Annual Summary Document
~2015~

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
6	Pascu Gabriel	Asist. Researcher	physicist
5	Negrila Radu	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. *A1.3 Experimental set-up preparation: device manufacturing and commissioning*
2. *A1.4 Prepared samples irradiation in the experimental set-up for different laser intensities*

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

1. *A2.3 Studies on the structural defects-dislocations in YbF_3 –doped (Ba/Ca)F_2 crystals before and after irradiation*

In the frame of objective *O3: Investigation of radiation effects on some semiconductor crystals* were performed the activities:

2. *A2.3 Selecting the solar cells subjected to experimentation*

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.*2 Efficiency evaluation of the selected PIC modeling software on the IBM Blue Gene supercomputer*
2. A4.*3 Validation of the selected software in comparison with results of laser beam driven proton and electron acceleration reported in the literature.*

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

Activity 1.3: Experimental setup preparation: device manufacturing and commissioning

Two components of the experimental setup were prepared: (1) the experimental stand for testing the solar cells performances before and after irradiation and (2) the mechanical device for positioning the probes (crystal samples and solar cells) inside the CETAL interaction chamber. Current stage of development (at the time of writing this report):

(1) The stand for testing the solar cells performances includes an AM0 solar simulator and instrumentations for measuring the current-voltage (I-V) characteristics of the solar cells. The procedure for purchasing the AM0 solar simulator was completed and we are waiting for the device to be delivered. We have decided on the fiberized solar simulator Solar LightLine A1, made by Sciencetech Inc. USA (Fig. 1). The optical fiber allows guiding the light to the sample mounted on the experimental box for measuring the I-V characteristics. The simulator is equipped with a standard AM0 filter generating one sun beam of AAA class according to ASTM standard.

Figure 1. SolarLight solar simulator

The instrumentation for measuring the I-V characteristics is based on a NI USB-6210 data acquisition board, made by National Instruments. The temperature of the probes is monitored by an industrial IR sensor connected to a computer. The acquisition board and the temperature sensor are devices available at the Photovoltaic Lab, West University of Timisoara. For this task - Activity 1.3 - these devices were configured properly (both hardware and software) for measuring the I-V characteristics of the solar cells.

(2) The mechanical device for positioning the probes inside the CETAL interaction chamber is being constructed according to the documentation carried out in the first phase (2014) of this project. The device will be made of duralumin, all the necessary profiles being purchased. The construction of the device is underway.

Activity 1.4. Prepared samples irradiation in the experimental setup for different laser intensities

Several probes are prepared and have been characterized according to Activity 2.3. Currently, we are waiting the scheduling for the irradiation of the samples at the CETAL facility in the next two months.

Activity 2.3 Studies on the structural defects-dislocations in YbF_3 – doped (Ba/Ca)F_2 before and after irradiation

The quality of the crystals was studied by examining the dislocations distribution using the chemical etching method. For this purpose the fresh cleavage surface (111) of the crystal were subjected to etching in aqueous solution of 2N-8N HCl. It has been observed that the shape and the evolution of etch pits and the values of dissolution rate depend on the etching conditions. Various etch pits shapes were also observed in doped BaF_2 and CaF_2 crystals (Fig.1).

The formation, multiplication and high mobility of the dislocations in ionic crystals lead not only to high densities of individual dislocations, but also cause arrangements of dislocations into well-developed grain sub-boundaries, which are stable and nearly immobile in contrast to individual dislocations (fig.1). Sub-boundaries cannot be easily removed by annealing. Some sub-boundaries appear at the beginning of the growth process.

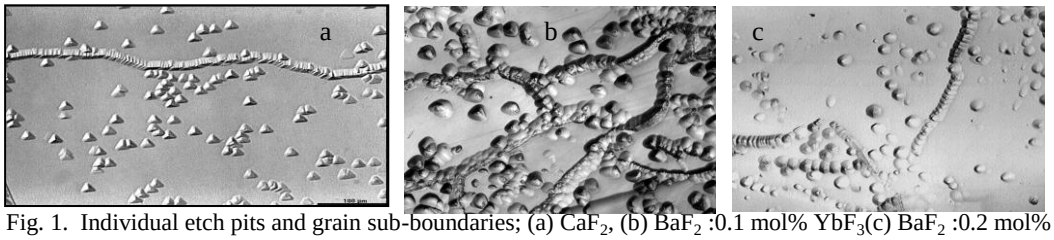


Fig. 1. Individual etch pits and grain sub-boundaries; (a) CaF_2, (b) BaF_2 :0.1 mol% YbF_3(c) BaF_2 :0.2 mol% YbF_3.

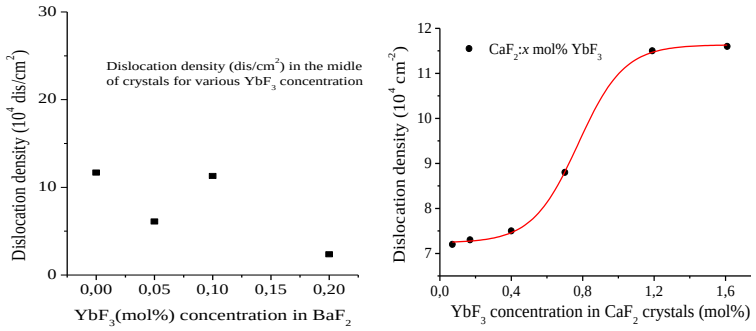
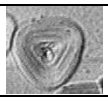
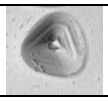
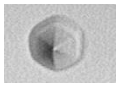


Fig. 2 Dislocation density vs dopant concentration.

The influence of the dopant concentration on the dislocations density and etch pits morphologies were studied. The dislocation density and the etch pits shape observed in various crystals are summarized in figure 2 and table 1.

Table 1. Etch pit shape and dislocation density in doped BaF_2 and CaF_2 crystals.

Crystal	BaF_2: 0.05 mol% YbF_3	BaF_2: 0.1 mol% YbF_3	BaF_2: 0.2 mol% YbF_3	CaF_2	CaF_2: 0.17 mol% YbF_3	CaF_2: 0.7 mol% YbF_3
Etch pit shape						
10^4dis/cm^2	6.1	11.3	2.4	5.5	7.3	8.8

Activity 3.1: Selecting the solar cells subject to experimentation

Testing the degradation of solar cells under LPA irradiation is a newly proposed approach, never performed before. Therefore, we have decided to conduct the experiments in two steps. First, the effect of the LPA radiation on unprotected terrestrial solar cells will be studied. This represents an opportunity to test the LPA irradiation procedure on less expensive solar cells (by two orders of magnitude), while acquiring expertise working with this technique. Secondly, the experiment will be repeated with solar cells for space applications in encapsulated in a solar panel. We have selected for testing the smallest available solar panel, which is usually employed in the construction of cube satellites (e.g. 0.5U CubeSat Solar Panel from Clyde Space).

Activity 4.2. Efficiency evaluation of the selected PIC modeling software on the IBM BlueGene Supercomputer

In order to evaluate the efficiency of the PICLS code on the BlueGene/P supercomputer, we performed a parametric study using a rectangular target comprised of three particle species (electrons, protons and deuterons) uniformly distributed within the target grid. The BlueGene/P processors have a running frequency of 0.85 GHz. As the domain decomposition in the PICLS code is done only on the Oy axis, a test namelist was devised, by varying the macroparticles attributed to each processor for the same Ox value from 2 to 10 macroparticles, while the number of processors was kept constant. The considered system size is 3000x2000 units of Debye length on top of which a 300x200 grid was generated . Each simulation comprised in the study ran for 4001 time steps. Figure 1 shows a linear increase of the total run time with the number of macroparticles per processor.

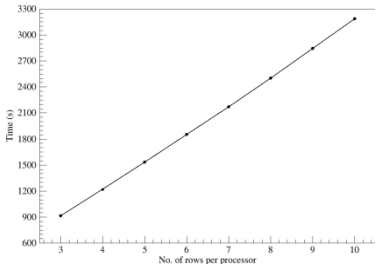
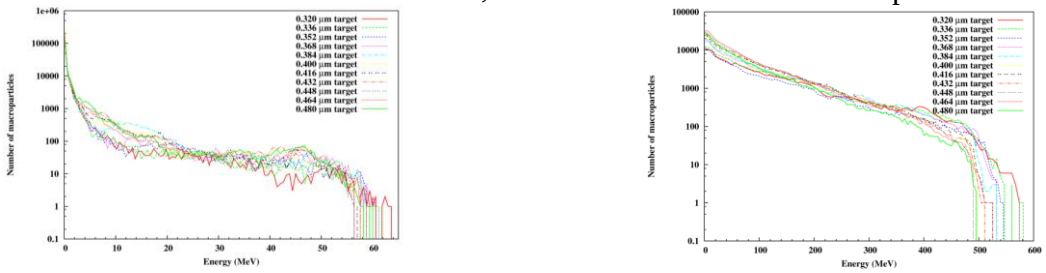


Figure 1. Total run time as a function of macroparticles per processor using the BlueGene/P supercomputer

Therefore when only 3 macroparticles/processor were used the total time was about 900 s and this time increased to about 3200 s for 10 macroparticles/processor. This linear trend of the total time is very helpful in predicting the running time of a simulation for different values of the number of macroparticles on each processor. In the end, after this test case, we performed a more realistic simulation, of a linearly polarized laser pulse interacting with an O gas target with a $\cos^2$ profile using a grid of 2000x2000. In this case 20 macroparticles were used on each processor and the simulation run for 12001 time steps. The total running time was about 432000 seconds (approximately 5 days).

Activity 4.3. Validation of the selected software in comparison with results of laser beam driven proton and electron acceleration reported in the literature

To validate the chosen code accuracy a parametric study was devised to probe the energy of the protons accelerated by the laser interaction with a ultra-dense thin foil. Previous works in the field have demonstrated that a microstructured target [1] and curved foils [2] have a collimating effect on the accelerated proton beam. The laser pulse used for the simulations was a circularly polarized one, having a 800 nm wavelength with an intensity of $I=10^{22}$ W/cm^2. The target density was considered $n_e=300n_c$. The target geometry used in the simulations is composed of a convex thin foil populated by carbon and electrons that has a proton rich microdot attached on its back surface. The foil thickness was varied from 320 nm to 420 nm, while the microdot size was kept constant.



a) protons energy profiles b) carbon ions energy profiles

Figure 2. Particle energy profiles for different target widths

From the above figures it is clear that we have a considerable number of particles accelerated to low energies, with a maximum energy of 64 MeV for protons and 580 MeV for carbon ions. The simulations reveal a quasi-constant number of particles in the mid-range of energies with less macroparticles accelerated to the maximum energy, and a majority of particles accelerated to low energies. A similar trend has been observed in previous works [3-8]. From the similarity of our results with the results previously reported in the literature we have concluded that the PICLS code is suited to study with accuracy the problems proposed in this project.

References:

[1] H. Schwoerer et al., Nature 439 (2006), 445-448
[2] D. Dahiya et al., Laser and Particle Beams (2015), 1-7
[3] O. Klimo et al., Phys. Rev. ST Accel. Beams 1**1** (2008), 031301
[4] H. Zhang et al., Phys. Plasmas 22 (2015), 013113
[5] E. L. Clark et al., Phys. Rev. Lett. 85 (2000), 1654-1657
[6] I. Spencer et al., Phys. Rev. E 67 (2003), 046402
[7] L. N. Su et al., Sci China-Phys Mech Astron 56 (2013), 457-461
[8] M. Kaluza et al., Phys. Rev. Lett. 93 (2004), 045003

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/2040 hours[*];

Nr. crt	Name	Role in the project	Worked hours	Full Time Equivalent
1	*Vizman Daniel*	Director	220	0.107
2	Nicoara Irina	Researcher	100	0.049
3	Paulescu Marius	Researcher	150	0.073
4	Stef Marius	Researcher	200	0.098
5	Popescu Alexandra	Researcher	200	0.098
6	Negrila Radu	Asist. Researcher	420	0.206
7	Pascu Gabriel	Asist. Researcher	174	0.085
8	Tatomirescu Emilian	Asist. Researcher	540	0.265

- 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	Tatomirescu Emilian	Asist. Researcher	Master student

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

- Conference presentation

1. Dragos Tatomirescu, Alexandra Popescu, Gabriel Pascu and Daniel Vizman - The PIC method for laser-plasma acceleration numerical modeling with possible applications in materials evaluation, The 8th International Conference On Advanced Materials, ROCAM 2015, Bucharest, Romania, 7-10 July 2015
2. Marius Stef and Irina Nicoara - Dislocation density and etch pits morphology on cleavage plan of YbF3 doped BaF2 crystals, The 8th International Conference On Advanced Materials, ROCAM 2015, Bucharest, Romania, 7-10 July 2015

[*] 1020 hours = 170 average monthly hours x 6 months

3. Marius Stef and Irina Nicoara - Growth And Spectroscopic Characterization Of YbF3 Doped BaF2 Crystals, The 4th International Conference on the Physics of Optical Materials and Devices, Budva, Montenegro 31 August - 4 September 2015

4. Irina Nicoara, Marius Stef and Octavian Bunoiu - Study of charge compensating defects in BaF2:YbF3 crystals using dielectric relaxation, 5th European Conference on Crystal Growth ECCG5, Bologna, Italy, 9-11 September 2015

5. Irina Nicoara, Marius Stef and Octavian Bunoiu - Some optical properties of YbF3 doped BaF2 crystals, 5th European Conference on Crystal Growth ECCG5, Bologna, Italy, 9-11 September 2015

- Publications

1. I. Nicoara and M. Stef, "Charge compensating defects study of YbF3 doped BaF2 crystals using dielectric loss", Physica Status Solidi b, accepted 2015

2. R. Negrila, M. Paulescu, D. Vizman, Irradiation of materials for space radiation studies, in *Materials in extreme environments for energy, accelerators and space applications at ELI-NP, Technical Design Report-HPLS-TDR4*, edited by D.Ursescu, T.Asavei, M. Bobeica, M. Cernaianu, M. Tomut, to appear in Romanian Reports in Physics.

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

- Collaborations, education, outreach.

Research internship

- Dragos Tatomirescu and Gabriel Pascu - Research internship on Particle-In-Cell simulations of high intensity laser plasma interaction at Centre Lasers Intenses et Applications, CELIA, Bordeaux, France under the supervision of Associate Professor Emmanuel d'Humières. The scope of the visit was also to strengthen the scientific collaboration with the PICLS software development group at University of Bordeaux.

Summer School

- Dragos Tatomirescu attended the International Summer School on Materials for Energy Conversion, Bucharest, 6-11 July 2015
- Dragos Tatomirescu attended the First ELI-NP Summer School - Perspectives in Physics with High Power Lasers and Gamma Beams, Bucharest - Magurele, 21-25 September 2015

Scientific seminar

- Dragos Tatomirescu, Gabriel Pascu and Alexandra Popescu attended the Scientific Seminar "On the prospects of laser driven hadron therapy" held by S. V. Bulanov at ELI-NP and IFIN-HH, Bucharest - Magurele, 30 July 2015,

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 2015**	
		Value	
		Planned	**Realized**
1	**PERSONNEL EXPENDITURES**, from which:	**123,101.00**	**163,852.00**
	1.1. wages and similar income, according to the law	100,460.00	135,739.00
	1.2. contributions related to salaries and assimilated incomes	22,641.00	28,113.00
2	**LOGISTICS EXPENDITURES**, from which:	**70,000.00**	**48,188.73**
	2.1. capital expenditures	35,000.00	44,888.00
	2.2. stocks expenditures	20,000.00	3,300.73
	2.3. expenditures on services performed by third parties, including:	15,000.00	0.00
3	**TRAVEL EXPENDITURES**	**45,005.00**	**28,541.84**
4	**INDIRECT EXPENDITURES – (OVERHEADS) * 25% from direct costs**	**50,776.00**	**48,299.43**
TOTAL EXPENDITURES *(1+2+3+4)*		**288,882.00**	**288,882.00**

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:

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

- A2.4 Absorption spectroscopy of various concentrations YbF_3 –doped (Ba/Ca)F_2 crystals before and after irradiation
- A2.5 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 properties point of view at the Crystal Growth Laboratory of the West University of Timisoara.

O3: Investigation of radiation effects on the semiconductor crystals

- A3.2 Characterization of solar cell conversion efficiency before and after irradiation

Several solar cells of 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

- A4.4 Comparison between numerical modeling and experimental investigations on the laser beam driven proton and electron radiation.