Annual Summary Document
~2014~

1. Cover Page (1 page):
   - Group list (physicists, staff, postdocs, students);

Nr. crt	Name	Role in the project	OBS
1	*Vizman Daniel*	Director	physicist
2	Nicoara Irina	Researcher	physicist
3	Paulescu Marius	Researcher	physicist
4	Stef Marius	Researcher	physicist
5	Negrila Radu	Asist. Researcher	PhD student
6	Pascu Gabriel	Asist. Researcher	PhD student
7	Tatomirescu Emilian	Asist. Researcher	Master student
8	Sarbu Ion	Tehnician	Staff

- Specific scientific focus of group is on the high energy radiation effects on some fluoride and semiconducting crystals

- Summary of accomplishments in the last year.

In the frame of objective *O1: Design and execution of crystal irradiation experiments* were performed the activities:

1. A1.1 *Defining of condensed matter irradiation experiments for the ELI-NP Technical Design Report*
2. A1.2 *Design of an experimental set-up for materials irradiation with laser accelerated particles*

In the frame of objective *O2: Investigation of radiation effects on the rare earth doped fluoride crystals* were performed the activities:

1. A2.1 *Growth of various YbF_3 – concentrations doped BaF_2 crystals*
2. A2.2 *Growth of various YbF_3 – concentrations doped CaF_2 crystals*

In the frame of objective *O4: Numerical modeling of the laser accelerated proton and electron radiation through interaction with a thin film* were performed the activities:

1. A4.1 *Assessment of existent PIC (Particle in Cell) simulation tools for particle acceleration from laser beam target interaction*

2. Scientific accomplishments (max. 3 pages) – Results obtained in the last year.

Due to the latest advances in laser technologies, increasingly high beam energies and intensities have been achieved, thus paving the way for challenging new phenomena, like those arising from the interaction of high intensity lasers with cold high density plasmas [1]. In literature, this phenomenon is known as laser plasma acceleration (LPA).

The LPA accelerated particles represent an interesting case study due to their similarity with cosmic radiation, which might be useful for testing electro-optical devices bound for outer space applications. The objective of this phase is to prepare physical and numerical experiments for the CETAL infrastructure in order to study the laser accelerated particle radiation generation and its interaction with fluoride crystals and in solar cells. The experience gained from the development of these experiments could then be used for LPA irradiation at the future ELI-NP infrastructure.

1.1 Defining of condensed matter irradiation experiments for the ELI-NP Technical Design Report

We have made two proposals for the Technical Design Report "Materials in extreme environments for energy, accelerators and Space applications at ELI-NP" :

1. *Degradation of optical crystals and solar cells in space*. High power lasers could be a better alternative for reproducing cosmic ray interaction with condensed matter. The energy spectrum of laser accelerated particles is similar to the broad, multi-MeV-scale spectra of natural cosmic radiation, as opposed to the quasi-monoenergetic spectrum of particle beams in classical accelerators. At ELI-NP the highest fluence of LPA radiation in the world will be obtained. Therefore, we propose to use ELI-NP facilities for accelerated testing of the degradation of optical crystals and solar cells performance in space-like irradiation conditions. Beyond the scientific experiments, it can be thought as a testing service that ELI-NP can provide to manufactures of space solar cells or optical components designed to be used for satellites.

2. *Doped fluoride crystals irradiation for fundamental studies of optical proprieties modification.* The aim is to use LPA radiation from ELI-NP in order to study the change in optical and dielectric properties of irradiated crystalline materials with perspective novel laser applications. A very important aspect of LPA usage for radiation induced optical defects in crystals concerns the availability of an easily tunable and cheap proton source, compared to the high costs involved with classical proton accelerators. Also, charge conversions from Yb3+ to Yb2+ could be rapidly reached with the high dose per pulse of the LPA radiation obtained at ELI-NP, for the improvement of the UV emission intensity of Yb2+ [2], which can be used in lasers for psoriasis treatment [3].

1.2. Design of an experimental set-up for materials irradiation with laser accelerated particles

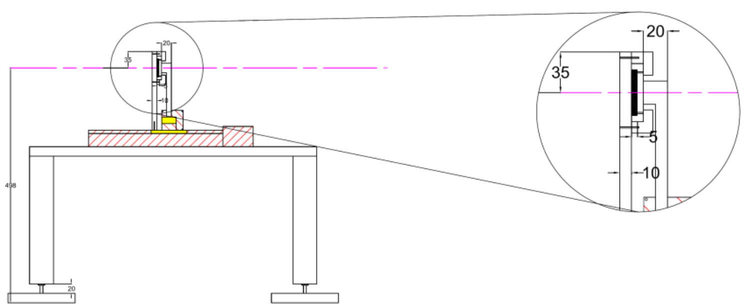

Figure 1. Front view of the experimental set-up

The experimental set-up for LPA solar cells and crystal samples irradiation was designed to fit inside the CETAL interaction chamber. The set-up includes two translation stages for sample positioning in front of the collimator window and fine tuning the particle fluence. The set-up is depicted in five design drawings which contain details drawings. Figure 1 presents the front view of the experimental set-up. A .dwg file for 3D visualization, that can be imported in the CETAL interaction chamber design, was also generated.

2.1 . Growth of various YbF3 – concentrations doped BaF2 crystals

In order to investigate the effects of space-like radiation on the Ytterbium doped Barium fluoride crystals, 9 crystal growth experiments have been conducted using the Bridgman technique. The experiments have consisted in the identification of the optimal BaF2 crystal growth conditions: a temperature gradient in the hot region between 10-15 K/cm, with an adiabatic region around the solidification temperature of 1654 K and in the cold region a temperature gradient around 16 K/cm. For oxygen scavenging from the crystal lattice, 4% PbF2 was added to the raw material. The average growth cycle was around 56 hours.

In Figure 2(a) two photos of the obtained BaF2:0.1mol%YbF3 doped crystals are presented. Several other Ytterbium concentrations have been used (0.05-0.2 mol%) for the other crystals. The crystals have been cleaved on the (111) direction, showing a good optical quality.

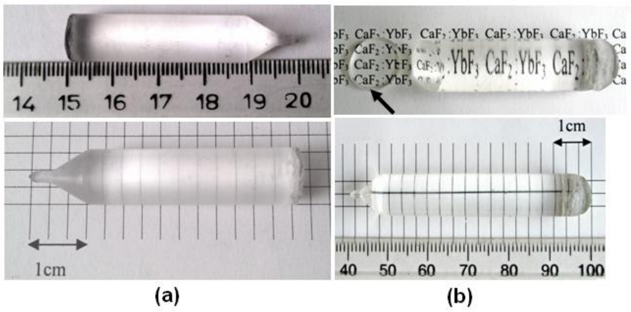

Figure 2.(a)Two BaF2:0.1mol%YbF3 doped crystals;(b) Two CaF2:0,17 mol%YbF3 doped crystals

2.2. Growth of various YbF3 – concentrations doped CaF2 crystals

Five Ytterbium doped Calcium fluoride crystals have been grown using the Bridgman technique. Figure 2(b) shows two photos of the obtained CaF2:0.17mol%YbF3 doped crystals. In the upper image a cleaved sample on the (111) direction can be observed. Several other Ytterbium concentrations have been used (0.07-1.61 mol%) for the other crystals.

Cleaved samples from all the BaF2 and CaF2 crystals will be characterized from the optical, dielectrical and structural proprieties point of view, before and after LPA irradiation at CETAL.

4.1 Assessment of existent PIC (Particle in Cell) simulation tools for particle acceleration from laser beam target interaction

Experimental analysis for the specific input parameters that create space-like radiation conditions is expensive, and therefore treating the problem from a numerical point of view is imperative. Interactions between high intensity lasers with high density plasmas are currently modeled using the Particle-in-Cell (PIC) method. The method is widely used to model systems with a large number of charged particles in their self-consistent electromagnetic field. The modeling of laser-plasma interaction at high laser intensities using PIC codes is done by describing the plasma system through the Vlasov equation for different charged particle species [4].

In our goal of establishing a numerical simulation team whose main area of interest will be the modeling of laser-plasma interaction at high laser intensities using PIC codes, we have assessed several PIC based codes in order to determine what particular code is best suited to our need. For this purpose we imposed several key requirements concerning the code availability, its scalability to the problem under study, the possibility of updates or direct contact with the developers and the computational cost of the code. Using these conditions, we selected six such PIC based codes, one of which is available only commercially, on a contractual basis, and five others that are being developed around the world by different research groups.

Having assessed these software tools (VSim, OSIRIS, QUICKPIC, VLPL, OOPIC, PICLS) we have established that the PIC code best suited for our current needs is the PICLS numerical tool. We have chosen this particular code due to several reasons. The code has a strong theoretical background in plasma simulations, and in the recent past it has been intensely optimized for laser-plasma interaction numerical simulations. The source code is being currently optimized at Université de Bordeaux, and can be made available to us for usage, edit and possible optimizations. Another important reason as to why this tool has been chosen is the willingness of the developers to correspond with our group to help us to thoroughly understand the implementation of the code and of possible fields of study.

In order to ascertain that the PICLS code can efficiently compile and run on our current infrastructure, the PICLS1D has been compiled on several workstations and the PICLS2D software has been compiled on BlueGene supercomputer of the HPC Center at West University of Timisoara. The following step is to compile the 3D version of the code. Some preliminary runs have been made in the interest of checking the good functionality of the picls2Dplot, the dedicated visualization tool for the output data.

Taking all these into account, we have found fit to continue our process of establishing a laser-plasma numerical simulation team having the PICLS PIC code at its core.

References

[1] B. Hidding, T. Königstein, O. Willi, J.B. Rosenzweig, K. Nakajima, and G. Pretzler, Nucl. Instr. Meth. A, 636 (2011) 31.

[2] W.J. Scouler, A. Smakula, Phys Rev 120 (1960) 1154.

[3] S. Majewski, D. Anderson, Nucl. Instr. and Meth. A241 (1985) 76.

[4] Y. Sentoku and A. Kemp, J. Comput. Phys. 227, 6846 (2008).

3. Group members (table):

- List each member, his/her role in project and the Full Time Equivalent (FTE) % time in project. The FTE formula to be used is: FTE = Total number of worked hours in the last year/1020 hours*;

Nr. crt	Name	Role in the project	Worked hours	Full Time Equivalent
1	*Vizman Daniel*	Director	78	0.076
2	Nicoara Irina	Researcher	50	0.049
3	Paulescu Marius	Researcher	80	0.078
4	Stef Marius	Researcher	80	0.078
5	Negrila Radu	Asist. Researcher	188	0.184
6	Pascu Gabriel	Asist. Researcher	188	0.184
7	Tatomirescu Emilian	Asist. Researcher	200	0.196
8	Sarbu Ion	Tehnician	15	0.014

- List of PhD/Master students and current position/job in the institution.

Nr. crt	Name	Position in the university	Obs.
1	Negrila Radu	Asist. Researcher	PhD student
2	Pascu Gabriel	Asist. Researcher	PhD student
3	Tatomirescu Emilian	Asist. Researcher	Master student

4. Deliverables in the last year related to the project:

- Conference presentation

1. Dragoş Tatomirescu, Gabriel Pascu, Alexandra Popescu, Daniel Vizman - PIC method in numerical simulation of laser-plasma interaction, TIM 14 Physics Conference, 20-22 November 2014, Timisoara
2. Marius Paulescu, Radu Andrei Negrila, Daniel Vizman - Overview about solar cells degradation in space, TIM 14 Physics Conference, 20-22 November 2014, Timisoara
3. Florina Cîrlan, Marius Stef, Gabriel Buse, Madalin Bunoiu, Irina Nicoara - Influence of YbF_3 concentration on the dislocation density on (111) surface of YbF_3 doped BaF_2 crystals, TIM 14 Physics Conference, 20-22 November 2014, Timisoara

* 1020 hours = 170 average monthly hours x 6 months

5. Further group activities (max. 1 page):

- Collaborations, education, outreach.

On 20, 21 of October 2014, five ELICRYS project members (Daniel Vizman, Alexandra Popescu, Gabriel Pascu, Radu Andrei Negrila, Dragos Tatomirescu) attended a PIC workshop at IFIN-HH Magurele, held by Emmanuel D'Humieres from University of Bordeaux-CNRS-CEA, CELIA, Talence, France on "Numerical simulation of laser ion acceleration - State of the art and perspectives". The scope of the visit was double, both to establish a new scientific collaboration with the PICLS software development group at University of Bordeaux and to strengthen the existing one with the group at IFIN-HH responsible for laser accelerated particle radiation experiments at the CETAL laser. In the latter interest, a work session was carried out to discuss the practical details for the design of an experimental set-up for materials irradiation with laser accelerated particles and of other relevant parameters for the reproduction of space-like radiation. These experiments are envisioned as a preamble to similar ones that will be developed at the future ELI infrastructure at higher laser intensities, capable of reproducing more accurately space-like irradiation conditions.

6. Financial Report for the last year (see the Annex).

Universitatea de Vest din Timisoara

Contract nr. 13/ 30.06.2014

Annex

Financial Report
according to the regulations from H.G. 134/2011

			lei
Type of expenditures		**Year 2014**	
		Value	
		Planned	**Realized**
1	**PERSONNEL EXPENDITURES**, from which:	**70,477.00**	**68,390.00**
	1.1. wages and similar income, according to the law	55,260.00	56,823.00
	1.2. contributions related to salaries and assimilated incomes	15,217.00	11,567.00
2	**LOGISTICS EXPENDITURES**, from which:	**10,000.00**	**6,698.19**
	2.1. capital expenditures	0.00	0.00
	2.2. stocks expenditures	10,000.00	6,698.19
	2.3. expenditures on services performed by third parties, including:	0.00	0.00
3	**TRAVEL EXPENDITURES**	**4,286.00**	**7,215.71**
4	**INDIRECT EXPENDITURES – (OVERHEADS) * 28.74% from direct costs**	**21,191.00**	**23,650.10**
TOTAL EXPENDITURES *(1+2+3+4)*		**105,954.00**	**105,954.00**

7. Research plan and goals for the next year (max. 1 page).

The activities organized within phase two of the project are listed below, in the framework of each specific objective:

O1: Design and execution of crystal irradiation experiments

- A1.3 Experimental set-up preparation: device manufacturing and commissioning. The experimental device will be constructed at the West University of Timisoara following the project carried out within A1.2 and reported in Sec. 2. This device will be installed inside the CETAL irradiation chamber.
- A1.4 Irradiation of the prepared samples in the designed set-up, for different laser intensities. This activity will be performed on the CETAL platform.

O2: Investigation of radiation effects on the rare earth doped fluoride crystals

- A2.3 Studies on the structural defects-dislocations in YbF3 –doped (Ba/Ca)F2 crystals before and after irradiation
- A2.4 Dielectric spectra of various concentrations YbF_3 –doped $(Ba/Ca)F_2$ crystals before and after irradiation

Cleaved samples from all the YbF3 –doped (Ba/Ca)F2 crystals will be characterized from the optical, dielectrical and structural proprieties point of view at the Crystal Growth Laboratory of the West University of Timisoara.

O3: Investigation of radiation effects on the semiconductor crystals

- A3.1 Selecting the solar cells subjected to experimentation
- A3.2 Characterization of solar cell conversion efficiency before and after irradiation

Several space solar cells of different technology (silicon , triple-junction GaInP/GaAs/Ge) will be exposed to a particle radiation flux generated by CETAL laser. The cells will be fully characterized before exposure and after exposure in the AM0 standardl conditions. Measurements will watch to both microscopic (structural defects) by optical microscopy and macroscopic effects (BOL and EOL cells efficiency).

O4: Numerical modeling of the laser accelerated proton and electron radiation through interaction with a thin film

- A4.2 Efficiency evaluation of the selected PIC modeling software (PICLS2D) on the IBM Blue Gene supercomputer (11.7 Tflops) installed at West University of Timisoara.
- A4.3 Validation of the selected software by comparison with results of laser beam driven proton and electron acceleration reported in the literature.