STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ÉTUDE DE L'ÉNERGIE NUCLÉAIRE

Radiation testing on opto-electronic devices at SCK·CEN

4th RD50 Workshop
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- Short presentation of SCK·CEN
- Irradiation facilities
- Some typical results on opto-electronic devices
- Future work

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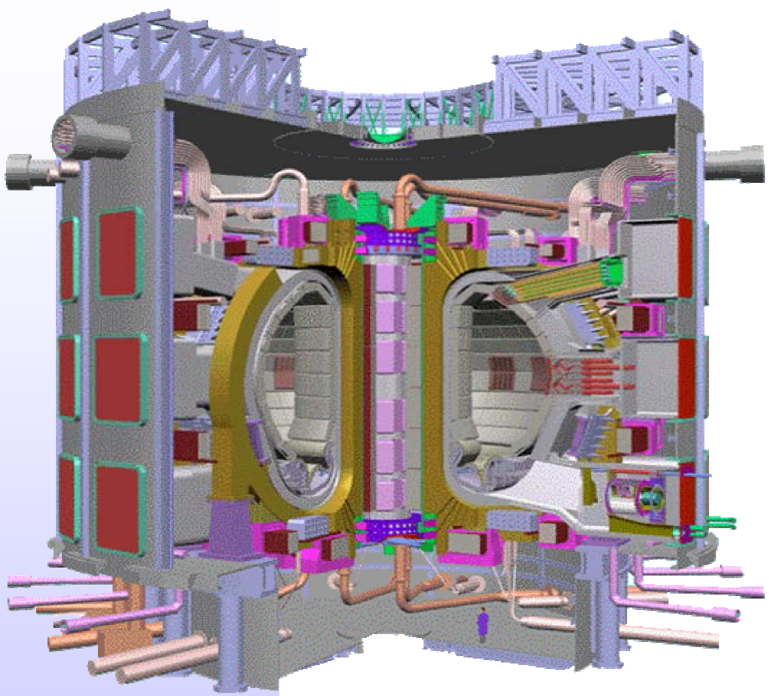
SCK•CEN is a Research Institute

- Institute of Public Utility
  - Ministry of Economic Affairs
    - Secretary of State for Energy
- 600 Employees
  - 200 scientists
- Annual Turnover 74•10^6 €
  - 50 % Governmental subsidy -50 % Contracts
- Core activities
  - Nuclear Safety and Radiation Protection
  - Industrial Applications of Radiation
  - Back-end of the Nuclear Fuel Cycle
  - Non-energetic applications of nuclear energy
    - increasingly relevant to society – medicine
  - Sustained development and non-technical aspects
    - social and economical factors, ethics, liability

Our main R&D environment is ITER as supported by the European Fusion Programme



- Environmental constraints
  - 100 MGy (10 Grad)
  - 10 kGy·h^{-1} (1 Mrad·h^{-1})
  - Occasional neutrons
  - 150 °C
- Instrumentation systems
  - Communication
  - Remote-handling & sensors
  - Fusion plasma diagnostics

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We've been experimenting on a broad range of devices/materials/technologies

- Laser diodes (AlGaAs VCSELs)
- Photodiodes (Si, InGaAs)
- A wealth of optical fibres
  - COTS and custom
- Fibre Bragg Gratings
- WDM Couplers
- Liquid crystals
- Fibre sensors
- Electronics
- Motors
- Polymers
- Cables (polymers, mineral insulated, …)
- Connectors & feedthroughs
- …

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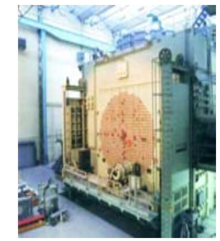
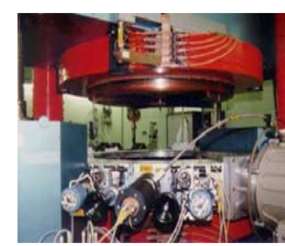
We exploit SCK·CEN's irradiation infrastructure



BR1

	Brigitte (^{60}Co - fuel)	RITA (^{60}Co)	Geuse II (fuel)	LNC (^{60}Co)
Dose-rate max.	1.4 krad•s^{-1}	300 rad•s^{-1}	15 rad•s^{-1}	140 mrad•s^{-1}
Dose-rate min.	140 rad•s^{-1}	30 mrad•s^{-1}	2 rad•s^{-1}	0.3 mrad•s^{-1}
Vol. (mm^2)	900 x 220 900x80	600 x 380	400 x 380	Hot cell
Vol. Temp.	50 - 200 °C	RT - 100 °C	RT	RT stabilised

BR2



VUB Cyclotron

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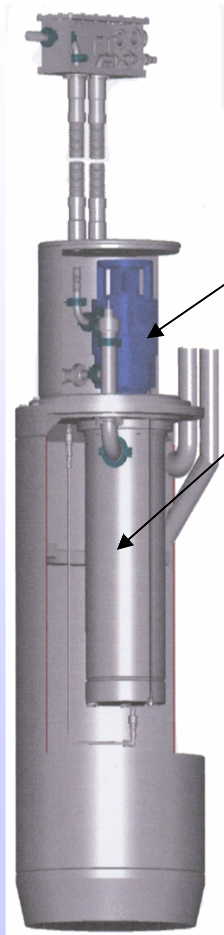
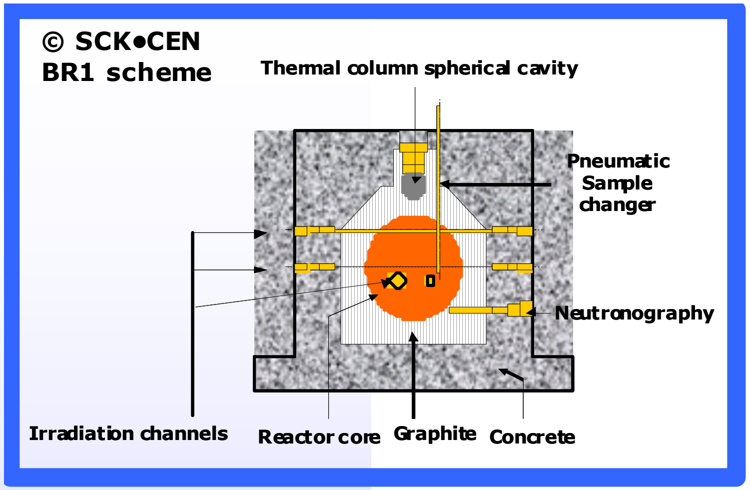
CERN irradiates opto-electronics for CMS in RITA

Vacuum System Module for RITA and GEUSE II is designed



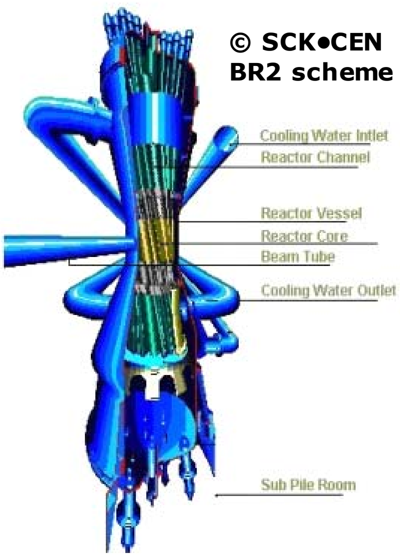
- Vacuum: 10^{-5} mbar
- Height: 600 mm
- Diameter: 200 mm
- Temperature: 120°C
- Organic material mass up to 1 kg

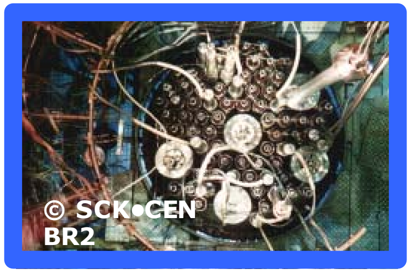
BR1 is a versatile neutron-gamma irradiation tool

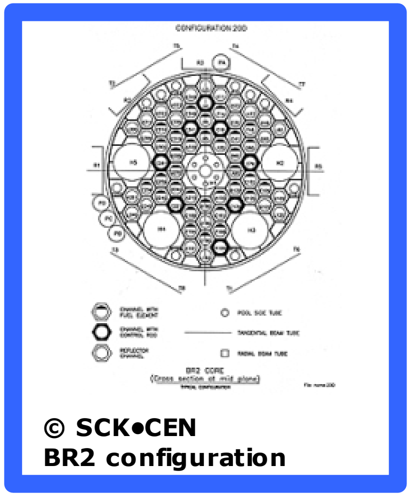


- Natural U, graphite-moderated, air-cooled research reactor
  - reactor physics experiments as neutron reference source
  - calibration of nuclear detectors
- Characteristics
  - Channels
    - ϕ 80 mm, square 100 ×100 mm^2
    - fast n > 2.86 10^8 n·cm^{-2}·s^{-1}
    - thermal n < 3.5 10^{11} n·cm^{-2}·s^{-1}
    - around 50 °C (control possible)
  - Sphere
    - empty - ϕ 1000 mm
    - 1 cm U shield – ϕ 325 mm
    - empty – thermal n < 7 10^8 n·cm^{-2}·s^{-1}
    - 1 cm U shield – fast n 2.18 10^8 n·cm^{-2}·s^{-1}

BR2 is a high neutron flux material testing reactor



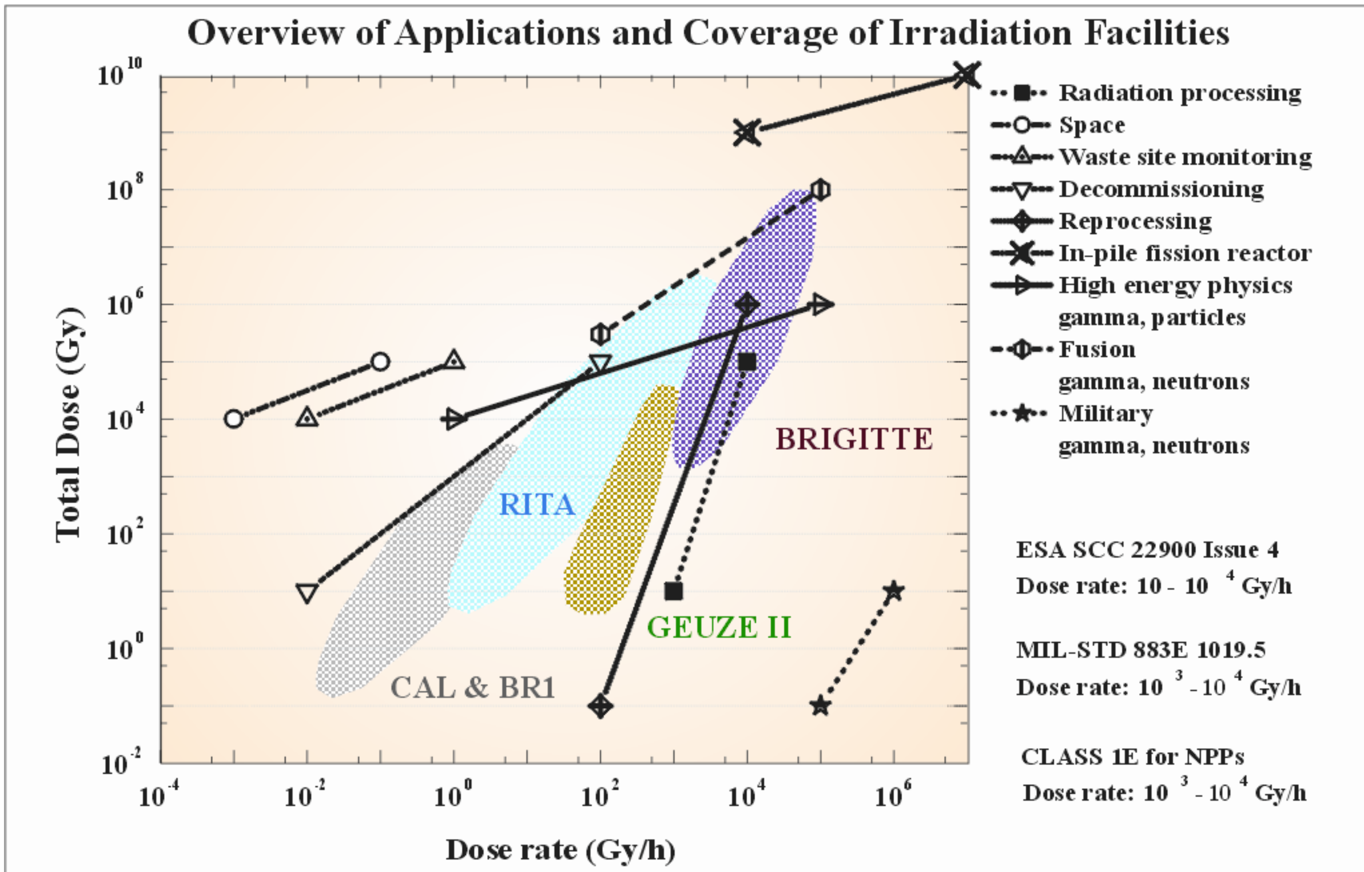




- PWR type reactor (flux up to 10^{15} n·cm^{-2}·s^{-1})
  - test of fuels and materials
  - production of radioisotopes
  - silicon doping for electronics industry
- Characteristics
  - Central channels
    - ϕ 84 mm
    - fast n – 2 10^{14} n·cm^{-2}·s^{-1}
    - thermal n – 4 10^{14} n·cm^{-2}·s^{-1}
    - (5 W·g^{-1} Al)
  - Peripheral
    - ϕ 200 mm
    - fast n – 3.5 10^{14} n·cm^{-2}·s^{-1}
    - thermal n – 1 10^{14} n·cm^{-2}·s^{-1}
    - (4 W·g^{-1} Al)

Aging, lifetime testing and temperature cycling studied in CLARA (2 m³)

We can cover most radiation effects application fields



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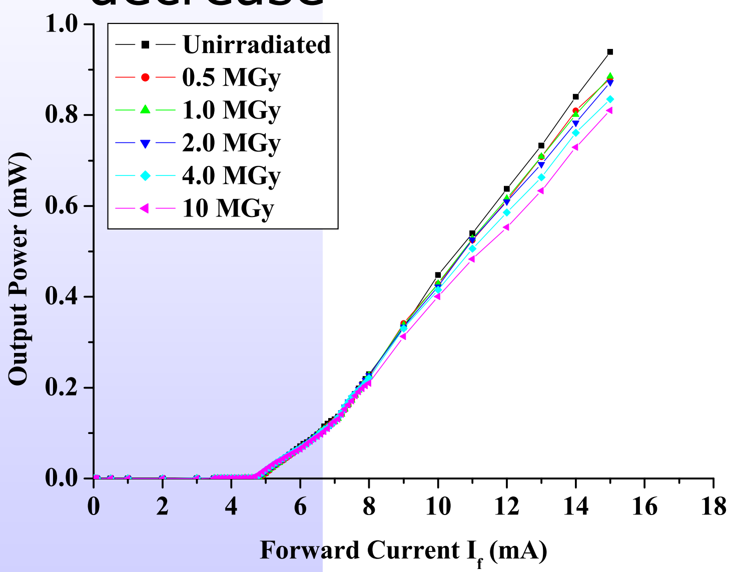
Gamma rays and Neutrons have different effects on VCSEL P-I curve

- Gamma Irradiation
  - No threshold current shift
  - External efficiency decrease



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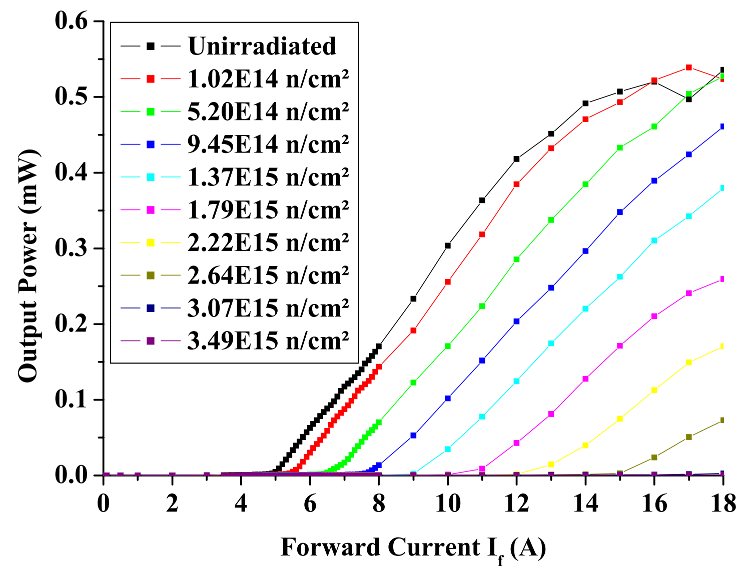


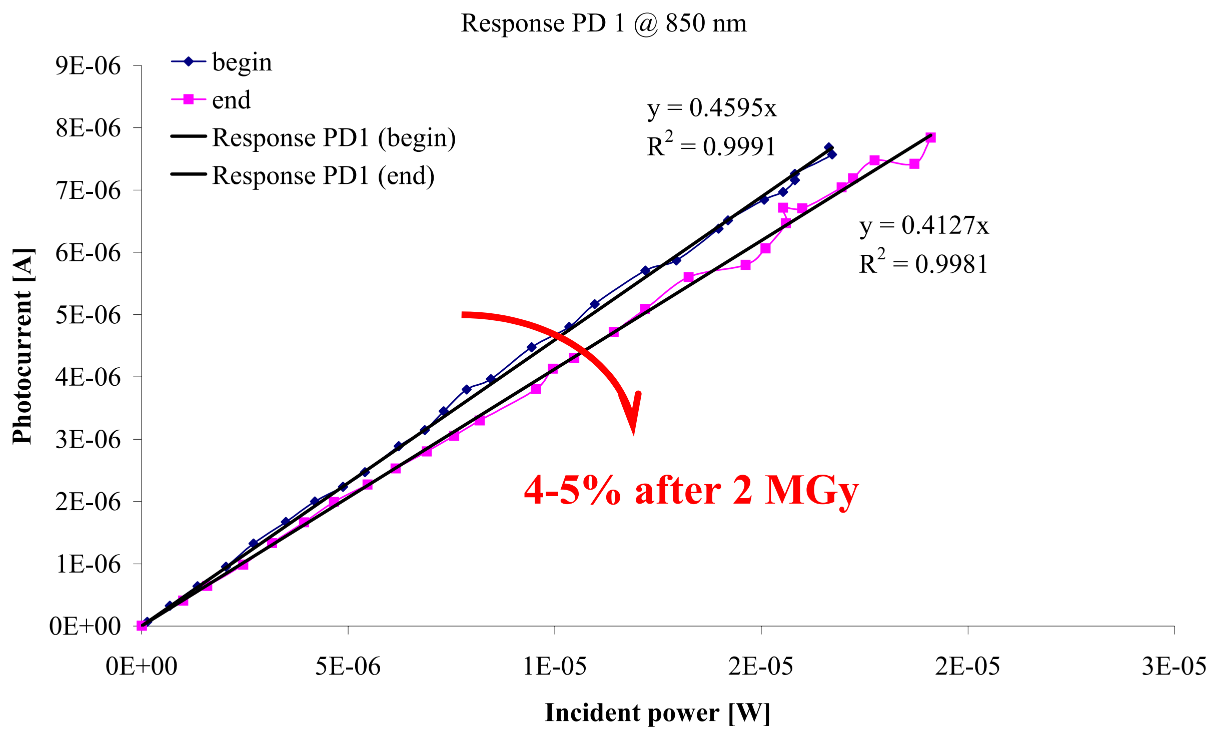
Pre-irradiation with gamma accelerates degradation

F. Berghmans et al., "Design and Characterization of a Radiation Tolerant Optical Transmitter using Discrete COTS Bipolar Transistors and VCSELs", *IEEE Transactions on Nuclear Science* **49**, pp. 1414-1420, 2002

COTS p-i-n photodiodes were monitored in-situ under radiation

- First ^{60}Co gamma experiment
  - 6 Si-PD
  - 2 kGy/h (10% accur.), 2 MGy, 60°C ± 1.5°C
- Mixed neutron/gamma experiment
  - pre-irradiated Si-PD (2 MGy)
  - $7\cdot10^{15}$ n/cm^2, 20 kGy (background), 60°C ± 1.5°C
- Second ^{60}Co gamma experiment
  - 8 Si-PD & 8 InGaAs-PD
  - 15 kGy/h (10% accur.), 10 MGy, 60°C ± 1.5°C

A typical result for a Si photodiode after 2 MGy

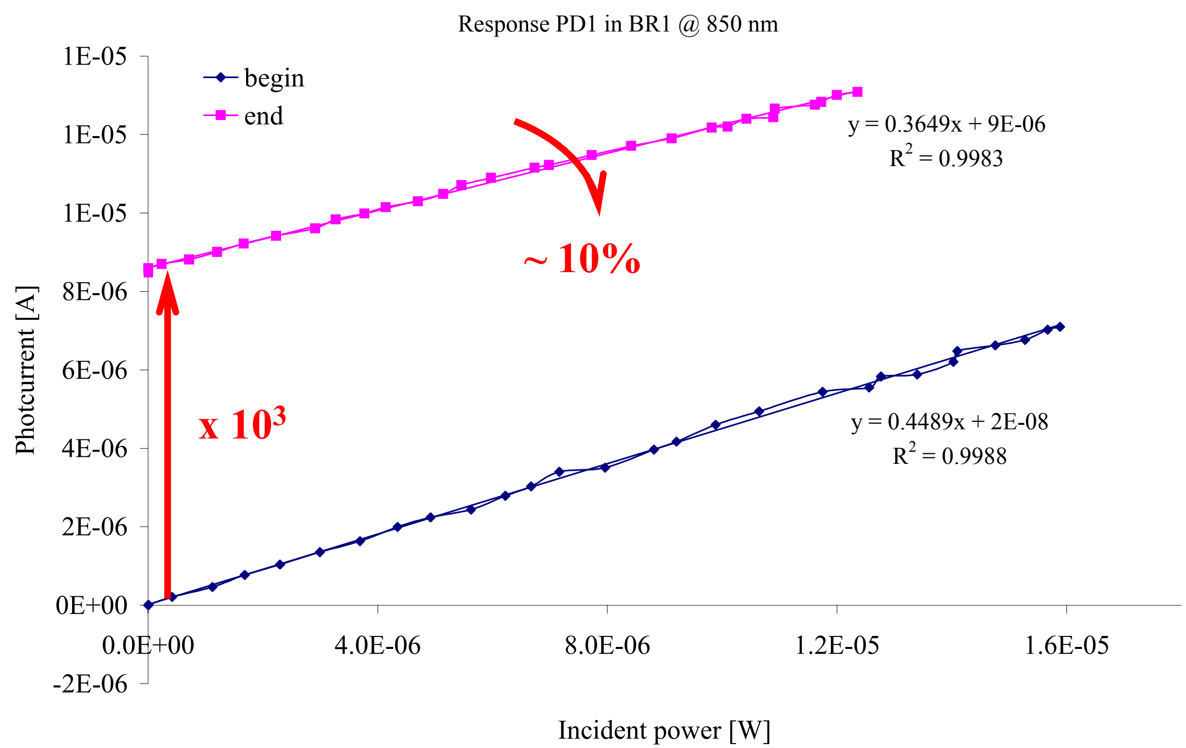


M. Van Uffelen et al., "Reliability study of photodiodes for their potential use in future fusion reactor environments", *SPIE Proceedings* **5465**, 2004, to be published

Neutron displacement damage is an issue

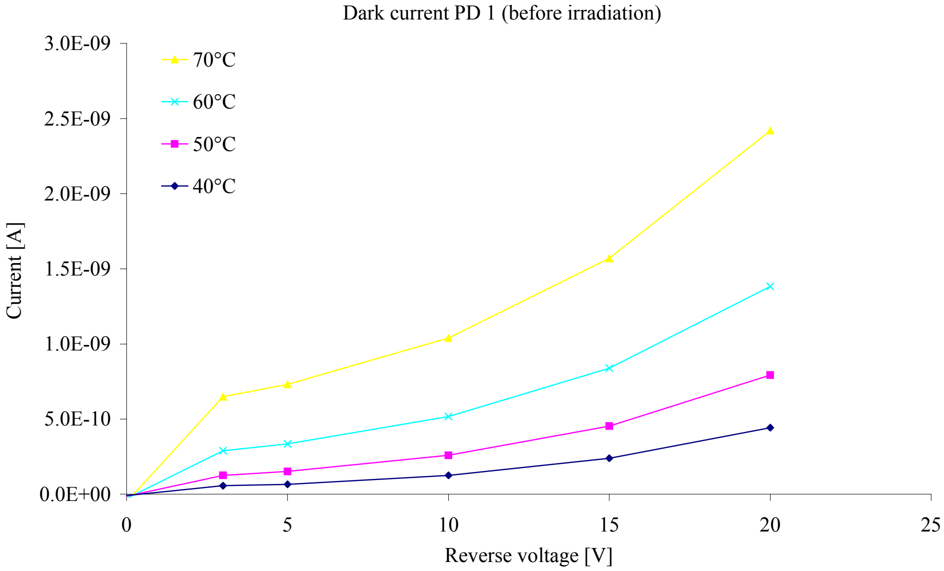
Total dose : D_γ = 20 kGy

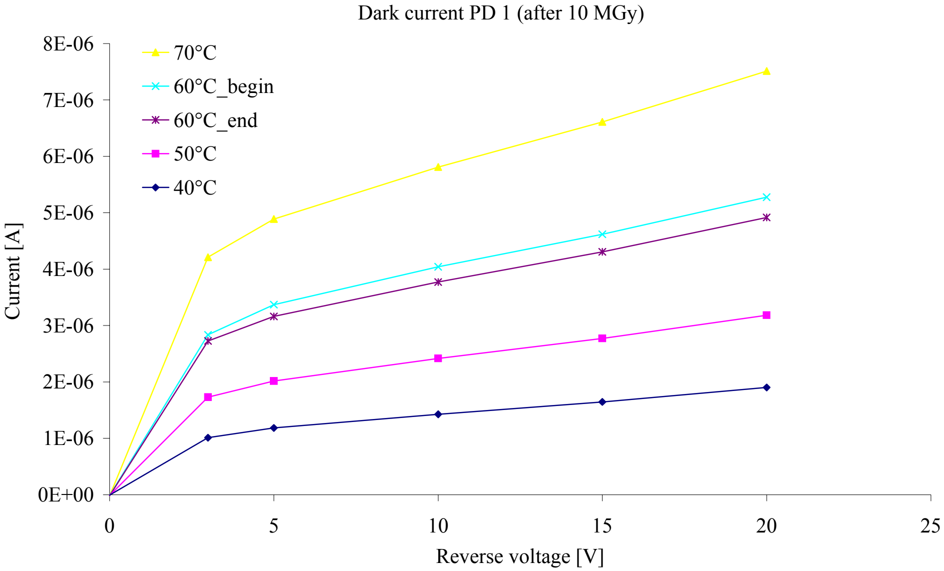
Fluence : $n_{th} = 7\cdot10^{15} n/cm^2$



M. Van Uffelen et al., "Reliability study of photodiodes for their potential use in future fusion reactor environments", *SPIE Proceedings* **5465**, 2004, to be published

InGaAs photodiodes show different dark current curves after irradiation

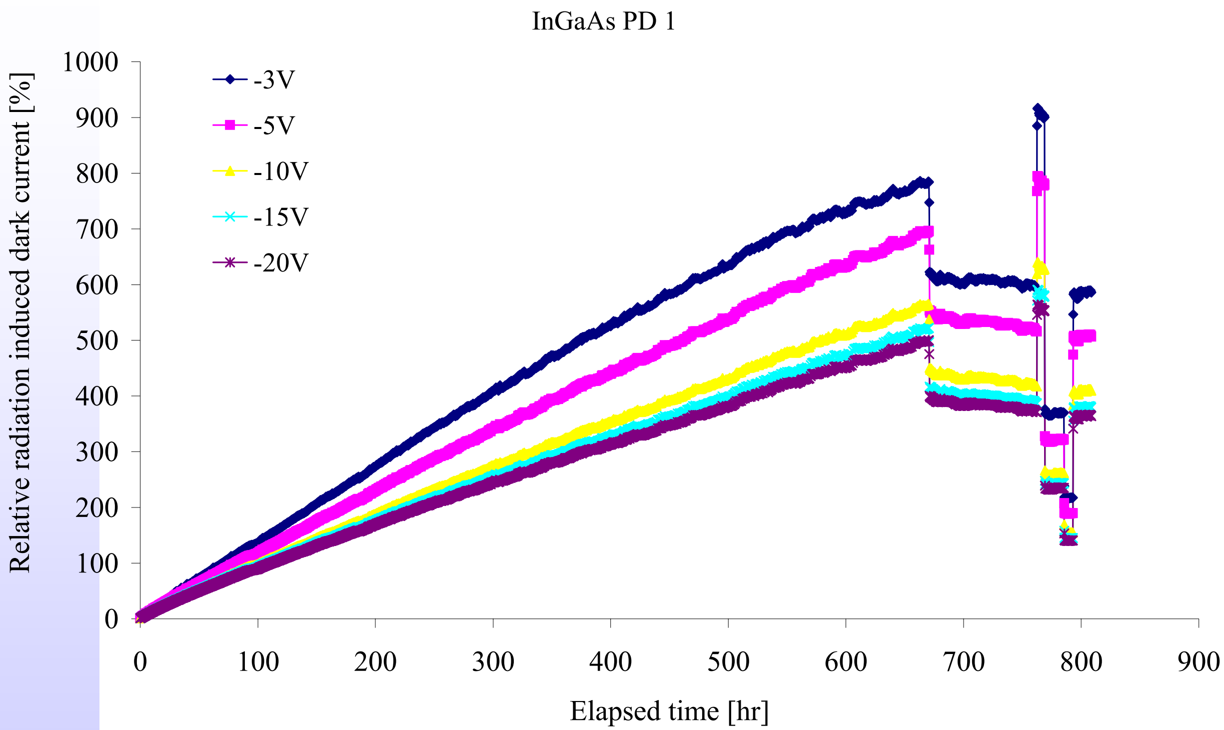




M. Van Uffelen et al., "Reliability study of photodiodes for their potential use in future fusion reactor environments", *SPIE Proceedings* **5465**, 2004, to be published

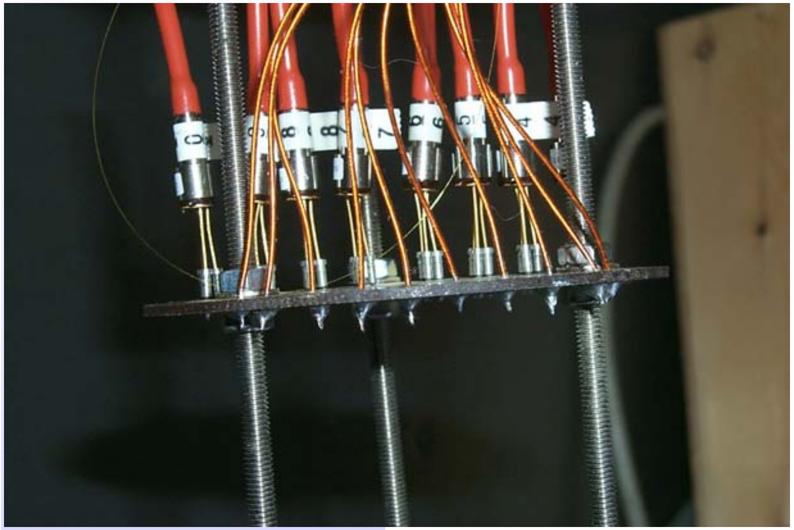
InGaAs photodiode dark current increases monotonously ~ 10^3

Dose rate : dD_γ /dt= 15 kGy/h

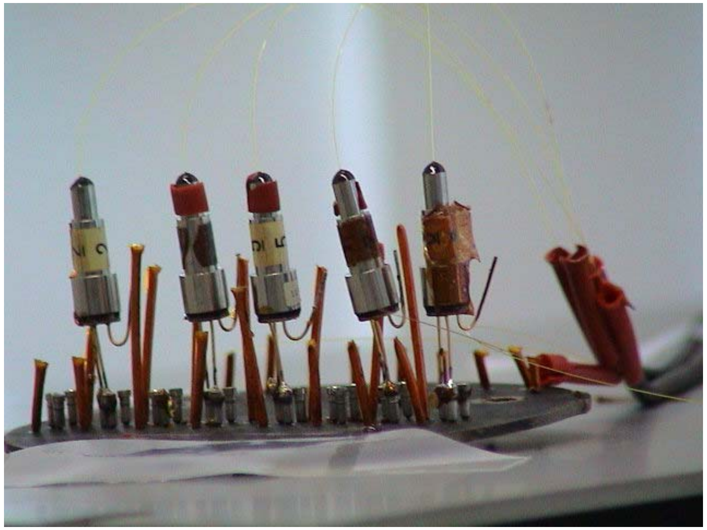


Packaging is an issue

Before irradiation



After irradiation



Future work is needed and could benefit from interaction with RD50

- Effects are generally understood but phenomenologically treated
  - No thorough theoretical investigation on material radiation effects ⇔ RD50
  - Material effects, device structure effects and device performance need to be linked
  - Modelling is essential for reliability assessment ⇔ RD50
- Further experimental work
  - Gain statistical significance
  - Qualification is essential but expensive and time consuming
- Our irradiation facilities are available
  - and can be adapted to your specific needs ⇔ RD50