Research Project Proposal, "Fall Campaign of Experiments 2017, at the IFIN-HH 3 MV Tandetron™ Accelerator

Proposal Title: Photonic devices under extreme operating conditions

Dan SPOREA[1], Laura MIHAI[1], Andrei STANCALIE[1], Ion BURDUCEA[2], Mihai STRATICIUC[2]

1 *National Institute for Laser, Plasma and Radiation Physics (INFLPR), 409 Atomistilor St., POBox 077125, Magurele, Bucharest, Romania*
2 *Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), 30 Reactorului St., Magurele. Bucharest 077125, Romania*

In the context of complex planetary and extra planetary space missions[1-5], extensive attention was paid by NASA, ESA and other entities working on space exploration,[6-12] to the impact of space ionizing radiations on materials, components and systems as they are subjected to: (i) solar particle events (solar flares, mostly electron rich, and proton abundant Coronal Mass Ejection), (ii) galactic cosmic rays (GCR) and (iii) trapped radiation belts (inner and outer belt).[13,14]
In the last years, along with colleagues from IFIN-HH, we run tests on radiation resistance for mid-IR optical materials, optical detectors and quantum cascade lasers (QCL), under a contract financed by the Romanian Space Agency.[15-19]

In the frame of the research contract "Photonics devices under extreme operating conditions - PHOENIX", financed by the Romanian Executive Agency for Higher Education, Research, Development and Innovation Funding (UEFISCDI), under Grant 24PED/2017, we conducted tests to evaluate the effects of different irradiation conditions on organic solar cells (OPV) and silicon photomultipliers (SiPM) for their possible use in ionizing radiation environments (space borne or terrestrial applications). IFIN-HH is partner to these contract and some irradiation tests were already performed under proton, gamma-ray, electron and alpha particles irradiation.[20-25]

Considering the context presented above the aim of this proposal is to study the behavior under 3 MeV proton irradiation of:

- three different types of OPVs;

- three types of SiPMs;

- two custom designed QCLs.

In some cases, materials composing the devices under tests will be investigated separately under proton irradiation.

The degradation of the studied devices and materials will be studied by off-line measurements, run between two irradiation sessions. The irradiation will be made in the dedicated implantation chamber and in the IBA chamber (beam currents up to 100 nA) at the 3 MV Tandetron^{TM}. After each irradiation step, the following measurements will be performed at the Center for Advanced Laser Technologies (INFLPR):

a) for solar cells: I-V characteristics (Isc, Voc, FF, ή), internal and external quantum efficiency, optical spectral transmittance, optical spectral diffused reflectance, THz spectroscopy and imaging;

b) for SiPMs: DCR, I-V characteristics, breakdown voltage, PDE, spectral response.

By the end of the tests the optical quality of the OPVs' cover window will be also evaluated by AFM (Atomic Force Microscopy) investigations. At this stage temperature induced recovery effects will be also studied.

The total dose expected to be delivered is in the range of 10^{14} - 10^{16} p/cm^2, for which we estimate 10 days, split in two sessions for off-line measurements.

Our research is performed in the frame of COST Actions: (i) "Stable Next-Generation Photovoltaics: Unraveling degradation mechanisms of Organic Solar Cells by complementary characterization techniques" (StableNextSol) - MP1307, (ii) "Fast advanced Scintillator Timing" (FAST) - TD1401, along with partners from: Germany, Finland, Portugal, Czech Republic and The Netherlands, partners developing the devices to be investigated or performing some measurements.

References

1. http://voyager.jpl.nasa.gov/ (*Voyager 1& 2).*
2. http://www.esa.int/Our_Activities/Space_Science/Rosetta (*Rosetta &Philae*).
3. https://twitter.com/NASA Europa (*NASA mission to Jupiter*).
4. http://www.nasa.gov/mission_pages/msl/news/msl20130312.html (*NASA Mars rover*).
5. http://sci.esa.int/ juice/ (*ESA Juice mission*).
6. http://radhome.gsfc.nasa.gov/.

7. http://www.esa.int/Our_Activities/Space_Engineering_Technology/Space_Environment/Radiation_effects.
8. Duzellier, S., Aerosp. *Sci. Technol*. **9**, 93–99 (2005).
9. Wyss, J. et al. *Nucl. Instrum. Meth*. **A 462**, 426-434 (2001)
10. Cowan, V. et al. *Appl. Phys. Lett*. **101**, 251108 (2012).
11. Mahdavi, M. et al. *Aerosp. Sci. Technol*. **6**, 72–75 (2013).
12. McKenna-Lawlor, S. et al. *Planet. Space Sci*., **63–64**, 123–132 (2012).
13. Bourdarie, S. et al. *IEEE Trans. Nucl*. Sci. **55**(4), 1810-1832 (2008).
14. Barth, J. L. et al. *IEEE Trans. Nucl. Sci*. **50**(3), 466-482 (2003).
15. Sporea, D. et al. Electron beam irradiation of materials and components to be used in mid-IR spectroscopy, in *Proc. SPIE 9899*, *Optical Sensing and Detection IV*, 98990O, doi:10.1117/12.2230234 (2016).
16. Sporea, D. et al. Proton irradiation tests of quantum cascade lasers, in *Proc. IEEE International Conference on Advanced Materials for Science and Engineering (ICAMSE),* doi: 10.1109/ICAMSE.2016.7840363 (2016).
17. Sporea, D. et al. Evaluation of mid-IR components for spaceborne instrumentation, in *2016 IEEE Metrology for Aerospace*, 308-313 (2016).
18. Sporea, D. et al. *Scientific Reports*, 40209 (2017).
19. Sporea, D. et al. in *THz Diagnostics of CBRN Effects and Detection of Explosives & CBRN*, Pereira M. and Shulika, O. (Eds.), Springer, Dordrecht, The Netherlands, 63-69 (2017).
20. Sporea, D. et al. Optical and THz reflectance investigations of organic solar cells, in *Proc. SPIE 9898*, *Photonics for Solar Energy Systems VI*, 989814, doi:10.1117/12.2230693 (2016).
21. Sporea, D. et al. *Polyethylene terephthalate, polyethylene naphthalate, Eagle XG and soda-lime glasses test under proton irradiation*, New Trends in Solar Cells Conference, Bratislava, Slovakia, 19-20 April, 2016.
22. Mihai, L. et al. *Proton and alpha particles effects on different glass and polymers substrates*, Industry Day – "Printed Electronics and Solar Cells", Lisbon, Portugal, April 7, 2017.
23. Mihai, L. et al. *Study of organic cells layers based on cross-linked poly(fluorene-alt-bithiophene) using THz imaging*, Industry Day – "Printed Electronics and Solar Cells", Lisbon, Portugal, April 7, 2017.

24. Engelmann, E. et al. *Investigation of radiation hardness of SiPM using the effect of hot carrier luminescence*, New Developments in Photodetection Conference, Tour, France, 3-7 July 2017.
25. Stăncălie, A. et al. *Investigation on electron beam radiation defects induced in KETEK PM3350 silicon photomultipliers*, 14th International Conference on Scintillating Materials and their Applications SCINT2017, Chamonix, 18-22 September 2017.

Person in charge @ INFLPR: dr. Dan SPOREA (dan.sporea@inflpr.ro)

Person in charge @ IFIN-HH: dr. Mihai STRATICIUC (mstrat@nipne.ro)