RMC

CVŘ
Research Centre Řež

Solar Cells for Space Applications - Gamma Radiation Resistance Testing for Polar Orbit CubeSats

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Research Centre Řež Ltd.

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Research Centre Řež Ltd. - Introduction

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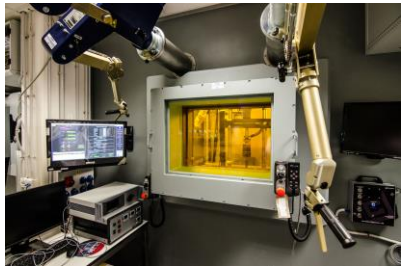
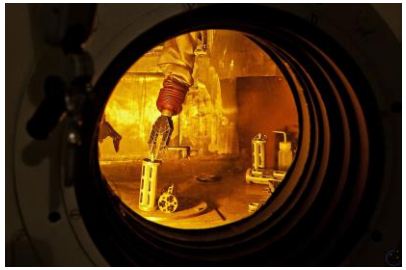
Research Centre Řež Ltd. (CVŘ) - Introduction

- The research organisation Research Centre Řež was founded on 9th October 2002 as 100% daughter company of UJV Rez (NRI – ***N**uclear **R**esearch **I**nstitute, founded 1955*)
- The main aim is research, development and innovations in the field of power generation especially nuclear as nuclear safety and reliability and operation of NPP support



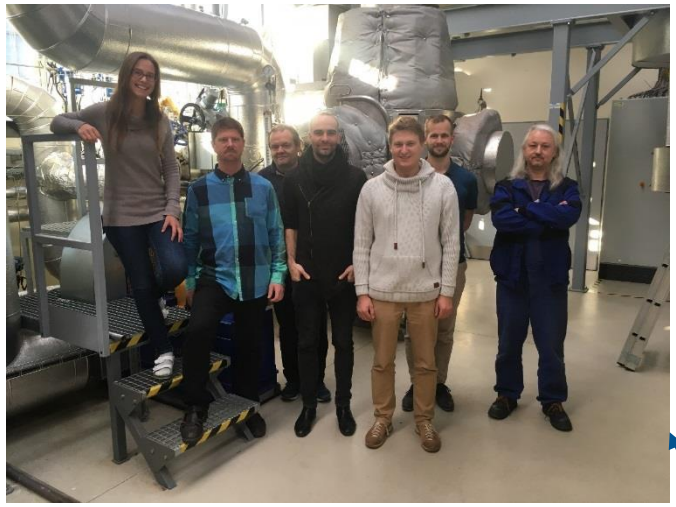


CVŘ Takes Part in These Consortia and Platforms

Information about Our Research Group

- Our group of laboratories consist of:
  - **Gamma irradiation facility**
  - **LOCA device** - testing of components under high pressure (up to 20 bar) and high temperatures (up to 300 °C or 800 °C)
  - **High voltage laboratory** – performs accredited HV tests on electrical components

Gamma irradiation facility



Our research team ☺

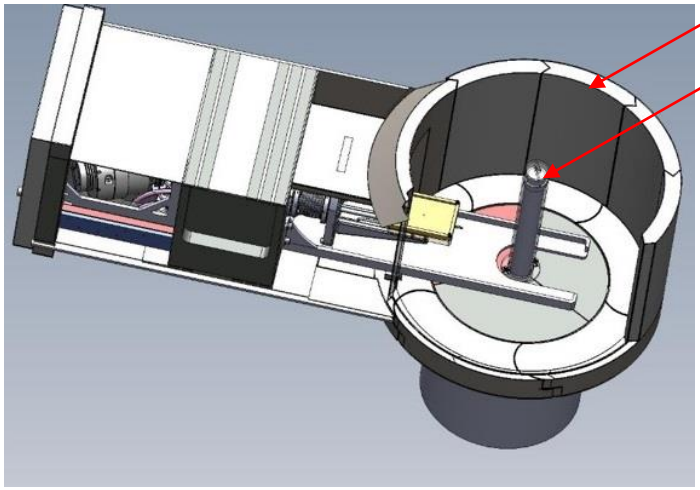
High voltage laboratory

LOCA (Loss-of-coolant accident) device

Gamma Irradiation Facility

- ^{60}Co gama radiation source with activity 200 TBq
- Experimental box with possibility to irradiate with various temperatures
- Testing thermal ageing of NPP components and gamma irradiation of polymers, electric cables, electronic devices and components,..
- Special space applications – testing of material degradation of solar cells for CubeSat.

Gamma irradiation facility

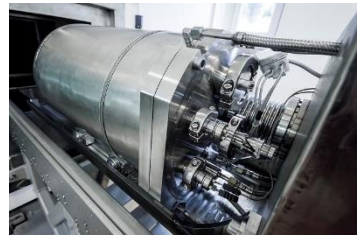


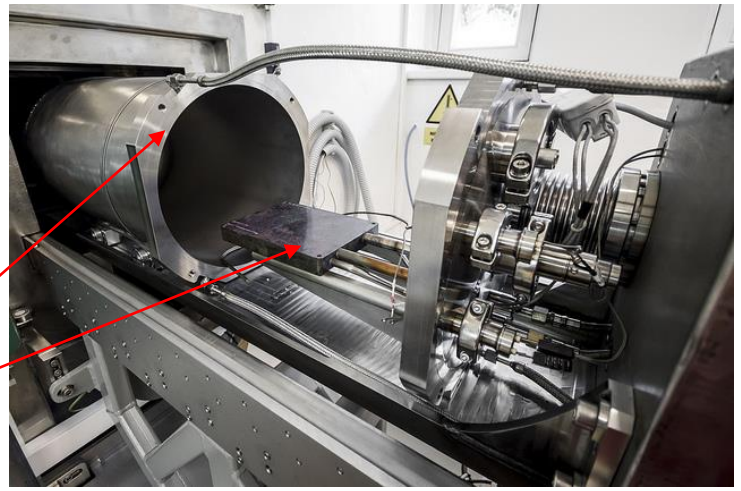
View inside the irradiation chamber

Dosimetry procedure

Gamma Irradiation Facility – Experimental Box

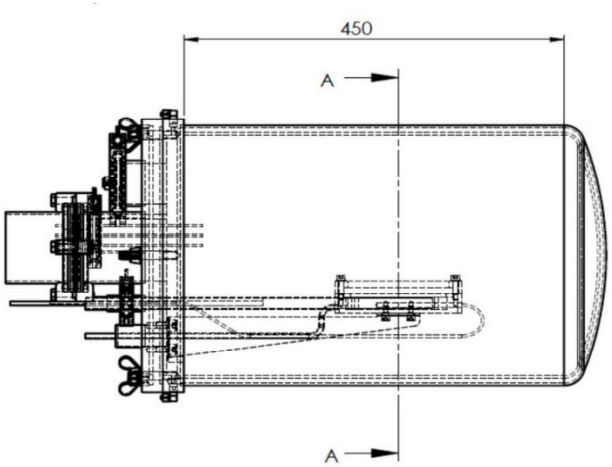
- Special experimental box with possibility of irradiation during low/high temperatures (-196°C/ 400°C) and vacuum
- Sample heating holder 150x200 mm
- Sample height on heating holder 150 mm (designed for small samples)
- Chamber lenght 450 mm



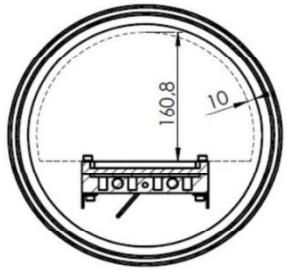


Double-layered cooling casing

Heating holder of samples



Technical drawing of the experimental box



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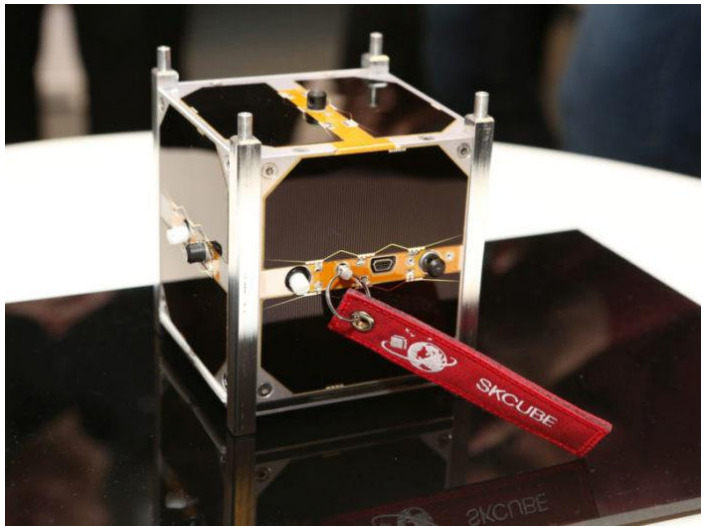
Gamma irradiation facility technology - overview

About the Project

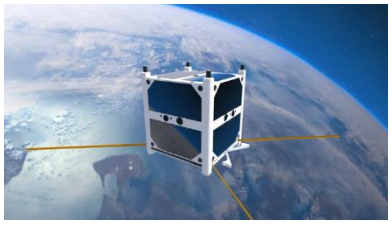
- Exposure samples of solar cells to partial space-simillar environment: gamma radiation and high/low temperatures
- The main goal of the study was to determine the influence of this conditions to degradation electrical properties of solar cells
- One type of tested solar cells was instaled at the **first Slovak satellite skCUBE** launched June 23, 2017
- Our group cooperated with the Slovak company **RMC s.r.o.**, which worked on the development of skCUBE

skCUBE launch

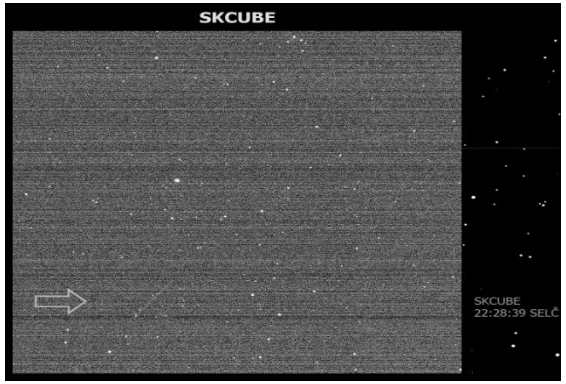
skCUBE logo



skCUBE nanosatelite



skCUBE visualisation

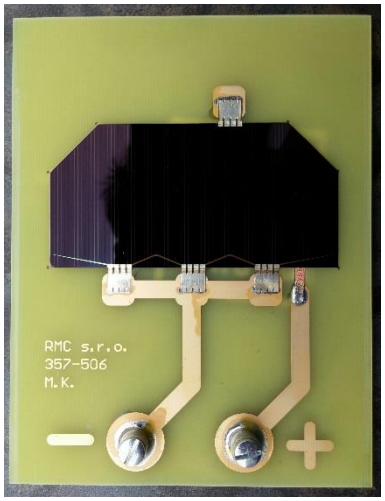


skCUBE on orbit (8/17/2018 by Milan Antoš)

Experimental Setup

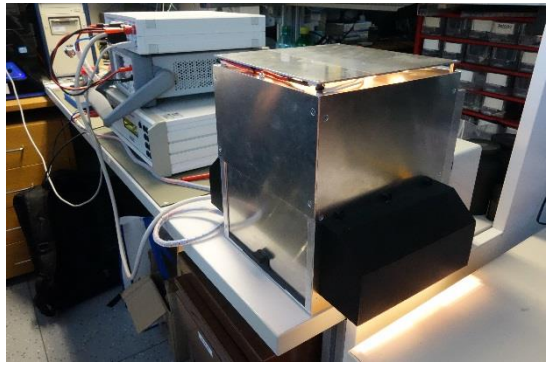
- Solar cells SMX TASC-02x25 by SPECTROLAB, Inc. from the United States of America (36 pieces)
- Solar cells 3G30A by the German company AZUR SPACE Solar Power GmbH (6 pieces)
- Gamma irradiation facility with special experimental box allowing low/high temperature environment and vacuum
- Lighting chamber with a measuring apparatus for measuring I-V characteristics

Gamma irradiation facility



Azur Space solar cell sample

Spectrolab solar cell sample



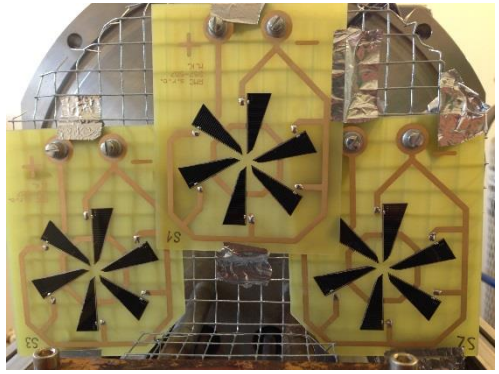
Lighting chamber with measuring apparatus

Methods

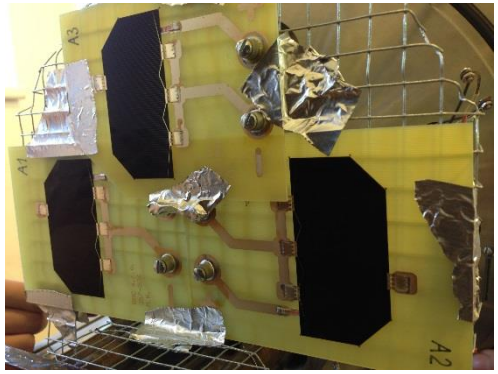
- Both sets of samples were divided into two groups with the conditions for gamma degradation research as follows:
  - **1st group:** 3 pieces of solar cells AZUR SPACE + 18 pieces of solar cells Spectrolab.

    Irradiation conditions: dose rate: 0.16 kGy/h, temperature inside the experimental box: -30 ° C.
  - **2nd group:** 3 pieces of solar cells AZUR SPACE + 18 pieces of solar cells Spectrolab.

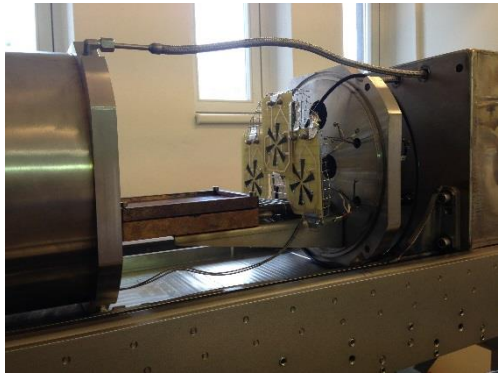
    Irradiation conditions: dose rate: 0.16 kGy/h, temperature inside the experimental box: +30 ° C.



Spectrolab samples setup



Azur Space samples setup

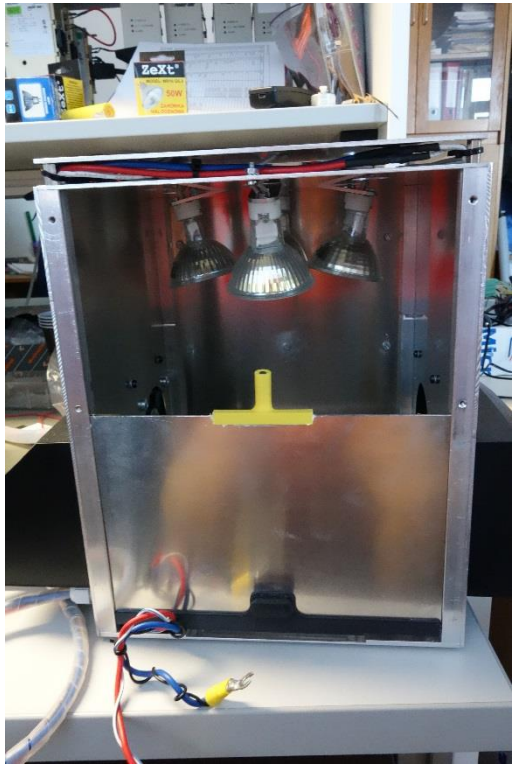


Samples in the experimental box

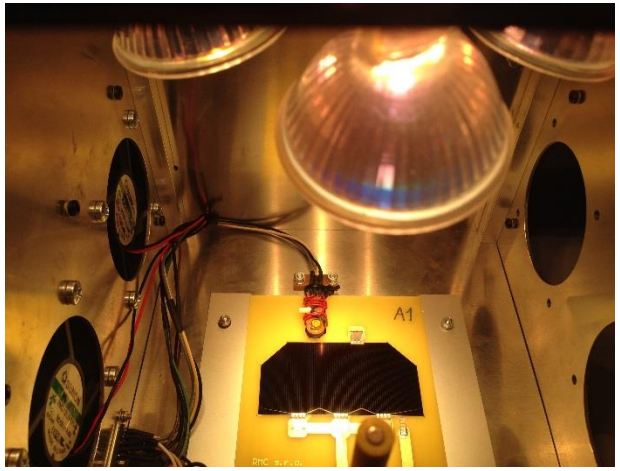
Methods

- A total of five irradiations were performed at cumulated doses of 0.5, 1, 2, 10 and 30 kGy
- After each exposure to the individual doses the I-V characteristics of all solar cells were measured in the lighting chamber

The view inside the experimental box



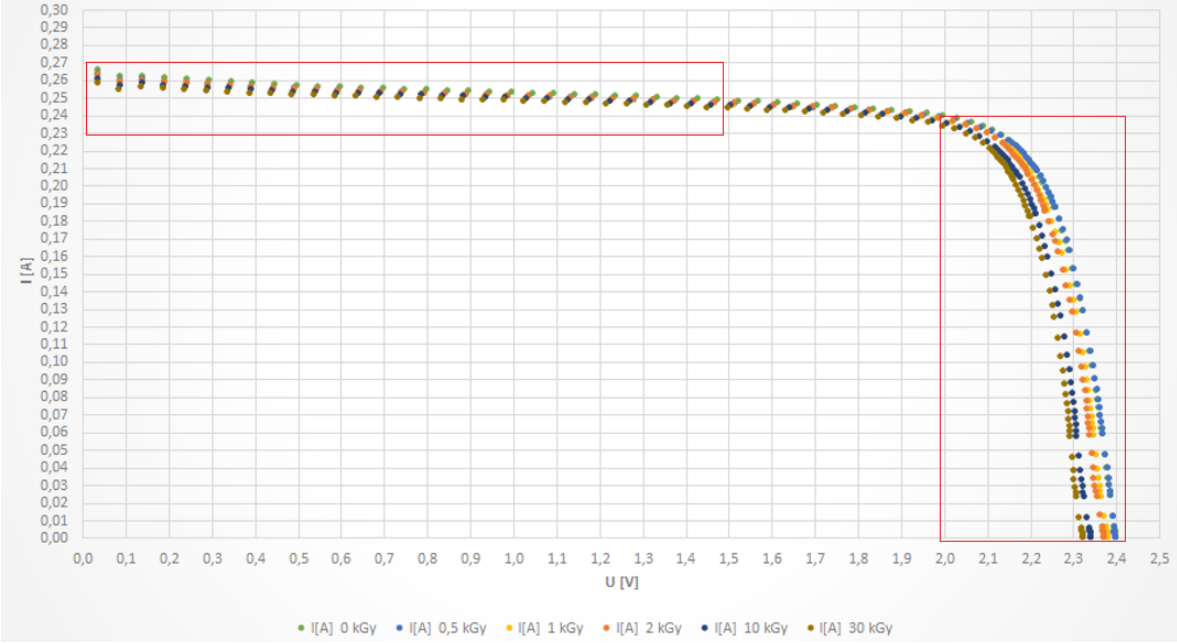
The lighting chamber with open upper side



The view inside the lighting chamber

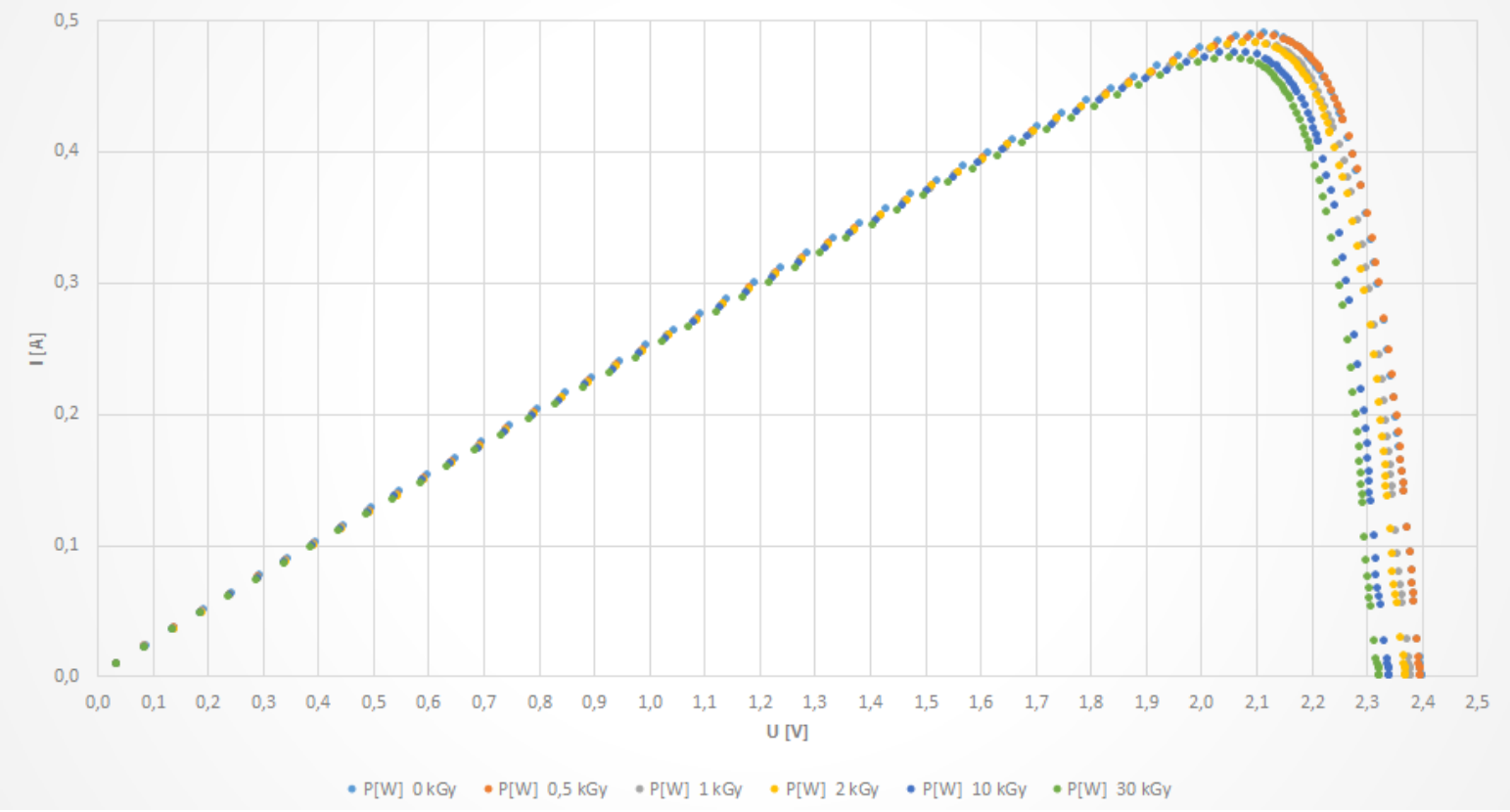
Results – Solar Cells SMX TASC-02x25 by SPECTROLAB, Inc.

- The no-load voltage for non-irradiated samples was 2.4002 V, while for irradiated samples at 30 kGy the value was 2.3233 V.
- The maximum value of voltage drop: 0.0963 V in the current range of 0.00-0.24 A (non-irradiated compared to 30 kGy irradiated state). This represents a decrease of about 4.8 %.
- The maximum value of current drop: 0.0072 A in the voltage range of 0.04-1.48 V (non-irradiated compared to 30 kGy irradiated state). This represents a decrease of about 2.7 %.



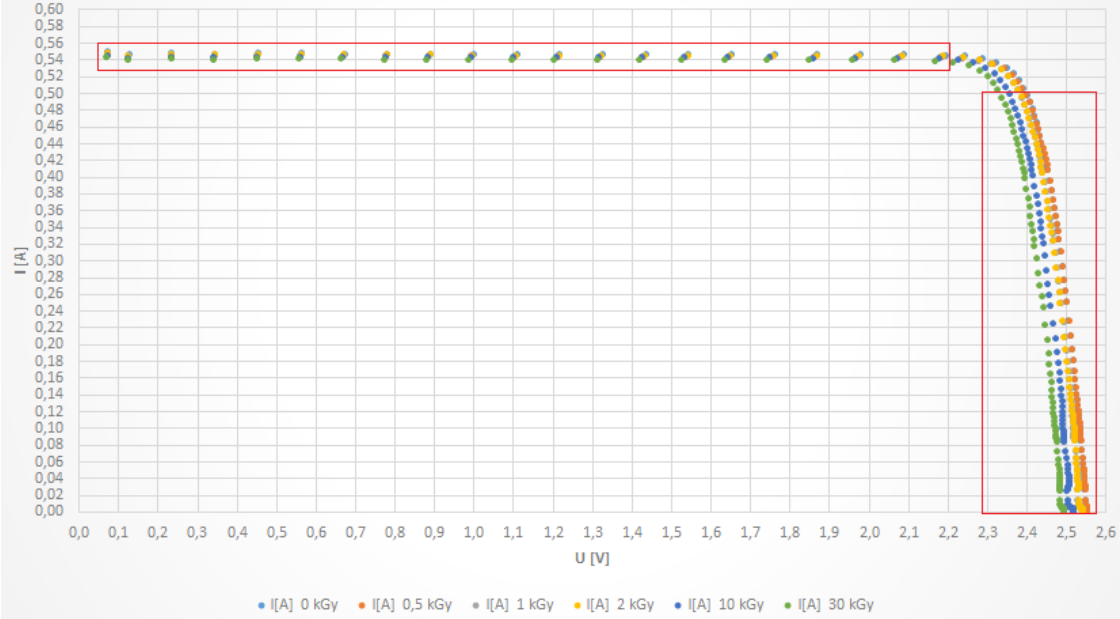
Results – Solar Cells SMX TASC-02x25 by SPECTROLAB, Inc.

- The maximum power of the solar cells decreased from the original value of 0.489 W (non-irradiated state) to 0.471 W (30 kGy irradiated state)



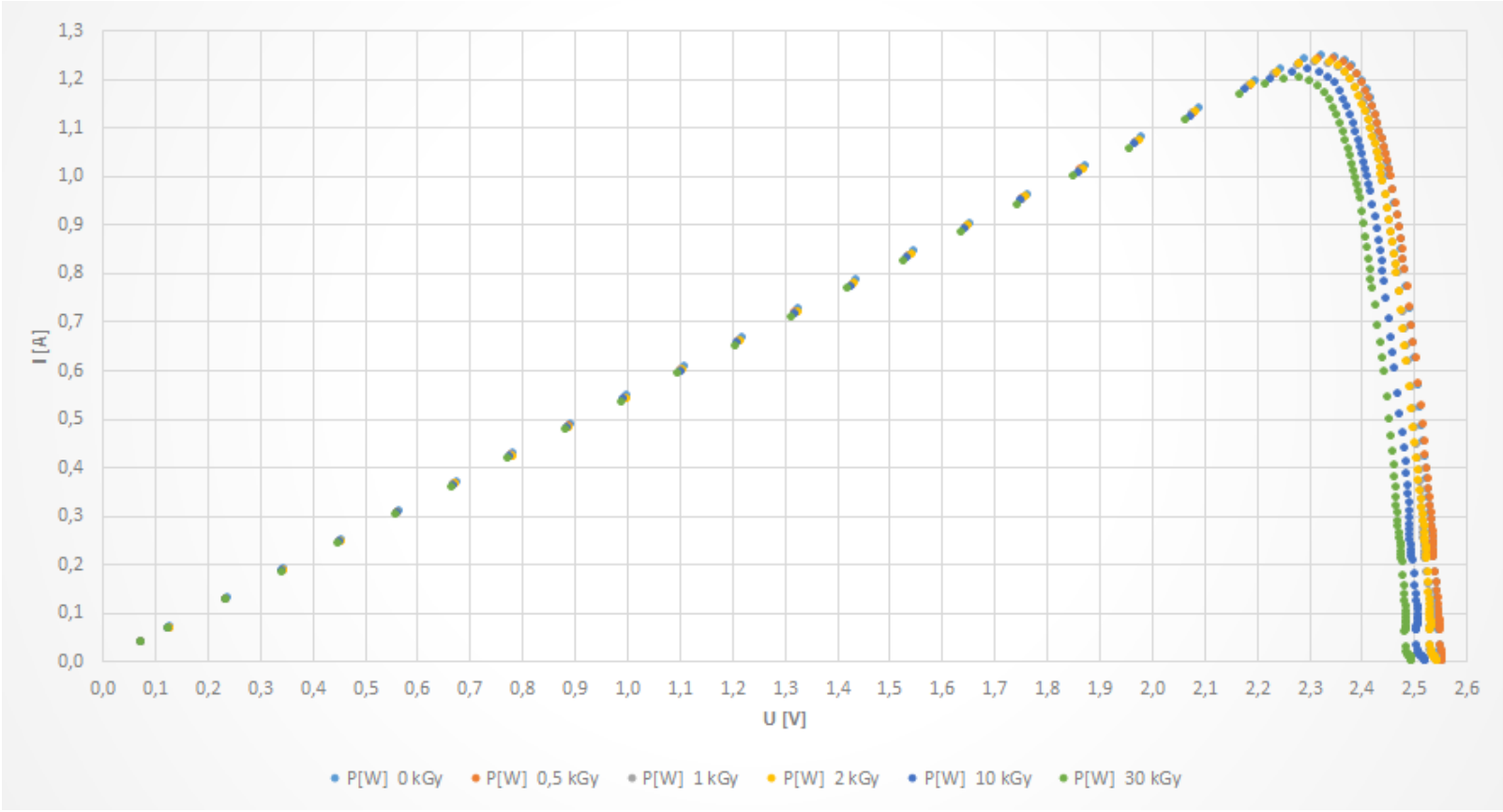
Results – Solar Cells 3G30A by AZUR SPACE Solar Power

- The no-load voltage for non-irradiated samples was 2.5544 V, while for irradiated samples at 30 kGy the value was 2.4963 V.
- The maximum value of voltage drop: 0.063 V in the current range of 0.10-0.50 A (non-irradiated compared to 30 kGy irradiated state). This represents a decrease of about 2.5 %.
- The maximum value of current drop: 0.0071 A in the voltage range of 0.07-2.20 V (non-irradiated compared to 30 kGy irradiated state). This represents a decrease of about 1.3 %.



Results – Solar Cells 3G30A by AZUR SPACE Solar Power

- The maximum power of the solar cells decreased from the original value of 1.247 W (non-irradiated state) to 1.201 W (30 kGy irradiated state)



Conclusions

- An overview of the no-load voltage (U_{oc}) and the maximum solar cell power (P_{max}) for non-irradiated samples and irradiated to 30 kGy are given in Tab. 1

Tab. 1: U_{oc} (open-circuit voltage) and P_{max} (maximum power) overview for 0 kGy and 30 kGy.

Azur Space samples				Spectrolab samples			
Non-irradiated state		Irradiated to 30 kGy		Non-irradiated state		Irradiated to 30 kGy	
U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]	U_{oc} [V]	P_{max} [W]
2.5544	1.247	2.4963	1.201	2.4002	0.489	2.3233	0.471

- The temperature effect was not demonstrated on the solar cells performance in both groups
- In conclusion, both types of solar cells proved to be very resistant to gamma radiation in the temperature range of ± 30 ° C

Thank you for your attention

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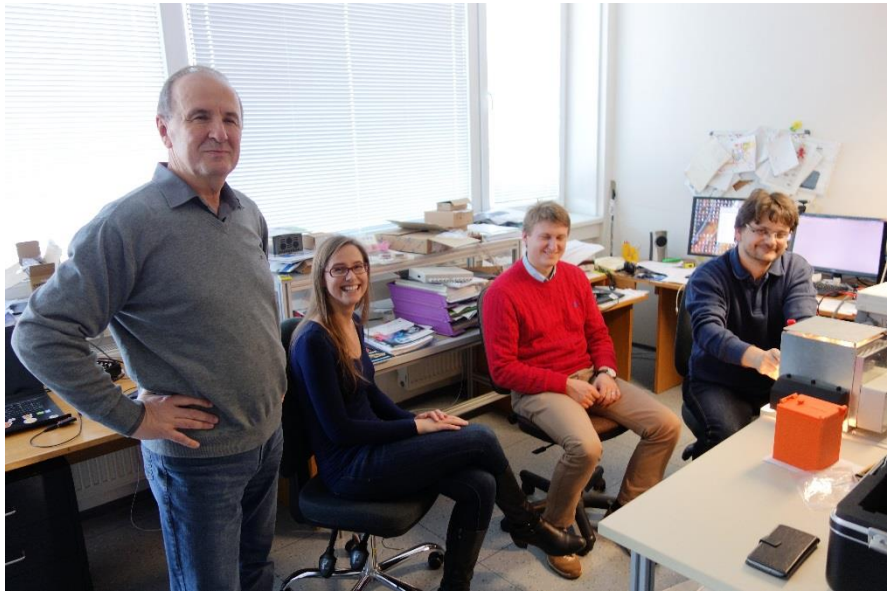

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