Radiation effects on optoelectronic devices

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2nd WORKSHOP ELICSIR PROJECT, 9-10.03.2021

Outline

- Introduction
- Main study
- Source monitor unit
- Photoresistors
- Photodiodes
- Phototransistors
- Influence of the temperature
- Conclusions

Introduction

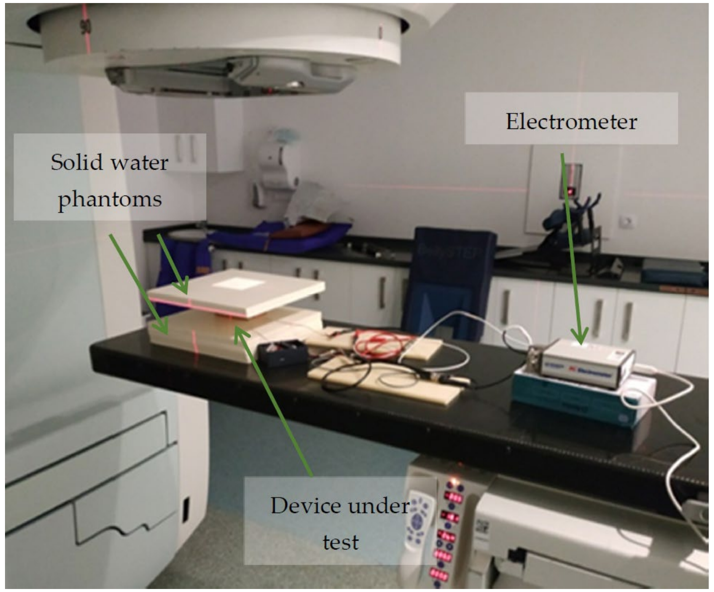
- Ionization chamber: One of the most used dosimetry systems in radiotherapy.
- Advantage of Semiconductor-based dosimeters:
  - Small size
  - Comparatively reduced cost
  - Lower or no bias voltage requirements.
- Optoelectronics devices principles:
  - Photoelectric
  - Photoconductivity

PTW 30010 Farmer Chamber

Preliminary study

- Devices: Photoresistors NORPS-12 and NSL-19M51.
- Source: LINAC Mevatron KDS (Siemens AG, Germany), 18 MV X-ray beam
- Dose rates of 50, 100, 150, 200, 250 and 300 cGy/min
- Location: 10x10 cm field at the LINAC isocenter.

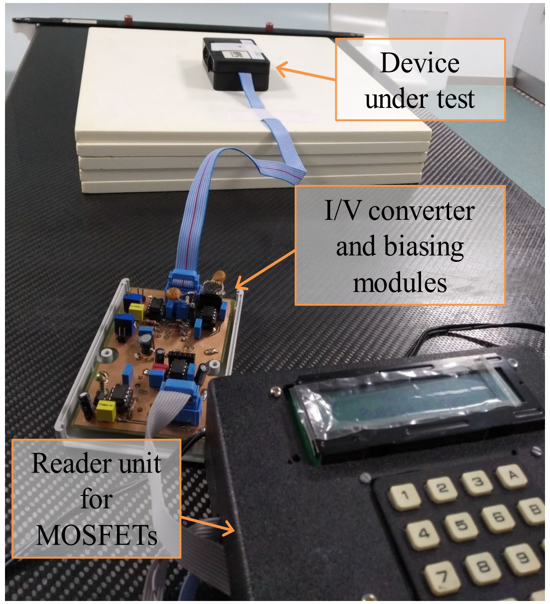
Main study (I)



Experimental setup for photoresistors study

- Devices: Photoresistors
- Source: LINAC Siemens Artiste, 6 MV X-ray beam
- Varying LINAC pulse repetition frequency: Dose rates of 50, 100, 150, 200, 250 and 300 MU/min (0.81 cGy/s, 1.62 cGy/s, 2.43 cGy/s, 3.24 cGy/s, 4.05 cGy/s and 4.87 cGy/s)

Main study (II)

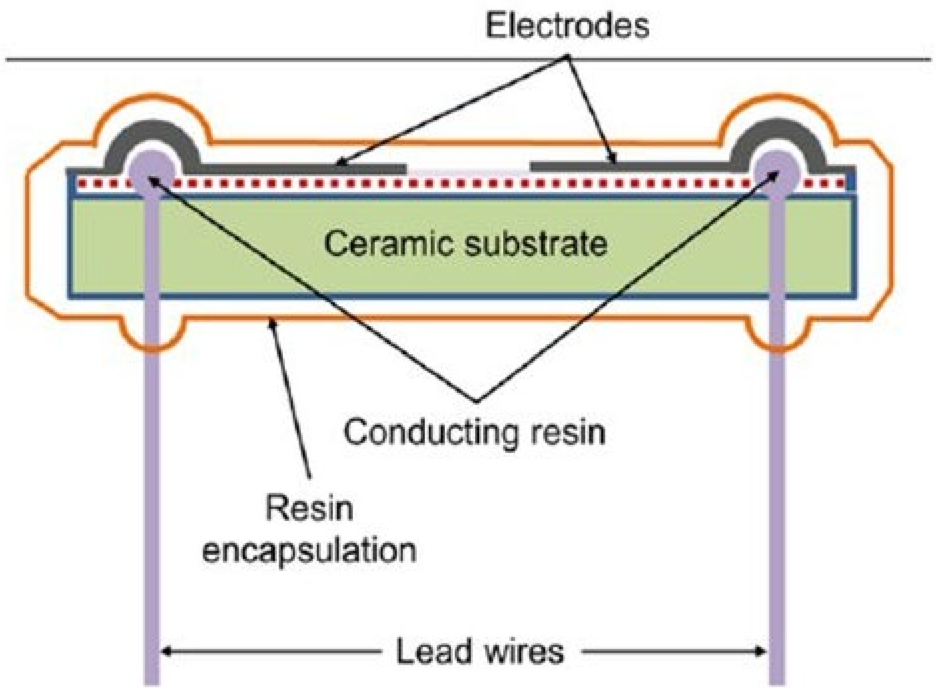


Experimental setup for photodiodes and phototransistors study

- Devices: Photodiodes and phototransistors
- Electronic equilibrium conditions for 6 MV: Five solid water phantoms with a thickness of 1 cm each were placed under the box containing the devices and two more solid water phantoms over it.
- Reference dosimeter: Ionization Chamber PTW30010
- Average dose rate by changing the pulse repetition frequency and instantaneous dose rate studies.

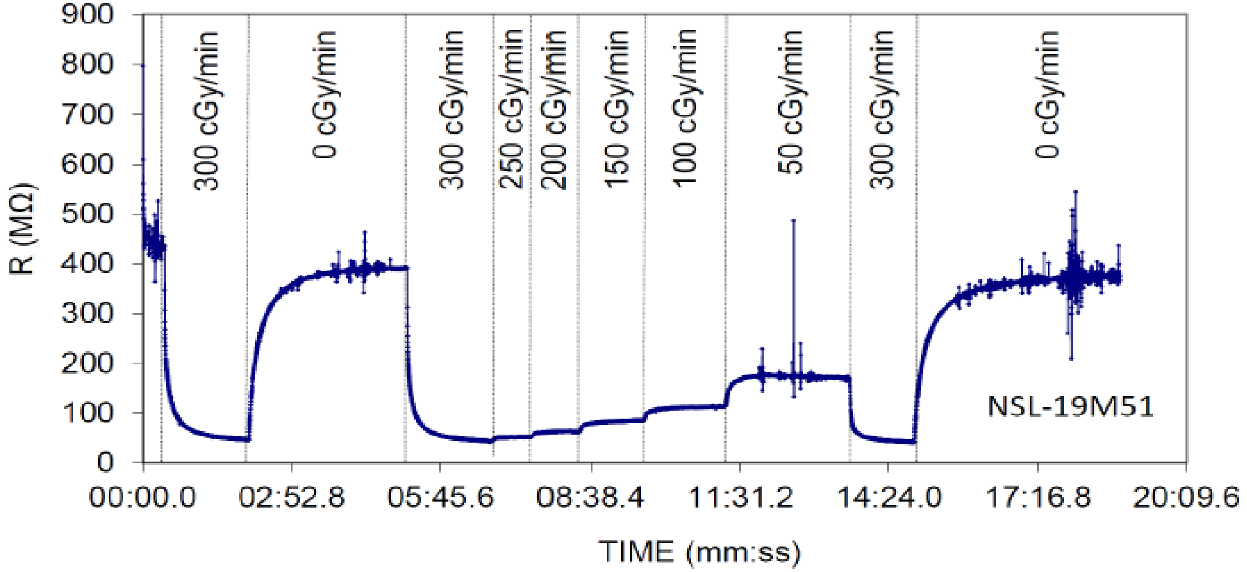
Photoresistors (I)

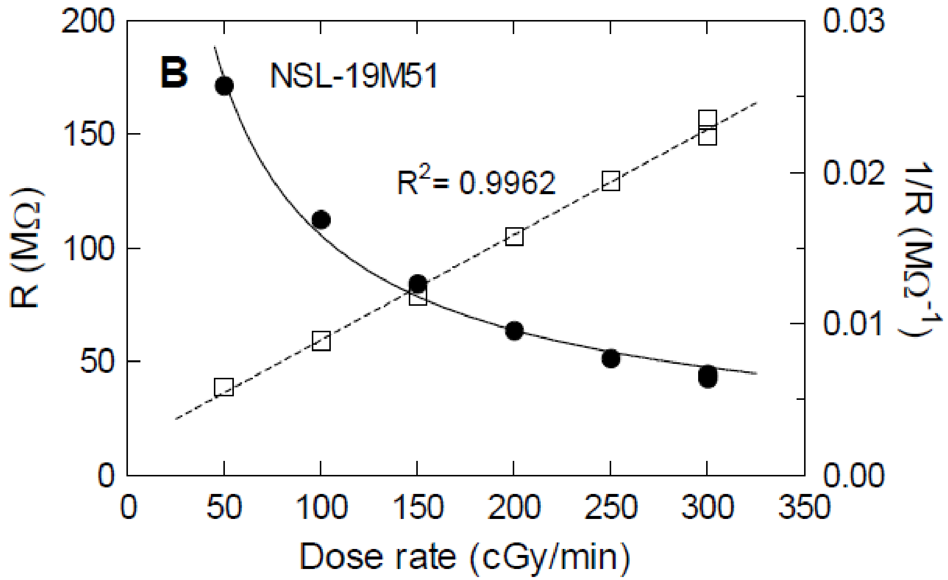
- Photoconductivity: Incremental change in the electrical conductivity of a semiconductor or insulator upon illumination
- Models: NORPS-12, NSL-19M51, and VT43N2



Photoresistors (II)

- Dosimetric characterization with a digital multimeter for the LDRs

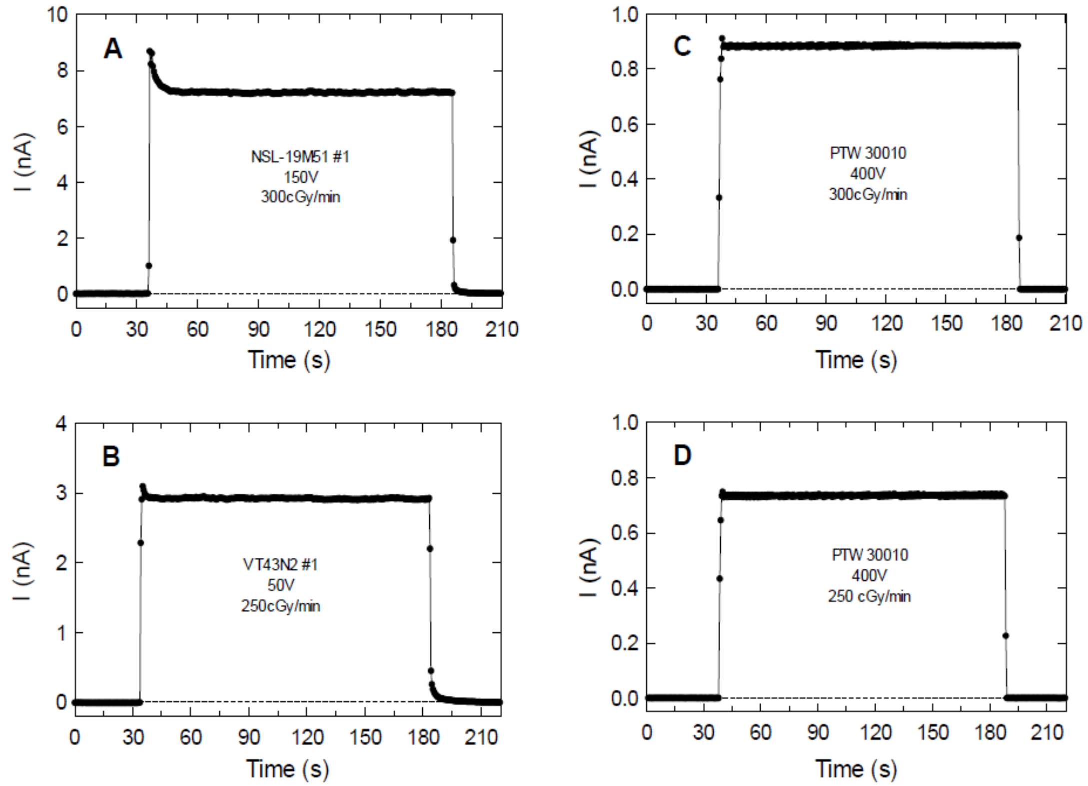


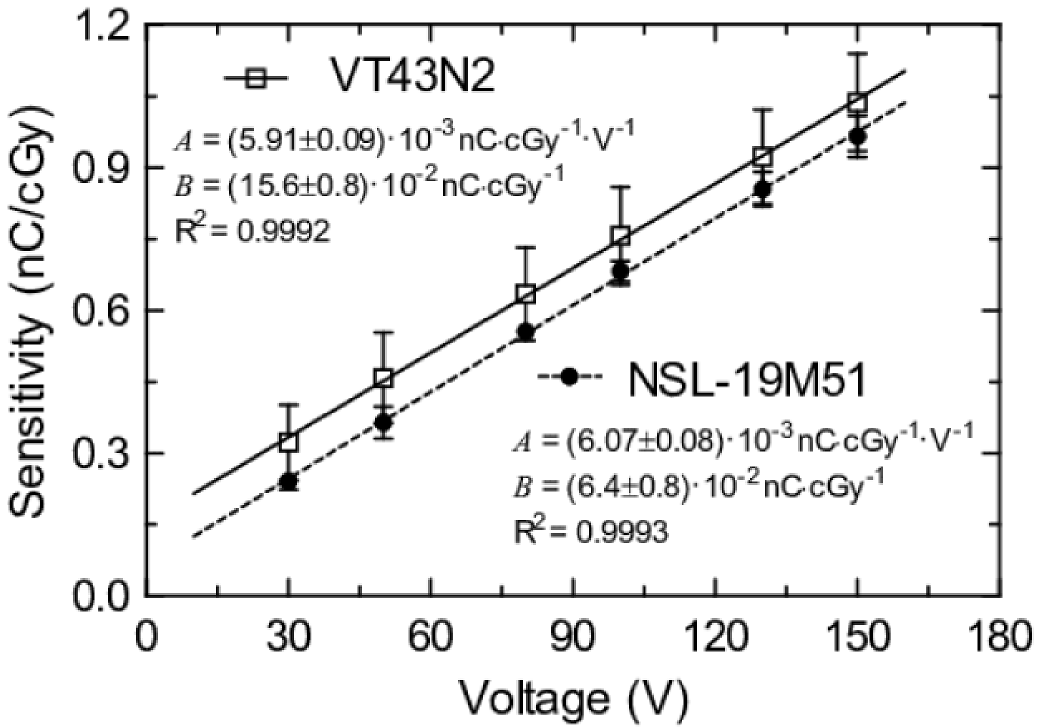


Resistance values of one LDR studied under different dose rate (a) and the correlation of the resistance and the 1/R with the dose rate quantitatively (b). Both figures show results for NSL-19M51 LDR

Photoresistors (III)

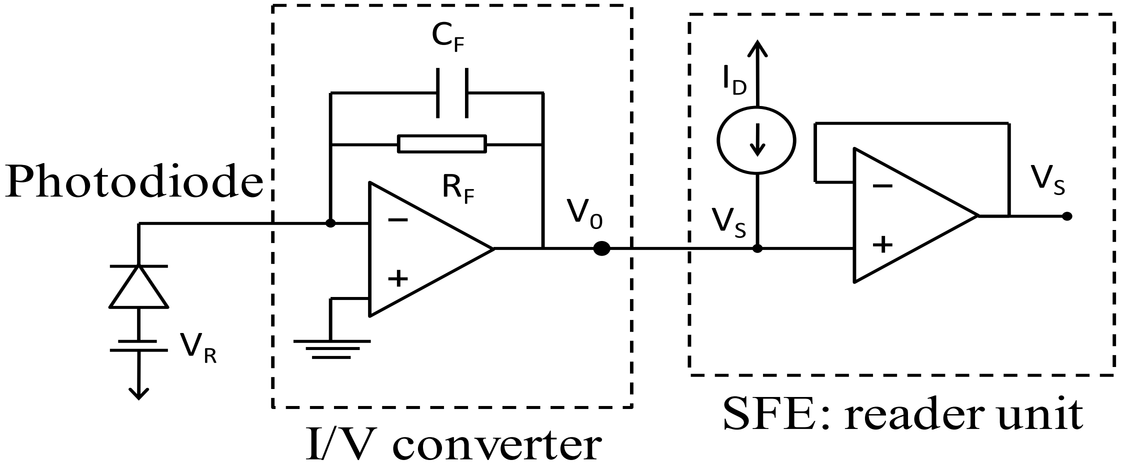
- Dosimetric characterization with a Clinical Electrometer





Current transients versus time of two LDR models and of ionization chamber (left figure) and LDR sensitivity versus bias voltage for studied models. Experimental data are represented by symbols and linear trend lines (y = Ax + B) (right figure)

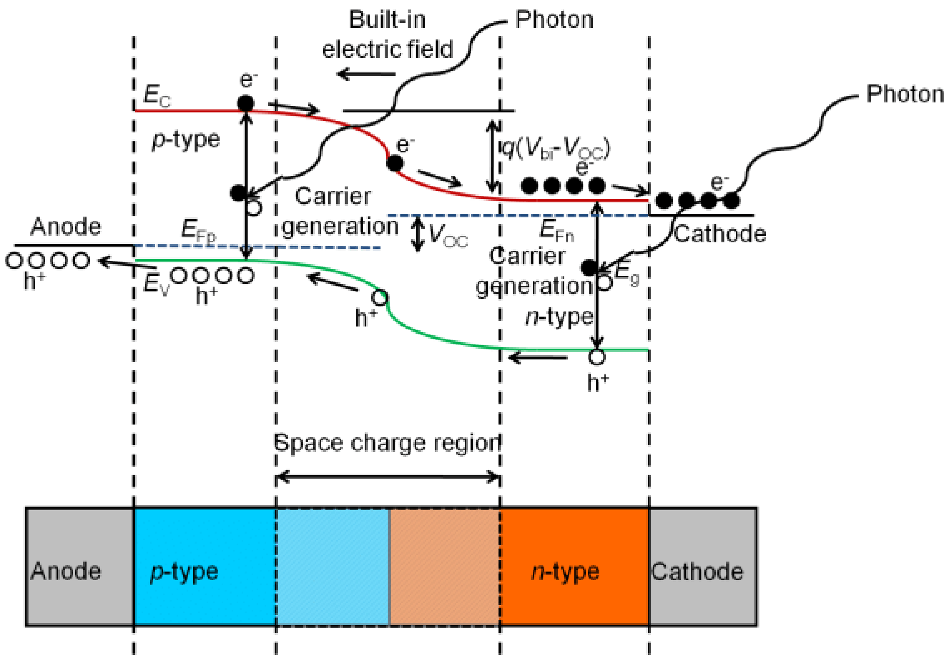
Source monitor unit



Scheme of current-voltage converter of the interface module and the Sensor Front End of the reader unit[1].

[1]M.A. Carvajal, M.S. Martínez-García, D. Guirado, J. Banqueri, A.J Palma, Dose verification system based on MOS transistor for real-time measurement, Sensors and Actuators A: Physical, Volume 247, 2016, Pages 269-276, ISSN 0924-4247, https://doi.org/10.1016/j.sna.2016.06.009.

Photodiodes (I)



Schematic of a Si PN junction diode as a radiation detector.

BPW34S photodiode

VTB8440 photodiode

Photodiodes (II)

i) Average dose rate by changing the pulse repetition frequency which is the procedure typically applied in radiation therapy:

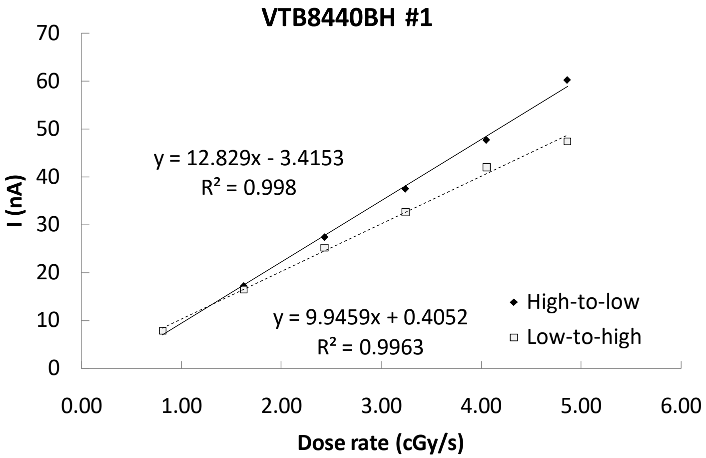
- 6 step decreasing dose rate
- 6 step increasing dose rate

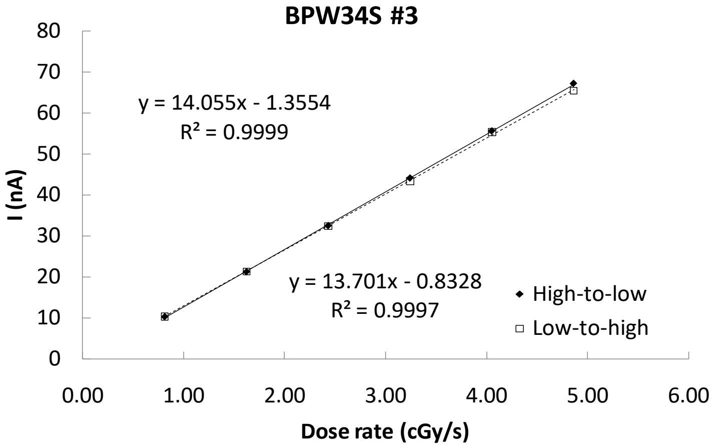
ii) Instantaneous dose rate (or dose-per-pulse) by changing the source-surface distance:

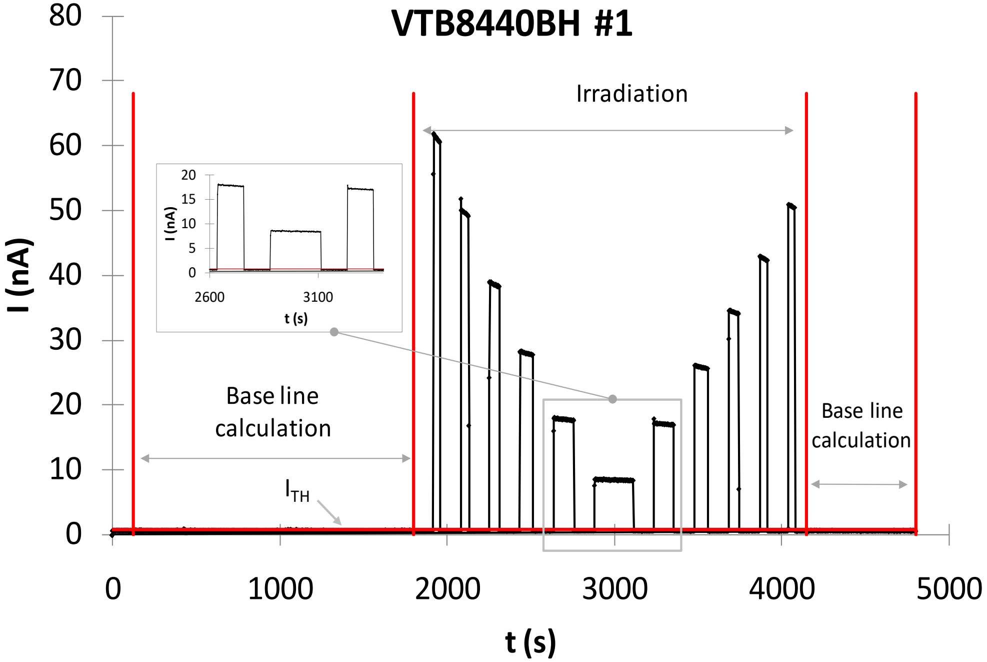
- Source-surface distance from 95 cm to 236 cm.

Photodiodes (III)

- Average dose rate





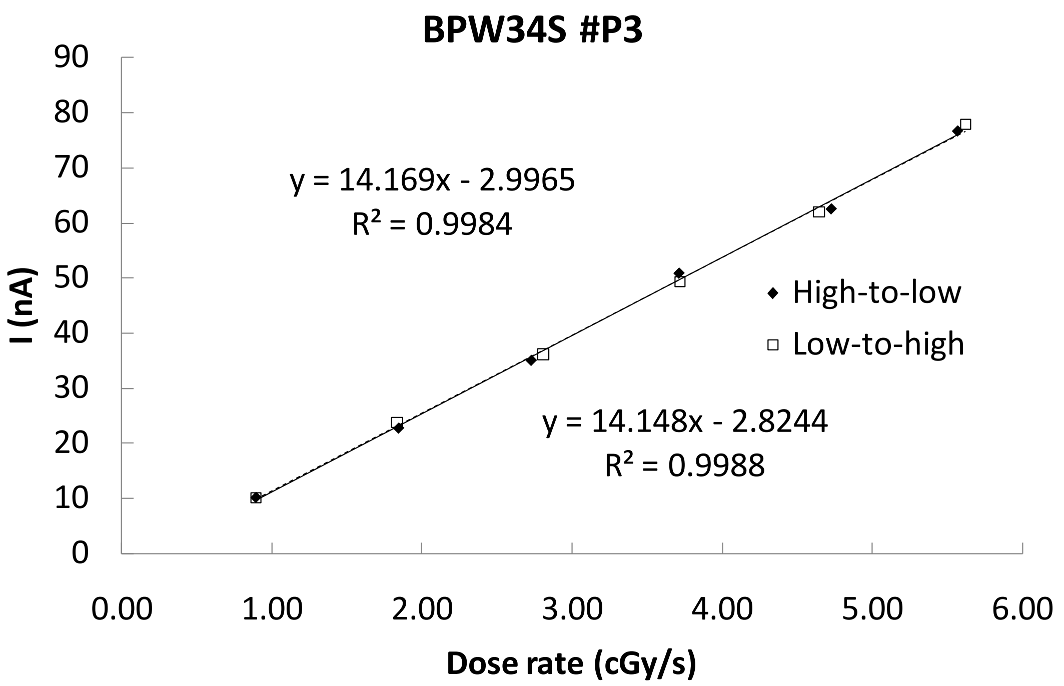


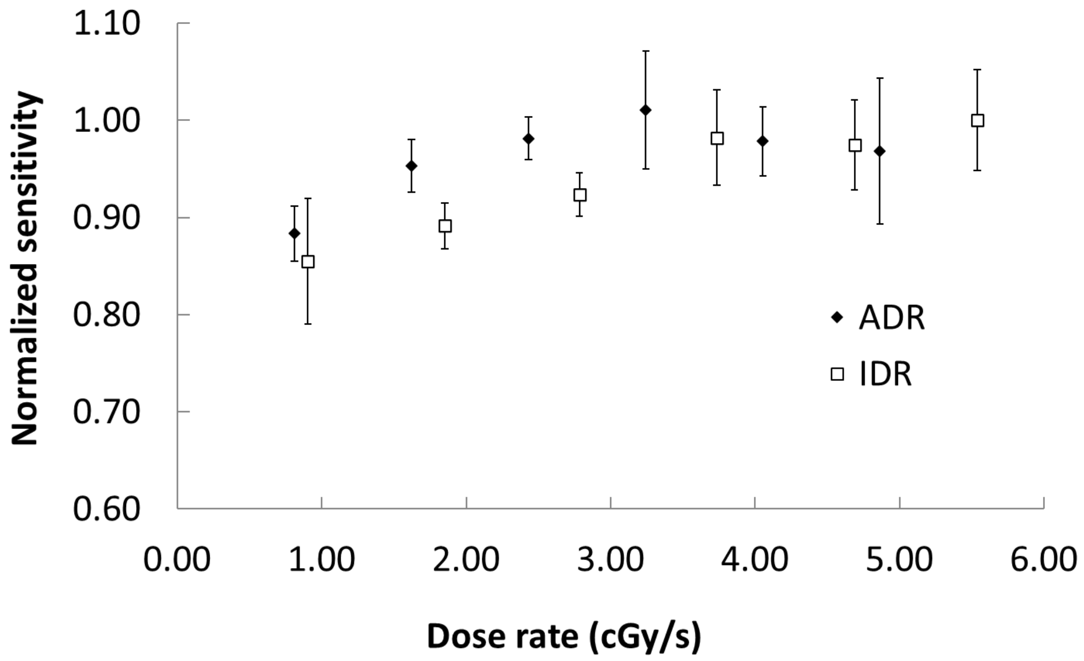
Model	Parameter	Mean	σ
VTB8440BH	Slope high-to-low (nC/cGy)	12.86	0.10
	Slope low-to-high (nC/cGy)	10.17	0.21
	Degradation (method 1)	21.0%	1.3%
	S_{ADR} (nC/cGy) at 1.94 Gy	12.3	0.3
	S_{ADR} (nC/cGy) at 21.4 Gy	9.6	0.9
	Degradation (method 2)	21.5%	8.2%
BPW34S	Slope high-to-low (nC/cGy)	14.0	0.1
	Slope low-to-high (nC/cGy)	13.9	0.2
	Degradation (method 1)	1.1%	1.6%
	S_{ADR} (nC/cGy) at 1.94 Gy	13.8	0.4
	S_{ADR} (nC/cGy) at 21.4 Gy	13.8	0.1
	Degradation (method 2)	0.2%	2.7%

Photodiodes (IV)

- Instantaneous dose rate

BPW34S S_{IDR} = 14.0 ± 0.4 nC/cGy



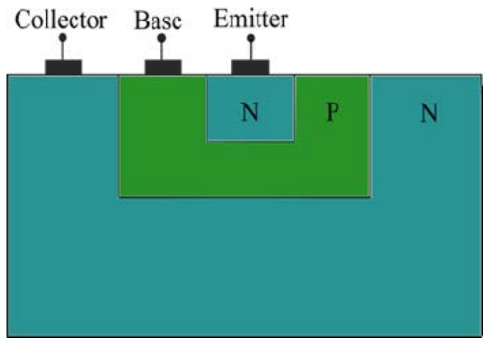


Phototransistors (I)

- Average dose rate study
- Devices under test:

OP505A NPN phototransistor

BPW85B NPN phototransistor

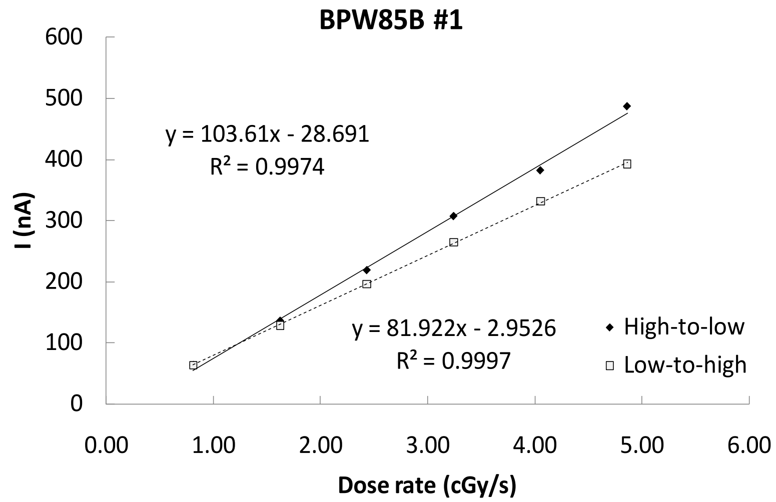


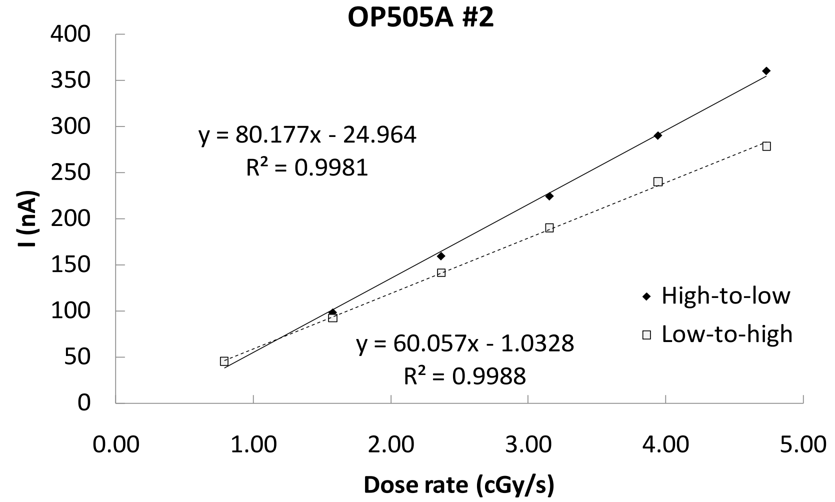
Cross-section of an NPN transistor
(similar to that of a photodiode)

Phototransistors (II)

- Average dose rate

Model	Parameter	Mean	σ
OP505A	Slope high-to-low (nC/cGy)	64	21
	Slope low-to-high (nC/cGy)	48	20
	Degradation (method 1)	26.4%	10.9%
	S_{ADR} (nC/cGy) at 1.94 Gy	61	20
	S_{ADR} (nC/cGy) at 21.4 Gy	48	20
	Degradation (method 2)	24.3%	11.6%
BPW85B	Slope high-to-low (nC/cGy)	91	17
	Slope low-to-high (nC/cGy)	71	13
	Degradation (method 1)	21.9%	1.4%
	S_{ADR} (nC/cGy) at 1.94 Gy	91	19
	S_{ADR} (nC/cGy) at 21.4 Gy	70	15
	Degradation (method 2)	22.5%	2.9%

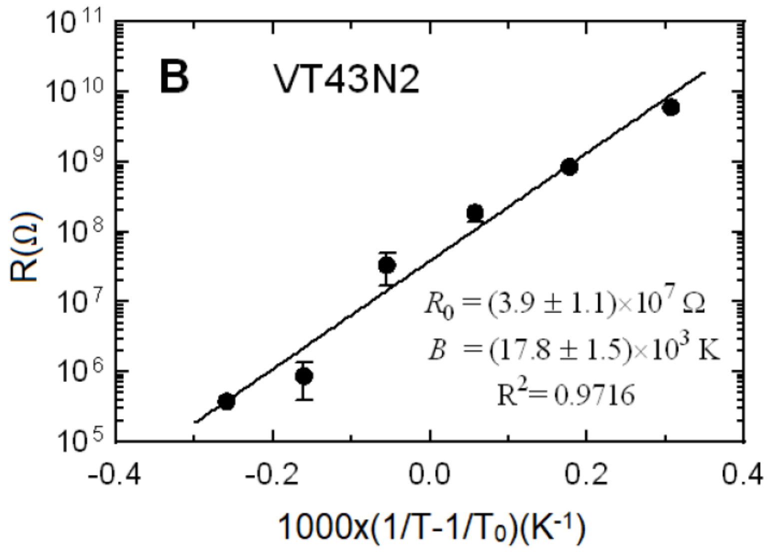




Influence of the temperature (I)

- Photoresistors: Temperature dependence can be modelled by the simple thermistor model.

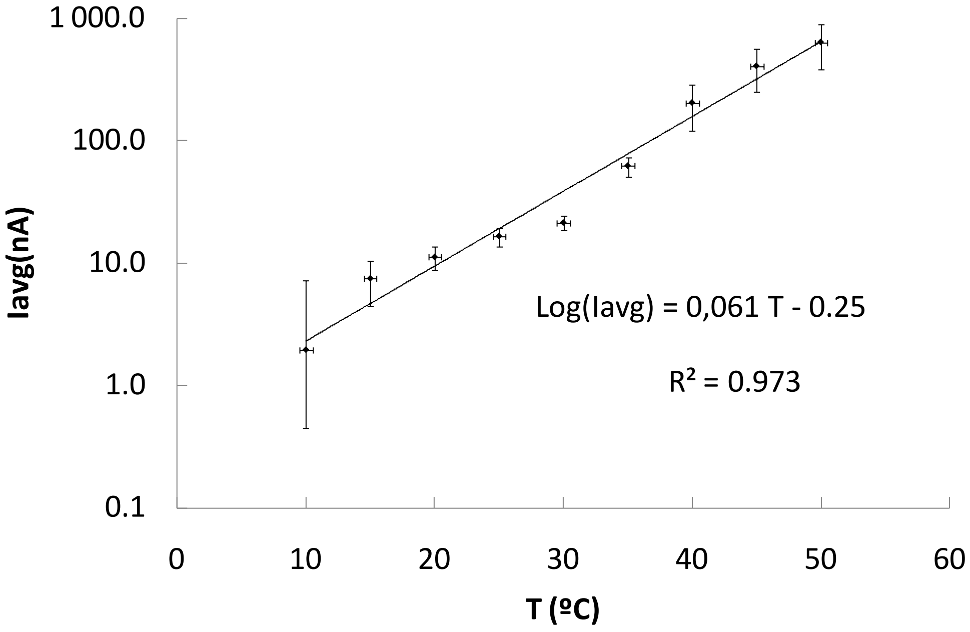
$$R(T) = R_0 \, exp\left[B\left(\frac{1}{T} - \frac{1}{T_0}\right)\right]$$



Average resistance of the three samples vs. the inverse of the temperature according to model of Equation for VT43N2 LDRs

Influence of the temperature (II)

- Photodiodes: The dark current in photodiodes depends exponentially on temperature, them, base line will be strongly affected by the temperature in dose rate and absorbed dose measurements.



Experimental results of the thermal characterization: Average experimental data of the set of three photodiodes BPW34S,

Conclusions

- Both sensitivity and degradation showed better results for the photodiode BPW34S as for the others optodevices under test.

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THANK YOU FOR YOUR ATTENTION- QUESTIONS?