Experimental Station for the Materials Study under Near the Earth Space Conditions

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Experimental Station for the Materials Study

Introduction

Study of effects in materials and electronic equipment under the influence of ionizing radiation is of great importance for the creation of radiation-resistant elements and devices for space, military and other special applications.

At present, when space exploration moved to a stage of intensive development, these tasks become relevant. Spacecrafts, during the period of their existence in space, are exposed to various factors of space.

According to modern concepts, the main factors capable of damaging the electronic equipment of spacecraft are followings:

- ionizing radiation (electrons with energies of 0.1-10 MeV),
- protons with energies of 1-10^4 MeV;
- radiation of the sun and planets; 10^{-5} Torr and high vacuum;
- temperature range from -100 ^{0}C to +100 ^{0}C;

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Average Particle Flux Parameters			
Type of Corpuscular Radiation	Composition	Particle Energy, MeV	Flux density, $cm^{-2} \cdot c^{-1}$
Galactic Cosmic Rays	Protons Helium nuclei Heavier nuclei	10^2-10^{15} (for all groups of nuclei)	1.5 0.1 $1.2 \cdot 10^{-3}$
Solar Cosmic Rays	Protons	1-10^4	10^3-10^4
Earth's Radiation Belts	Protons Electrons	1-30 >30 0.1-1 >1	$3 \cdot 10^7$ $2 \cdot 10^4$ $1 \cdot 10^8$ $1 \cdot 10^6$
Hot Magnetospheric Plasma	Protons Electrons	10^{-3}-10^{-1}	10^7-10^{10}

Fig.1. In near the Earth space environment particles and their parameters

Space Environment Simulating Setup at AREAL Facility

The nature and extent of the radiation effect on the physical parameters of materials strongly depends on the:

- type and energy of radiation
- intensity
- irradiation conditions

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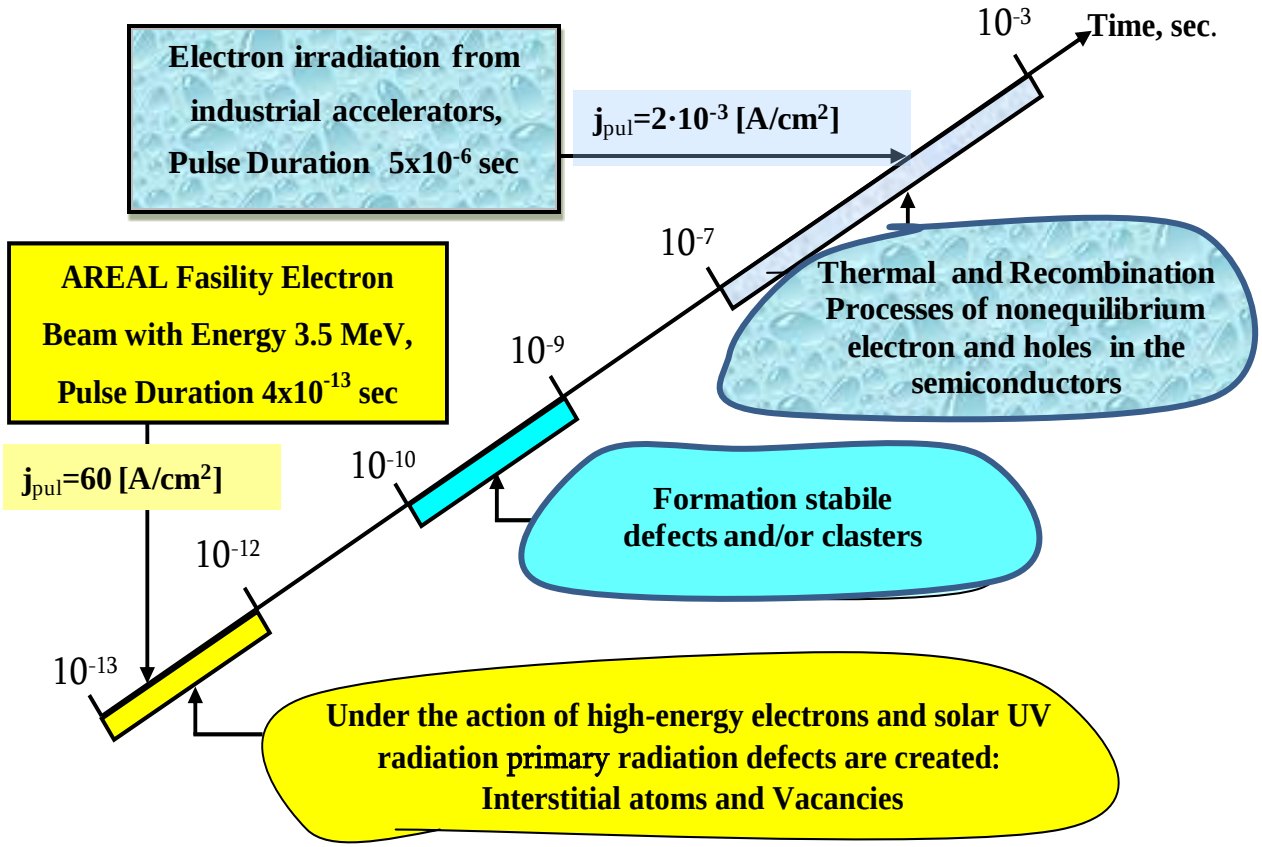

Fig.2. Schematic presentation of the processes occurring in a semiconductor crystal after the irradiation by high-energy electrons.

Aim

The aim of this work is the development of experimental setup simulating some near the Earth space environment conditions for study materials and devices at AREAL Facility with the following parameters:

- Vacuum - 10^{-5} Torr (1.33×10^{-3} Pa),
- Electron beam with energy up to 4MeV, pulse duration 4×10^{-13} sec,
- Measurement temperature range from -100 ^{0}C to +100 ^{0}C,
- Solar ultraviolet radiation.

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1.Experimental setup

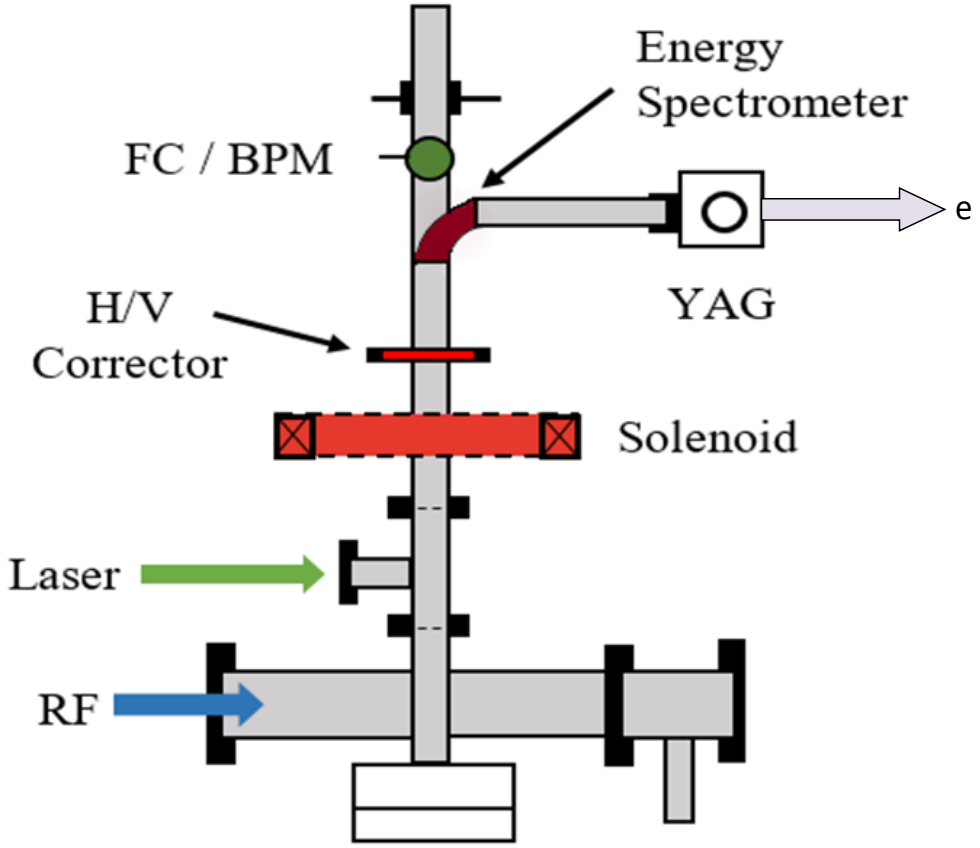

Fig.3. Schematic diagram of AREAL facility

Peculiarities
of AREAL facility

- Energy – 3,7 MeV
- Bunch charge – 60 pC
- Bunch length – 0,4 ps
- Repetition rate – 12 Hz

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1.Experimental setup

Fig.4. General view of the experimental chamber

Space Environment Simulating Setup at AREAL Facility

1.Experimental setup

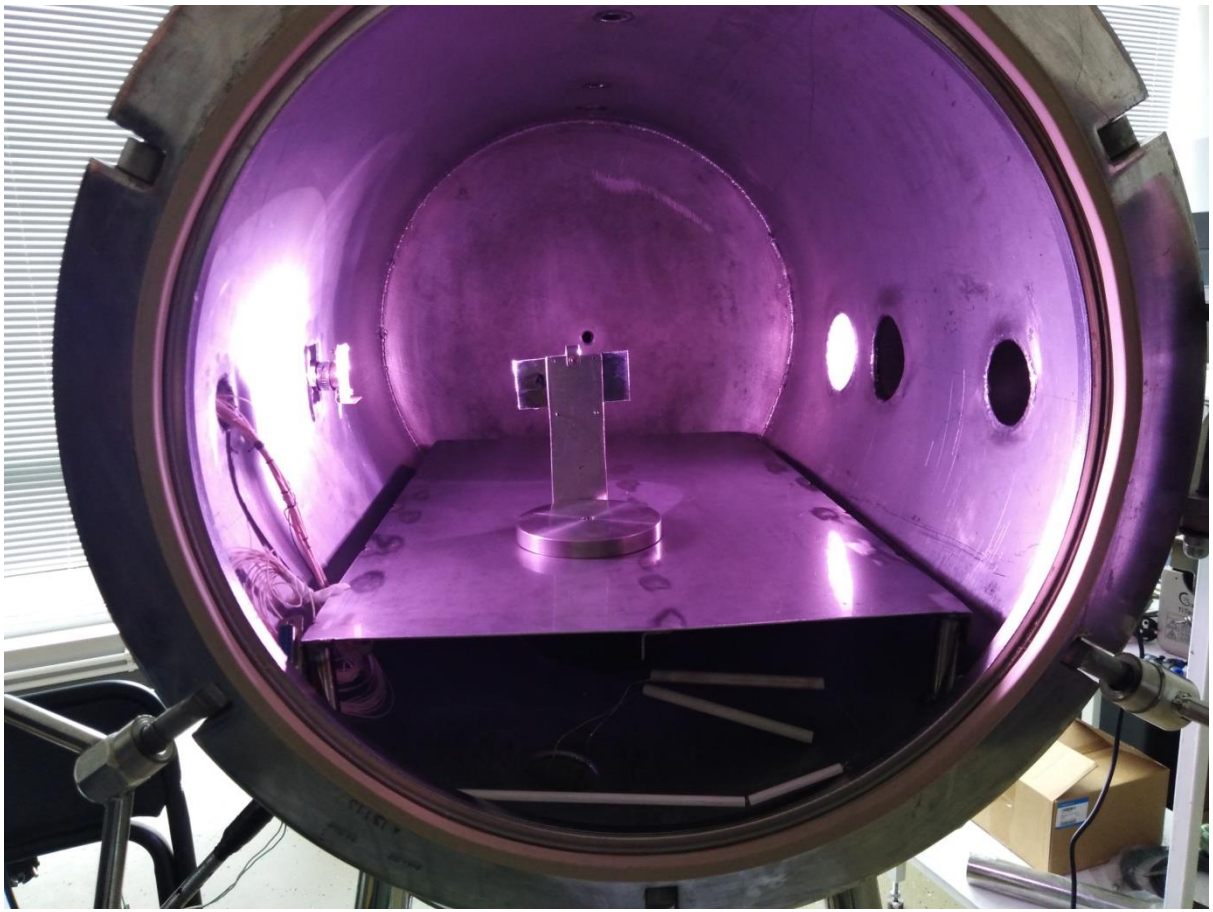


Fig.5. General view of the experimental chamber

Space Environment Simulating Setup at AREAL Facility

1.Experimental setup

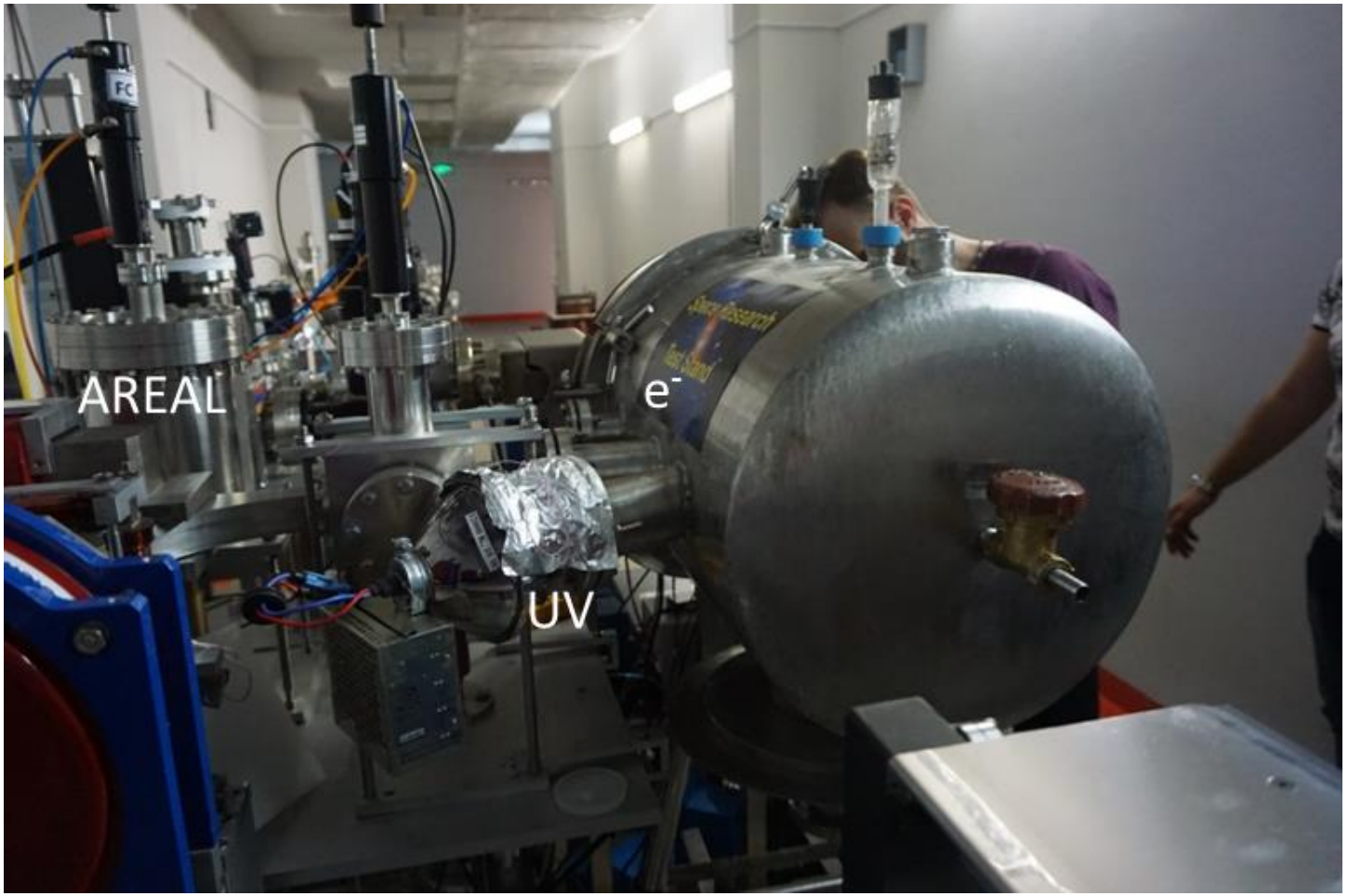


Fig.6. General view of the Space Environment Simulating Setup

Space Environment Simulating Setup at AREAL Facility

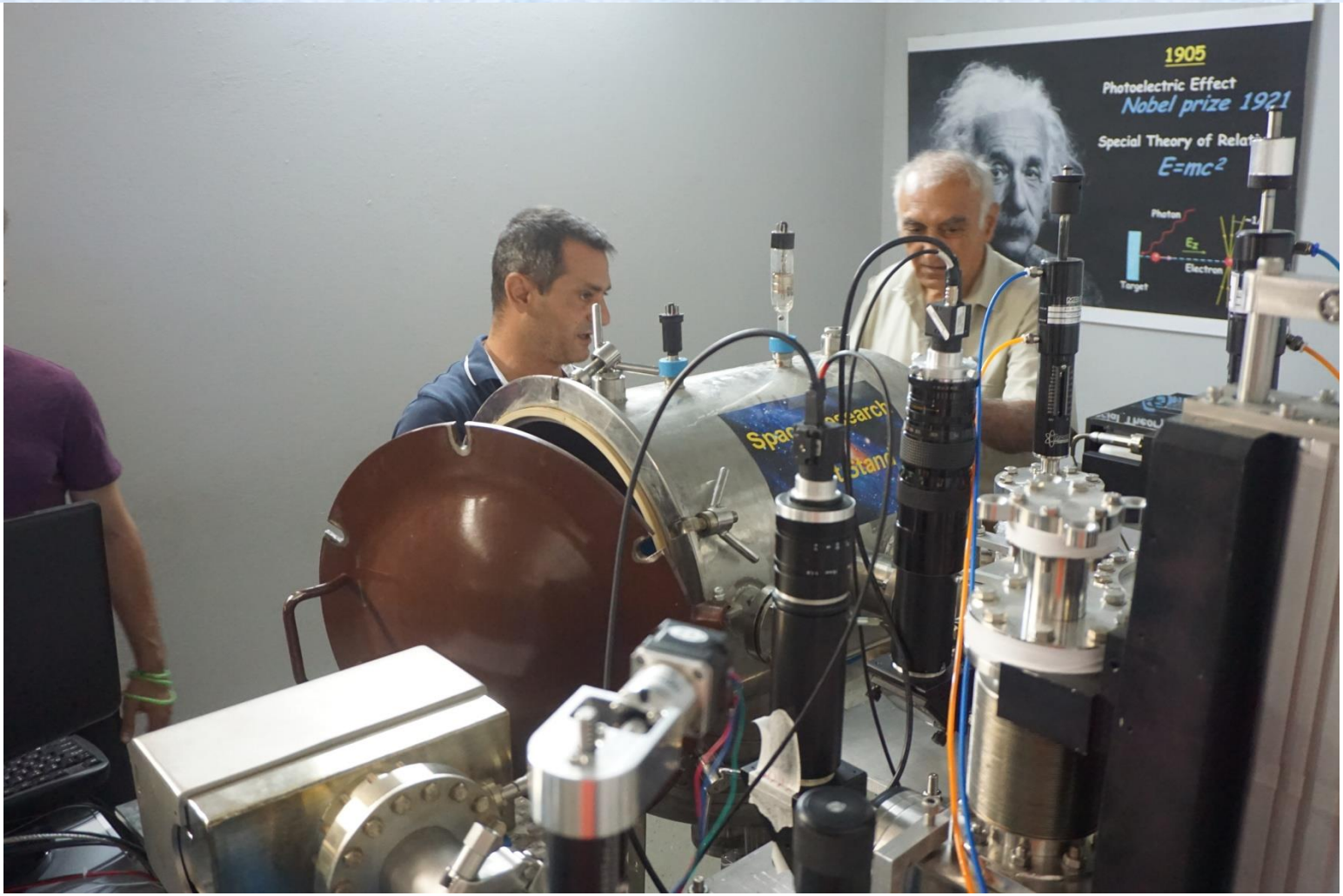


Fig.7. General view of the Space Environment Simulating Setup

Space Environment Simulating Setup at AREAL Facility

1.Experimental setup

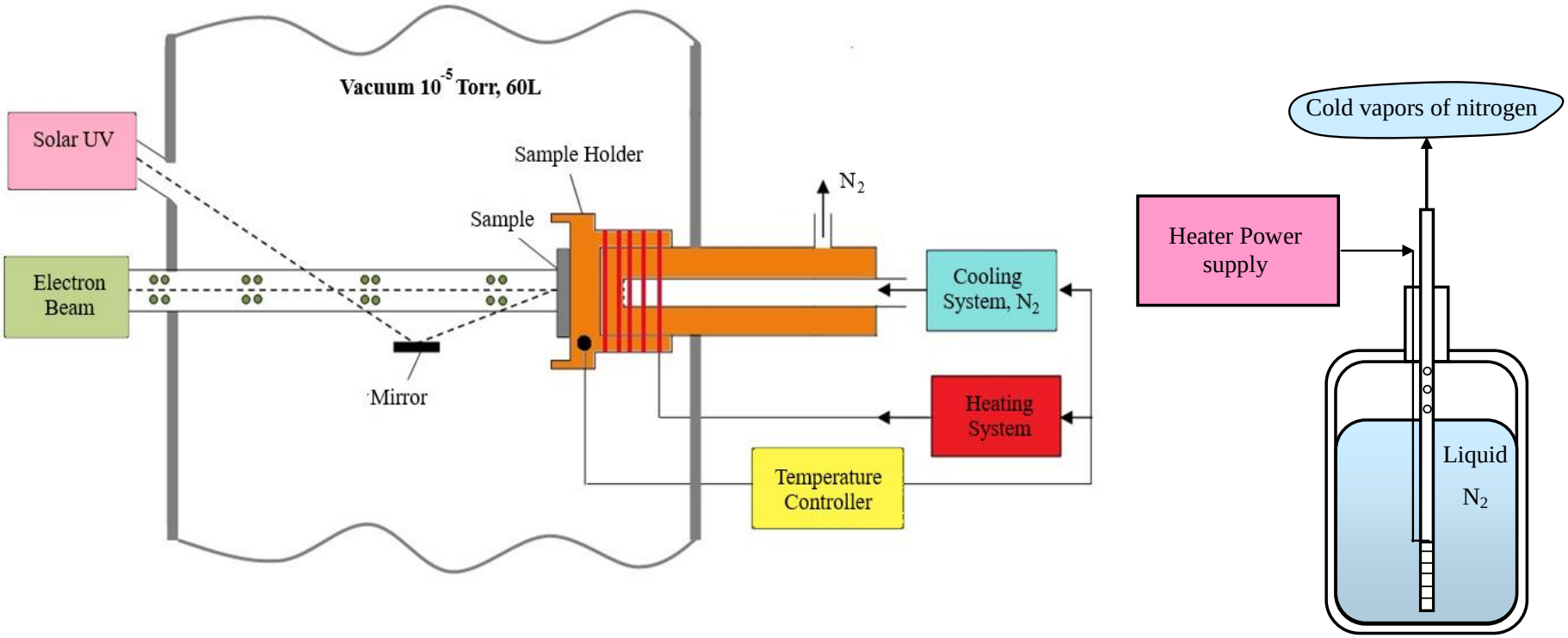
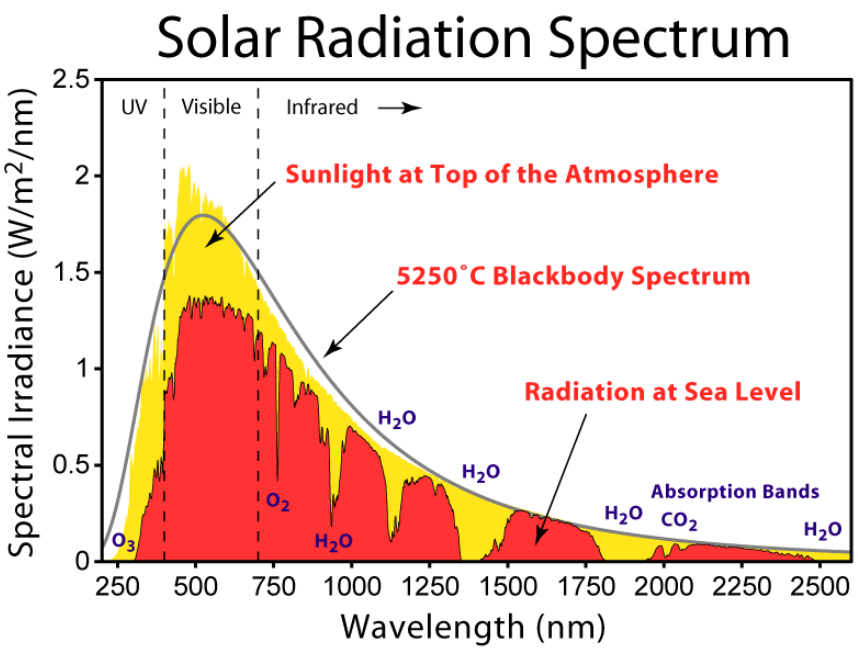


Fig.8. Schematic diagram of cooling/heating system

Space Environment Simulating Setup at AREAL Facility

1.Experimental setup



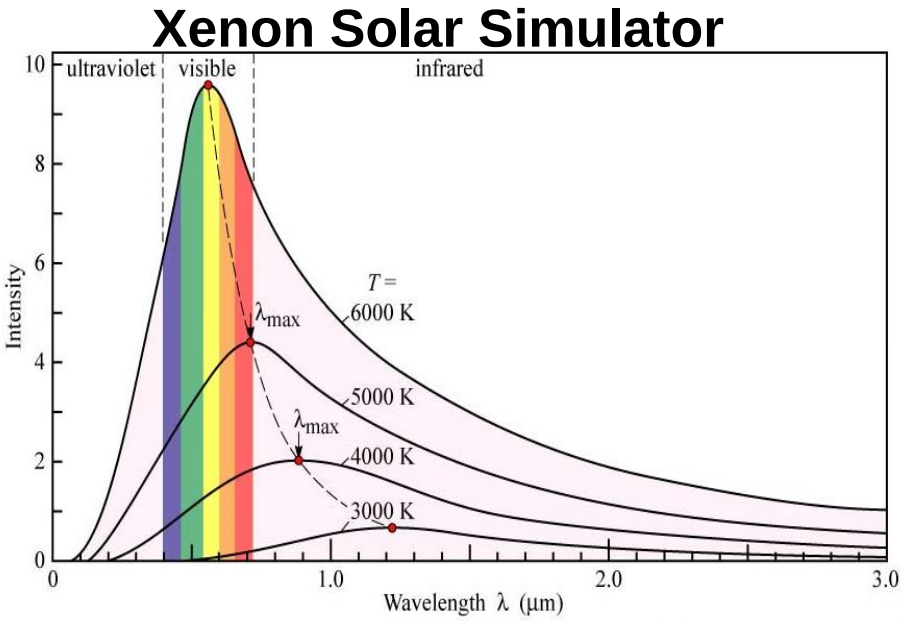


Fig. 9.Spectra of sunlight and xenon lamp

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2. Experimental results

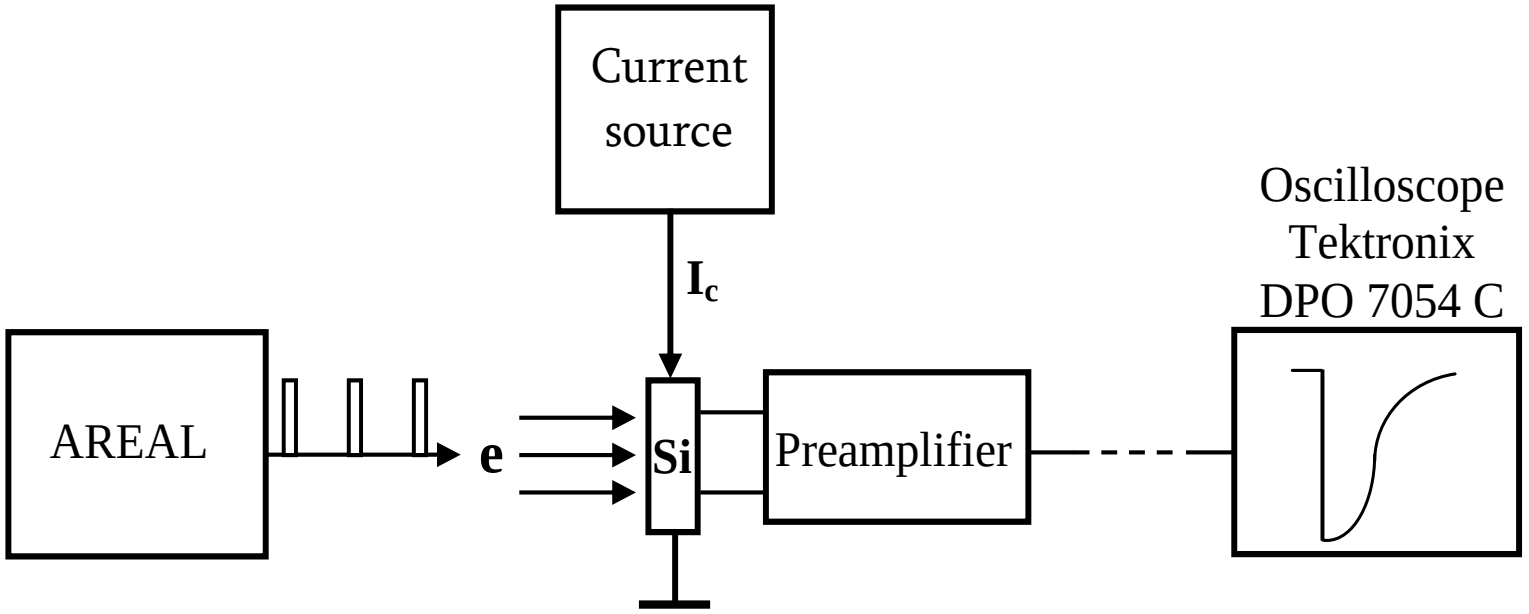

Fig. 10. Schematic diagram of the n-Si sample irradiation (in-situ) and observation of resistivity change at in- situ process.

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2. Experimental results

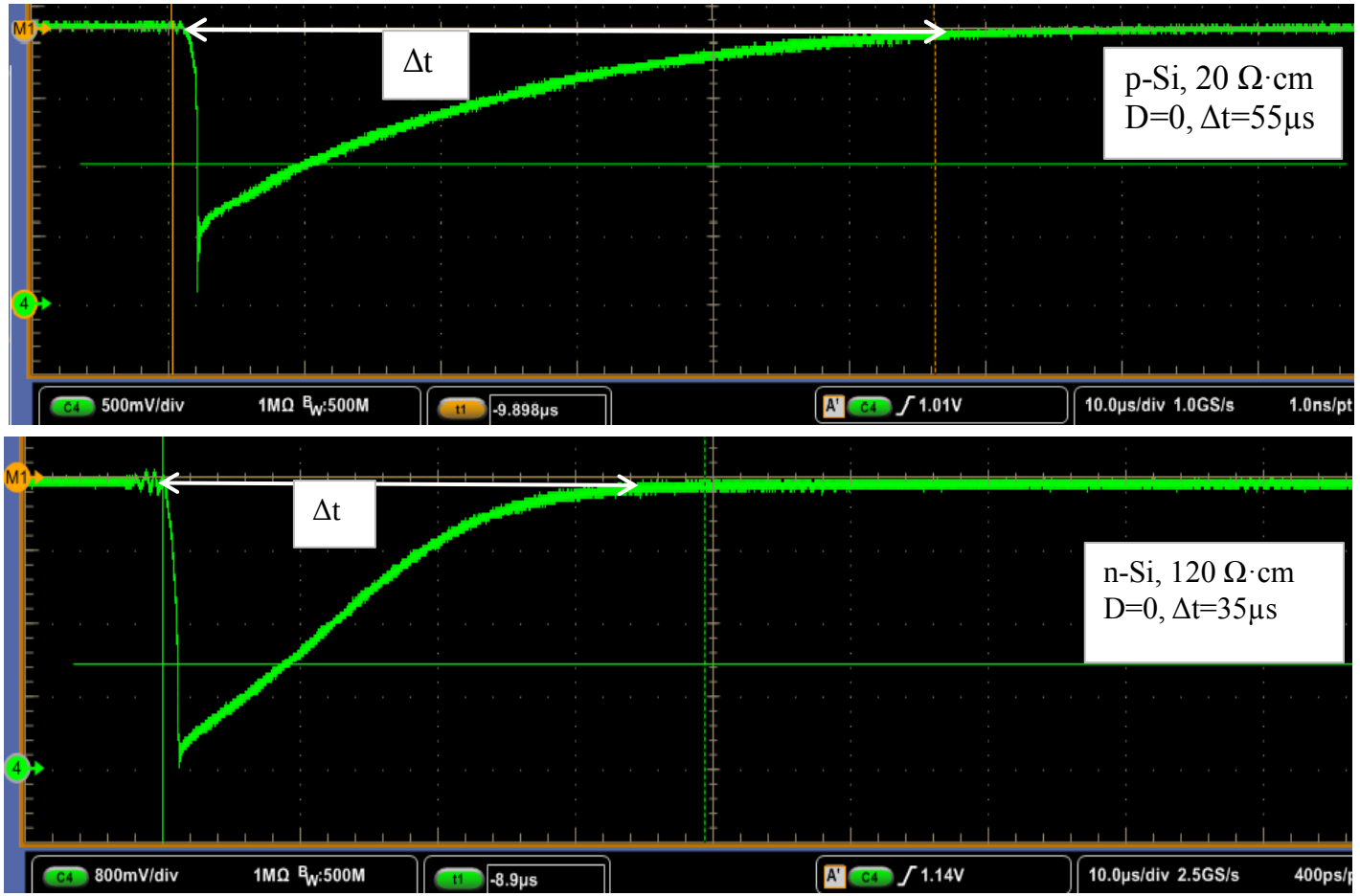

Fig. 11. Behavior of silicon crystal resistance under irradiation by ultrafast electron pulses of energy 3.5 MeV (Measuring temperature T=300 K).

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2. Experimental results

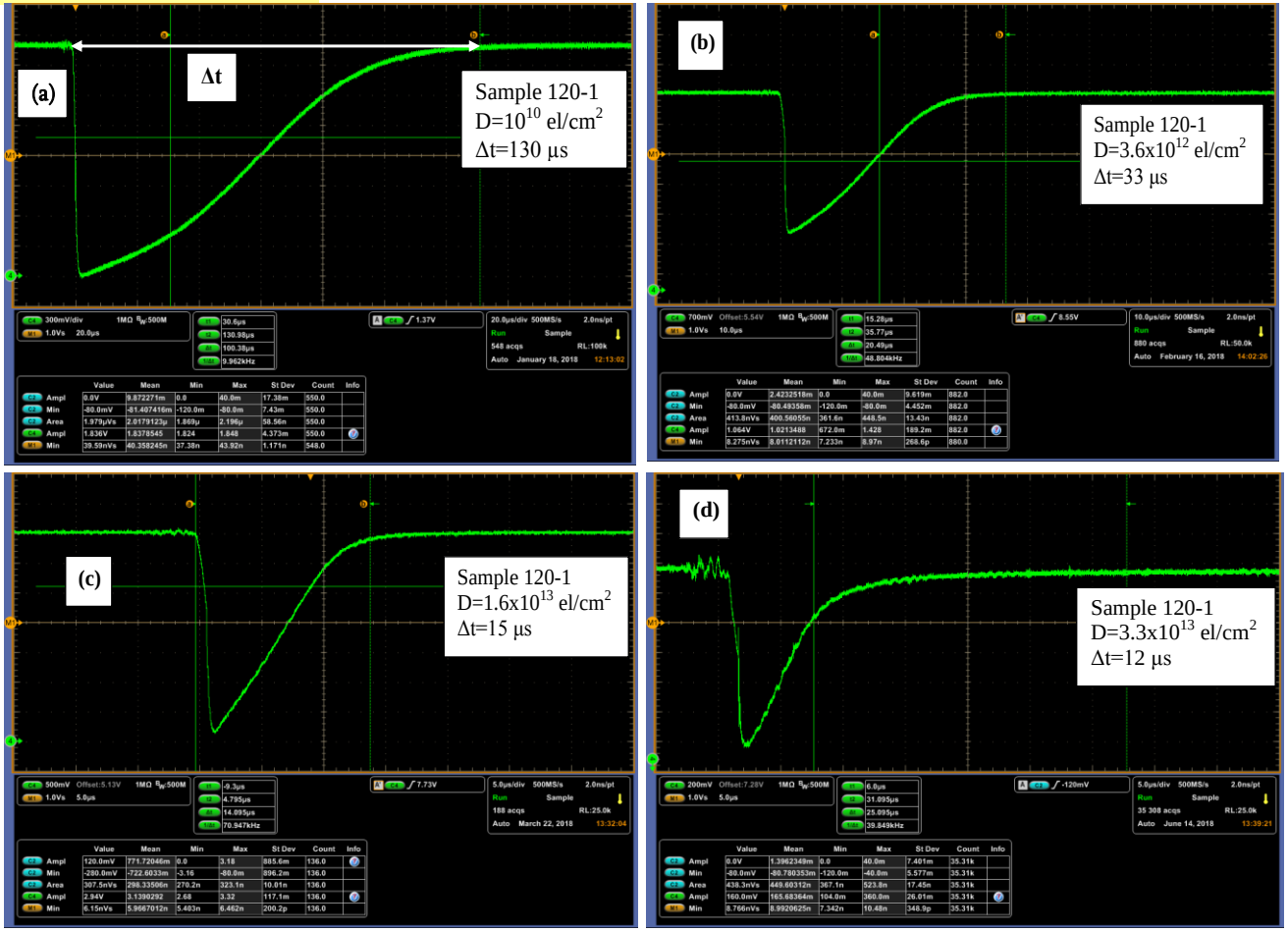

Fig. 12. Oscilloscope pictures show the resistivity changes of a crystalline silicon sample, measured in-situ under the influence of electron pulse irradiation for different doses.

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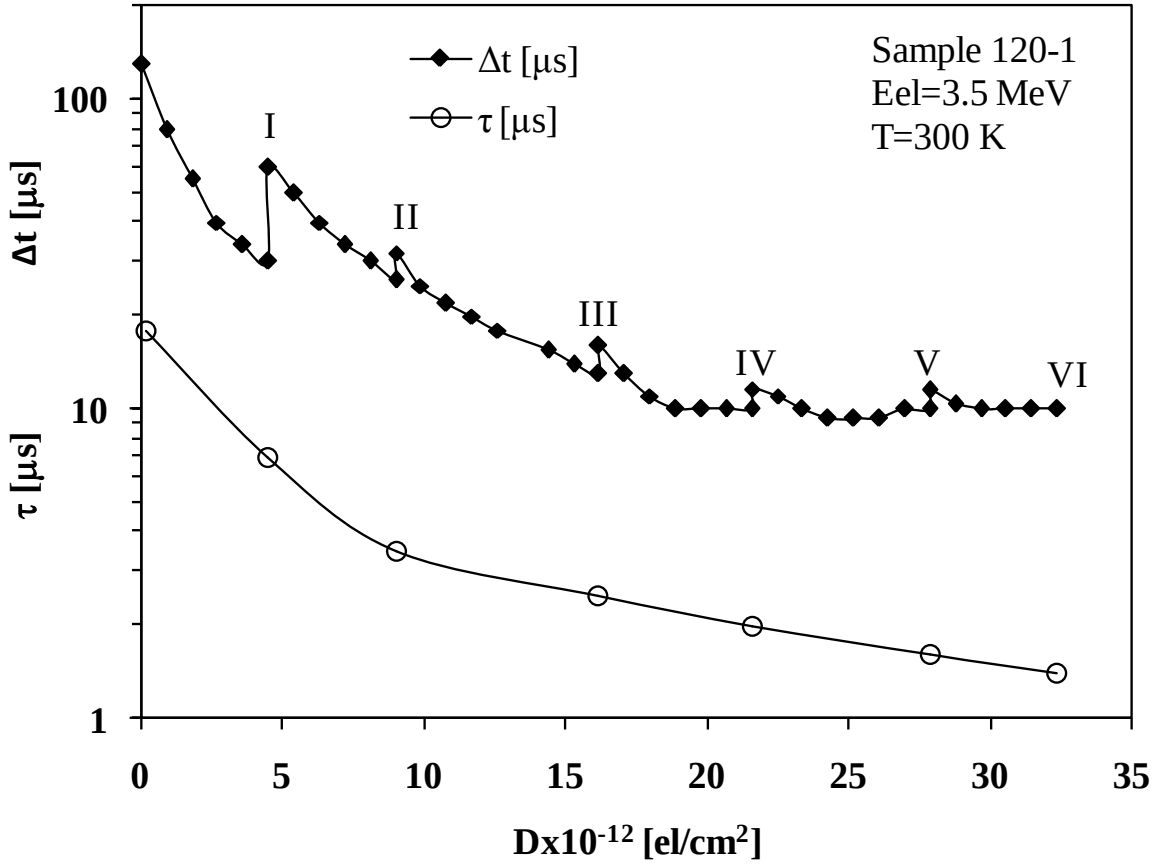
2. Experimental results



Non-equilibrium charge carriers are generated by illumination of a sample with a radiation wavelength of 1.05 μm, the decay process of which is detected by microwave absorption at a frequency of 10 GHz, which is recorded on an oscilloscope

Fig. 13. Irradiation dose dependence of the characteristic time Δt(D) and the lifetime τ(D) of the minority charge carriers in crystalline Si.

Space Environment Simulating Setup at AREAL Facility

3.Conclusion

1. It was designed an experimental setup (vacuum chamber) for the study of materials characteristics under extreme conditions at the AREAL Facility with the following parameters:
   - Vacuum - 10^{-5} Torr ($1{,}33 \times 10^{-3}$ Pa),
   - Electron beam with energy up to 4 MeV, pulse duration 4×10^{-13} sec,
   - Measurement temperature range from -100 ^{0}C to +100 ^{0}C,
   - Solar ultraviolet radiation.
2. Due to irradiation by electrons with ultrafast pulse duration 4×10^{-13} sec, at the first time in radiation physics was obtained image of nonequilibrium electrons and holes recombination process in semiconductors.

PROJECT-17A-1C002 (2017-2019)

"Study of Ultrafast Electron Beam Impact on the Non-Equilibrium processes in Semiconductors"

1. H. N. Yeritsyan, A. A. Sahakyan, N. E. Grigoryan, V. V. Harutyunyan, V. V. Arzumanyan, V. M. Tsakanov, B. A. Grigoryan, G. A. Amatuni, ***In-Situ Study of Non-Equilibrium Charge Carriers' Behavior under Ultra-Short Pulsed Electrons Irradiation in Silicon Crystal,*** *Journal of Modern Physics, accepted for publication.*

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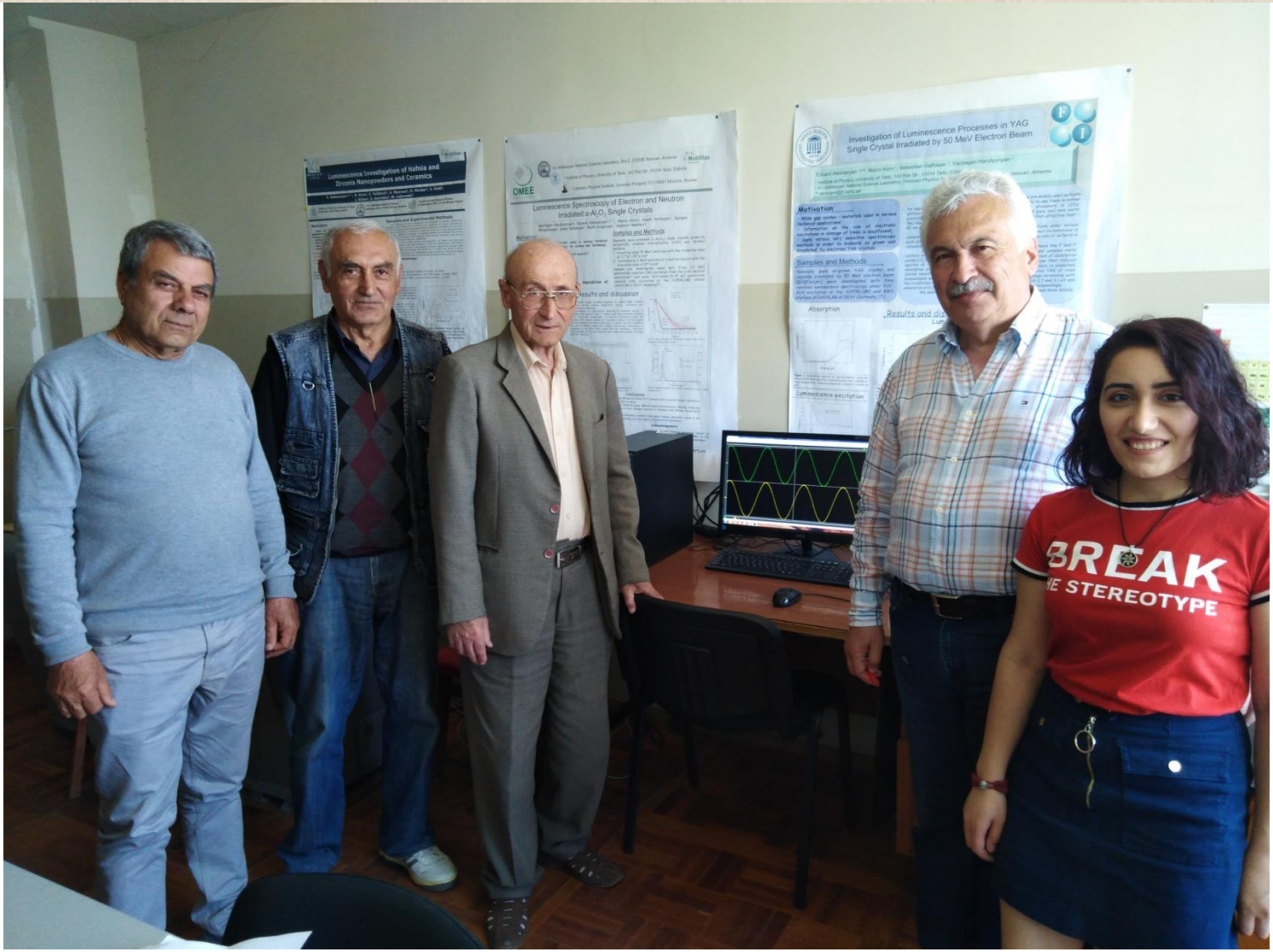
"Study of Ultrafast Electron Beam Impact on the Non-Equilibrium processes in Semiconductors"



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Thank you!