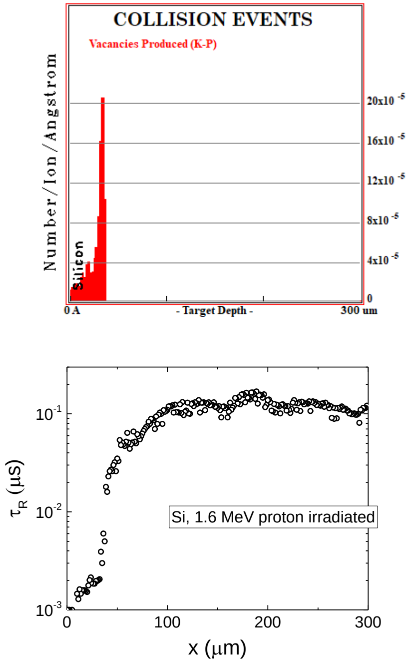
T. Ceponis, M. Burkanas, A. Cicinas, L. Deveikis, J. Pavlov, V. Rumbauskas, J. Venius, E. Gaubas, *Combined techniques for recovery of radiation damaged detectors*, Mat. Sc. Sem. Proc. 168 (2023) 107863.

Profiling of carrier lifetime and electrical characteristics in modern sensor structures



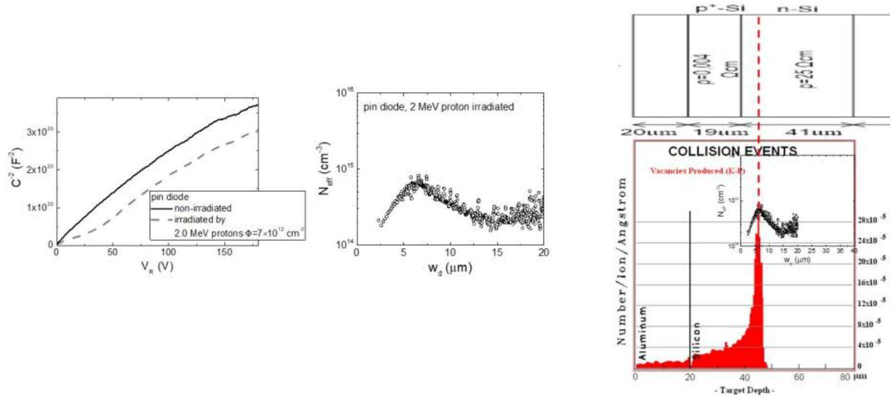
MW-PC characteristics (left) and measured profile of carrier lifetime (right) in Si LGAD structure.

1.6 MeV protons, $\Phi = 10^{15}$ cm^{-2}



Comparison of TRIM simulated defects distribution profile with the measured profile of carrier lifetime.

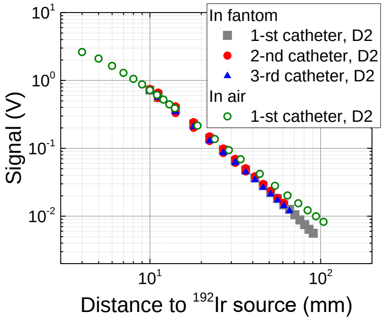
2.0 MeV protons

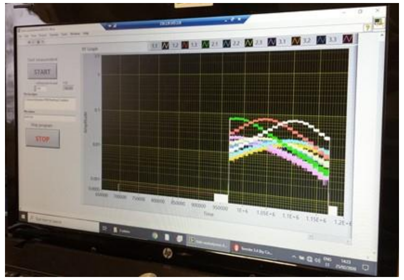


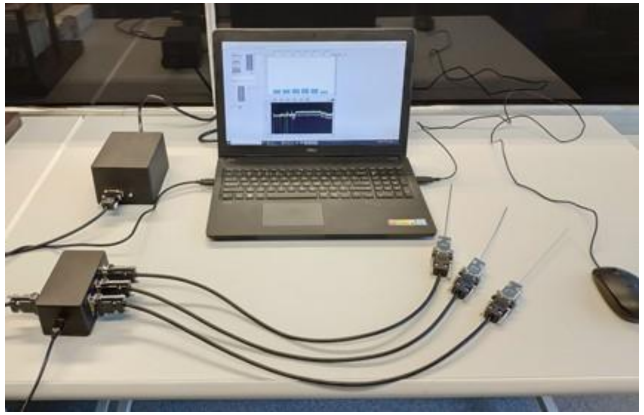
Correlation of C-V characteristics (left), calculated N_{eff} profile (middle) and simulated defect distribution profile in pin diode structure irradiated by 2.0 MeV.

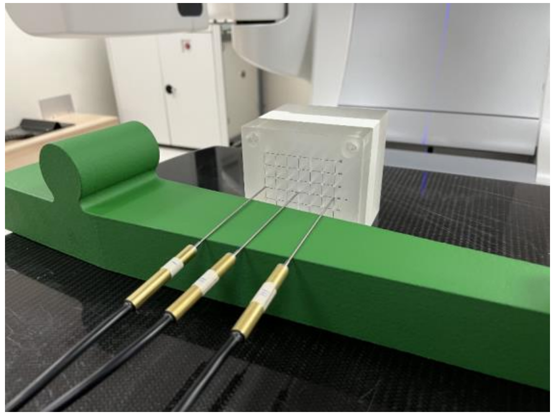
T. Ceponis, L. Deveikis, E. Gaubas, R. Markevicius, J. Pavlov, G. Pellegrini, V. Rumbauskas, Profiling of carrier lifetime and electrical characteristics in PIN and LGAD structures, Presentation at RD50 workshop, Seville 2022-11.

Radiation dose monitoring systems for medical applications

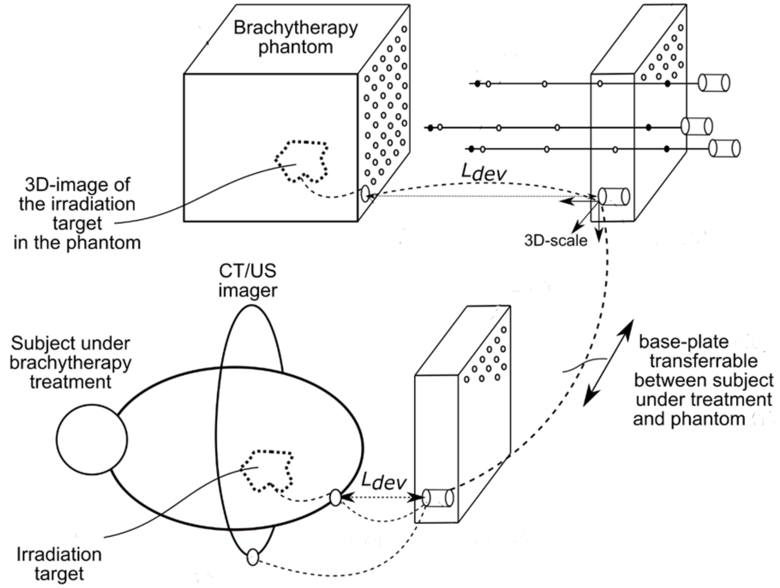








- Development of technology and instrumentation for time-resolved positioning of radiation emitters and for dosimetry during the brachytherapy planning and a subsequent in vivo brachytherapy treatment stages, where the method and apparatus are based on triangulation of needle-type probes fixed within time-space resolved coordinates.
- The technology and instrumentation have been approved at The National Cancer Institute (Lithuania).
- In vivo tests of radiation dose monitoring during brachytherapy therapeutic procedure are being performed at National Cancer Institute (Lithuania) since October 2022.



E. Gaubas, T. Čeponis, K. Pūkas, V. Rumbauskas, M. Užgirytė, J. Venius, K. Akelaitis, A. Cicinas. SYSTEM AND METHOD FOR BRACHYTHERAPY PROCEDURE PLANNING AND VERIFICATION, EU patent application No. EP21210650.4, submission date: 2021 11 26.

Summary

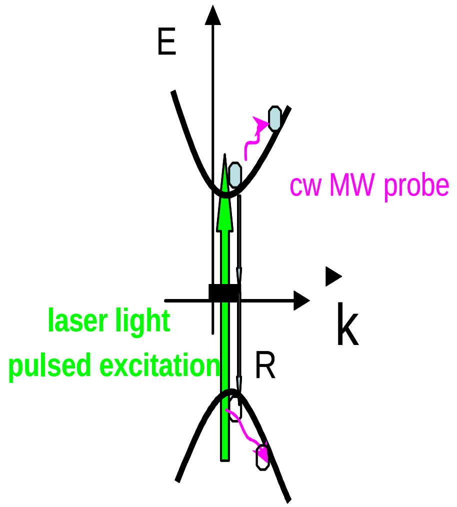
- Activities devoted to search of radiation hard materials, defect engineering for development of radiation hard particle and photo sensors, development of technologies and instrumentation for spectroscopy of high energy radiations and for dosimetry, development of advanced material ex situ and in situ characterization techniques and instruments.

- Participation at CERN RD50 (Development of Radiation Hard Semiconductor Devices for Very High Luminosity Colliders) collaboration.

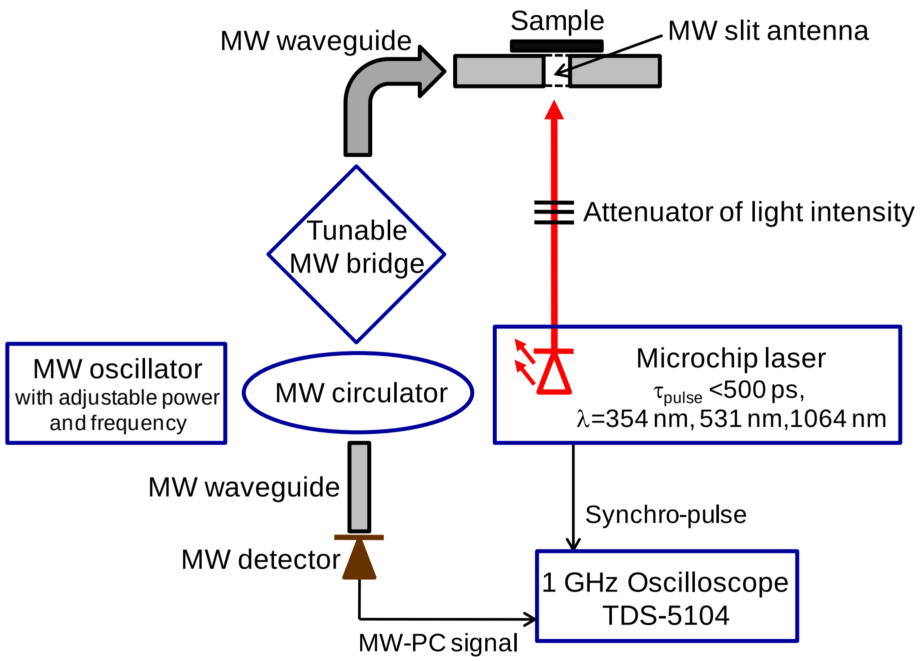
- We are open for new collaborations with interested groups.

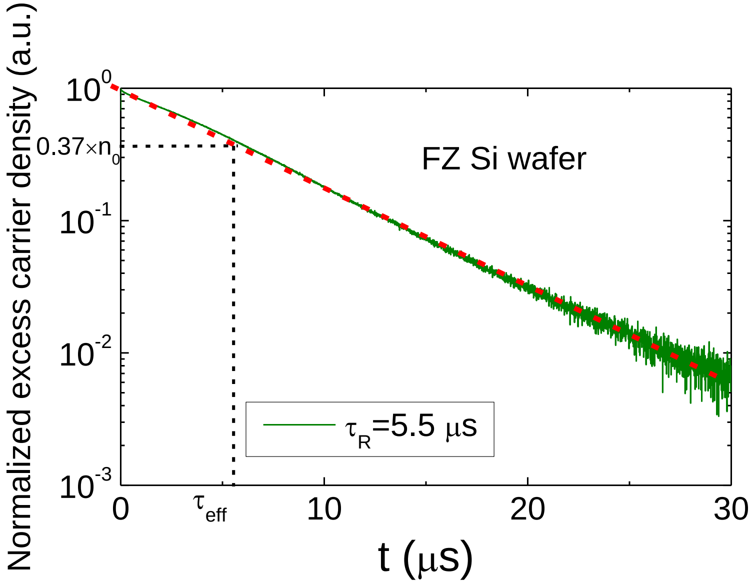
Thank you for your attention

Principles of microwave probed photoconductivity transients technique



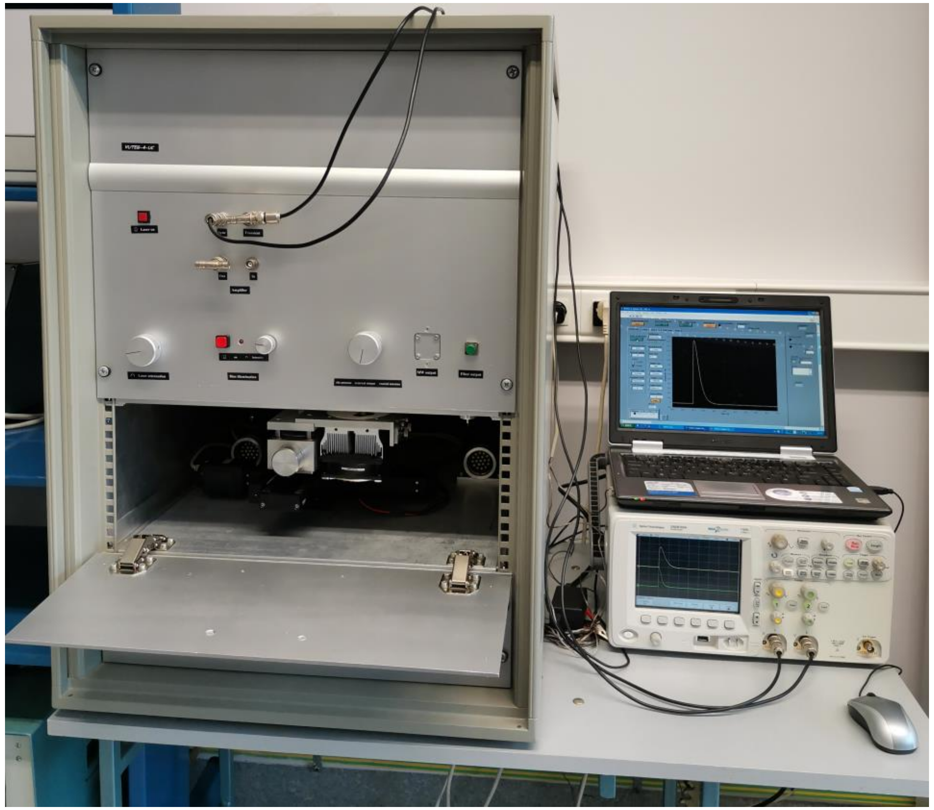
The microwave probed photoconductivity technique is based on the direct measurements of the carrier decay transients by employing MW absorption by excess free carriers.





$$\tau_R = n \Big/ \left(-\frac{\partial n}{\partial t} \right) \Big|_{\exp(-1)}$$

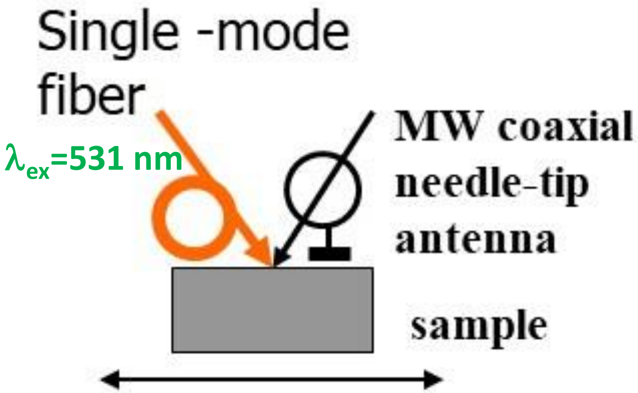
Instrumentation for measurements of microwave probed photoconductivity transients



Vilnius University proprietary made instrument VUTEG-4.

Technical capabilities of the instrument VUTEG-4:

- 2D recombination lifetime scanning of Si wafers of dimensions up to 12 cm in diameter.
- Scan regime of wafer edge is foreseen in this instrument, which is implemented using a needle-tip MW antenna probe intersecting with a single mode fibre tip.
- Assurance of the nitrogen gas and temperature stabilized environment during measurements.



Experiment geometry for cross-sectional profiling of recombination lifetime.