Measurements and analysis of depth-resolved photoluminescence spectra in swift heavy ion bombarded insulators

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Outline

- Introduction
- Aim
- Experimental Procedure
- Results And Discussion
- Conclusions
- References

Introduction – Track formation

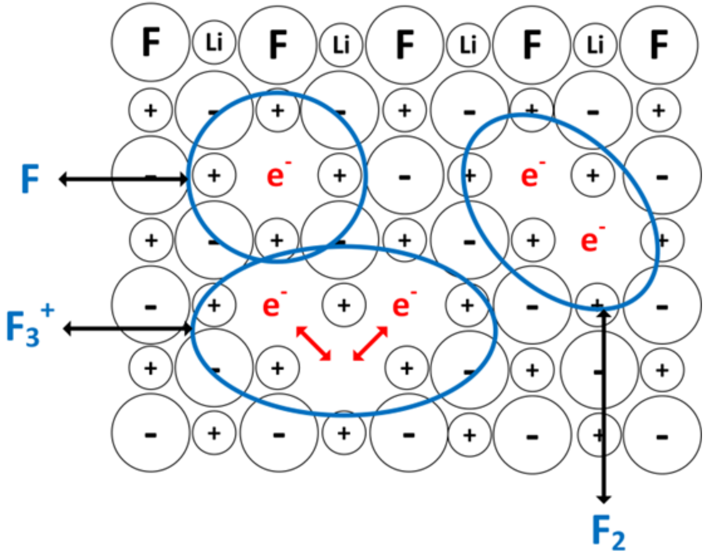
- High-energy heavy ions (M > 20 amu and E > 1 MeV/amu) are often referred to as **swift heavy ions**.
- For swift heavy ions (SHI), the nuclear energy loss is generally negligible, but the electronic energy loss is sufficiently high to result in the creation of damage tracks in many materials.
- The track is discontinuous or continuous trail of defects resulting from a dence electronic excitation deposited in a short time and in nanometric scale.
- Radiation damage refers to the transfer of kinetic energy from an energetic incident particle to a solid and the resulting rearrangement of atoms in the solid. [1]

Introduction - LiF

- Defects in alkali halides under various types of irradiations e.g. neutrons, photons, electrons, and Ions are studied extensively during the past few decades.
- Lithium fluoride (LiF) is an ionic crystal and an insulator. [2]
- Lithium fluoride is an optoelectronic material having great applications in field of radiation dosimetry, optical isolators, detectors for ionizing radiation, in high power laser amplification and generation of ultra short pulses. [3]

Introduction - LiF

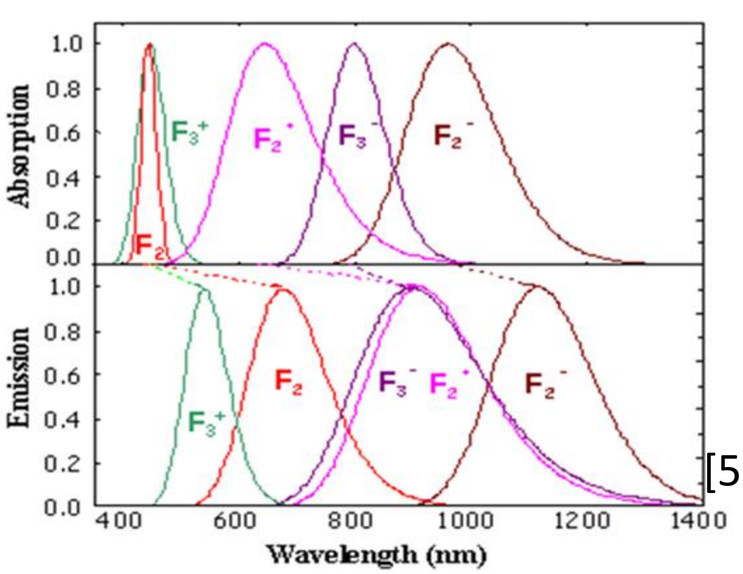
- The optical properties of this material can be modified by point and extended defects, created due to different types of particle irradiation.
- The defect centers induced by ion irradiation in LiF are mainly F center, and more complex defects F-aggregate centers such as F_2, F_3 and F_4. [2]



- F centers – an electron on anion vacancy,
- F_2 centers – two electrons trapped in two anion vacancy,
- F_3^+ - two electrons trapped in three anion vacancy. [3]

Introduction - LiF

- Various experimental methods of luminescent spectroscopy are widely used in studies of radiation defects induced in transparent or semitransparent solids by any kind of ionizing radiation and by swift heavy ion bombardment. [4]



[5]

- The emission range is peaked at 530 nm and 670 nm, for F_3^+ and F_2, respectively. [4]

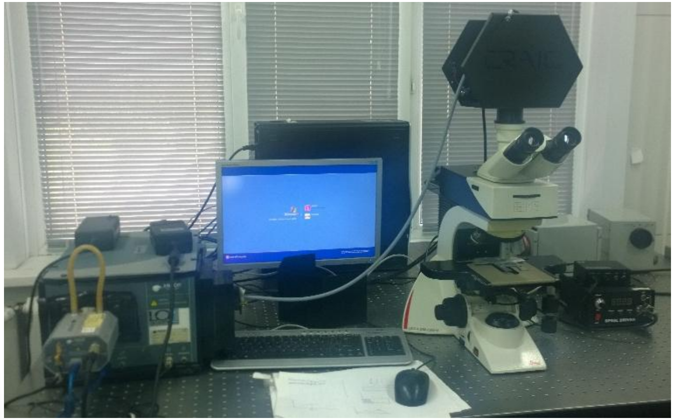
Aim

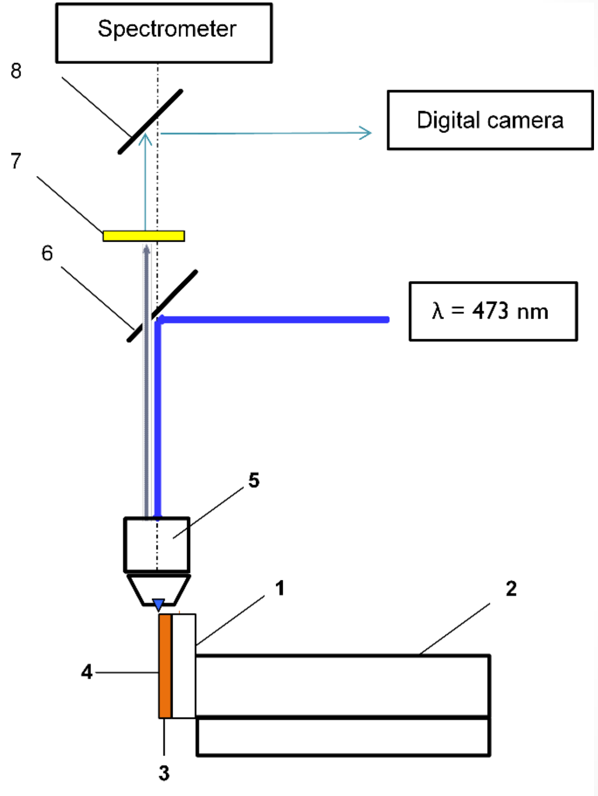
- The a… defects (colo… swift heavy…

Ion	Energy (MeV)	Fluence (ions/cm^2)
Kr	107	5 x 10^{11}
		7 x 10^{12}
		5 x 10^{13}
Xe	167	6 x 10^{11}
		3 x 10^{12}
		1 x 10^{13}
Bi	710	4.6 x 10^{11}
		5 x 10^{12}
		1.4 x 10^{13}

Experimental Procedure

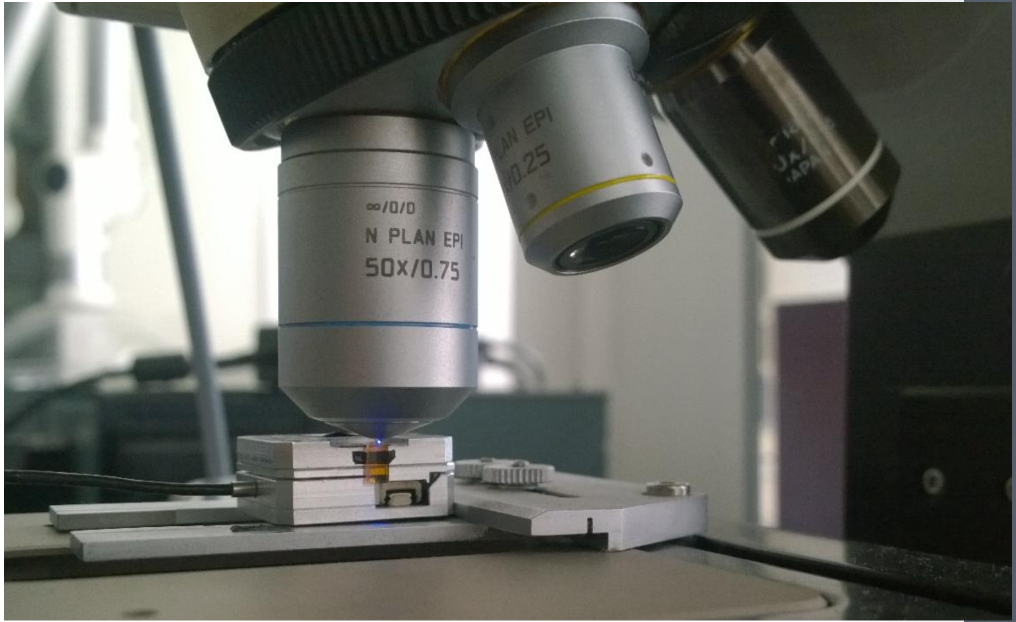
1. Specimen
2. Piezo stage (1 step – 1 μm)
3. Irradiated area
4. Irradiated surface
5. Lens
6. Semitransparent mirror
7. Filter
8. Mirror aperture

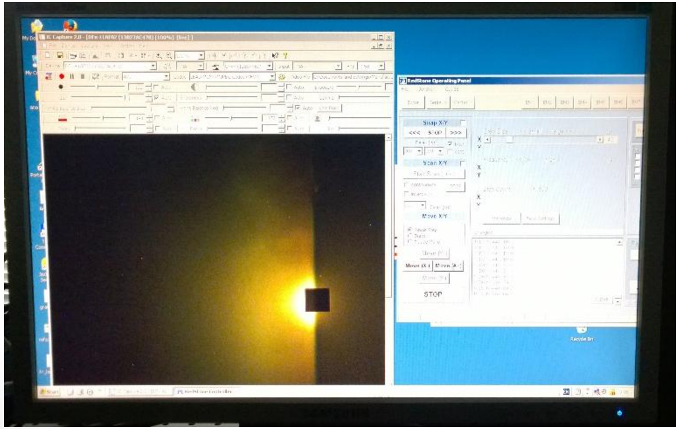




Experimental Procedure

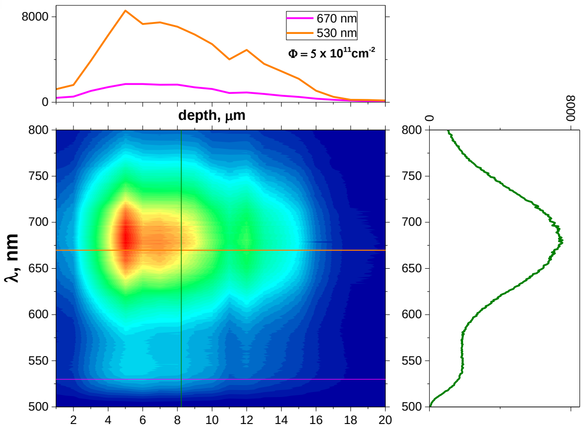
- The specimen is mounted on the one-coordinate piezo stage, which moves with step of 1 μm along ion beam axis under fixed high aperture objective.



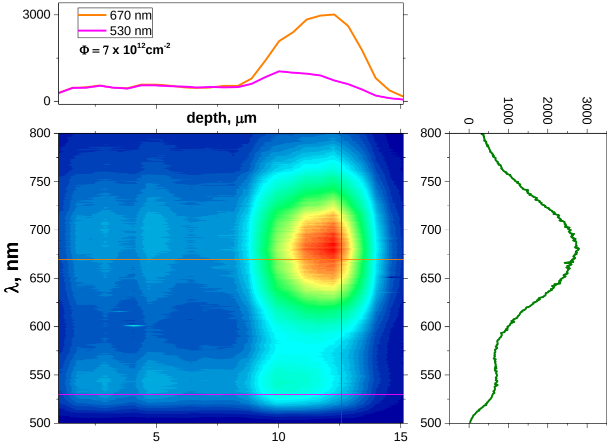


- Photoluminescence spectra were collected for every step of piezo stage.

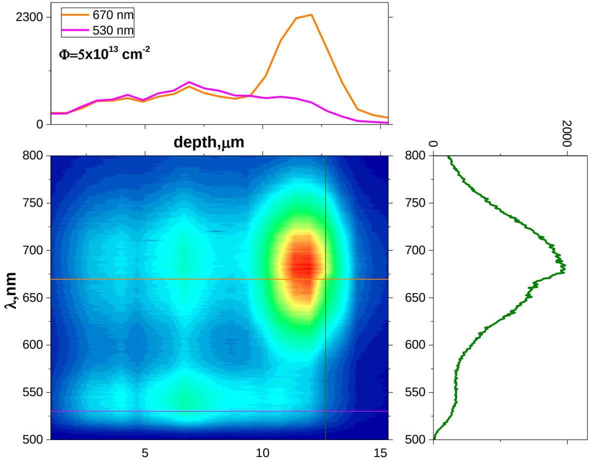
Results And Discussion – Kr, 107 MeV



$\Phi = 10^{11}$ ions/cm^2

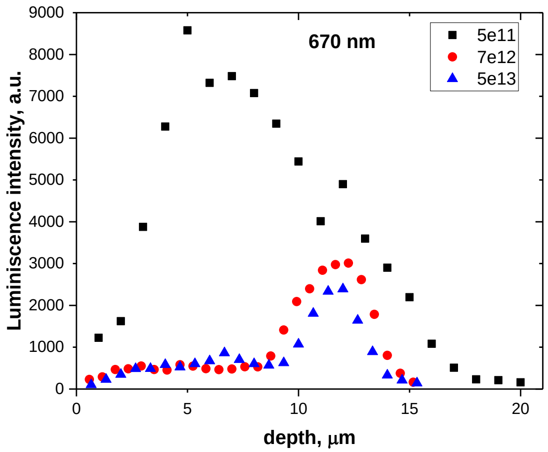


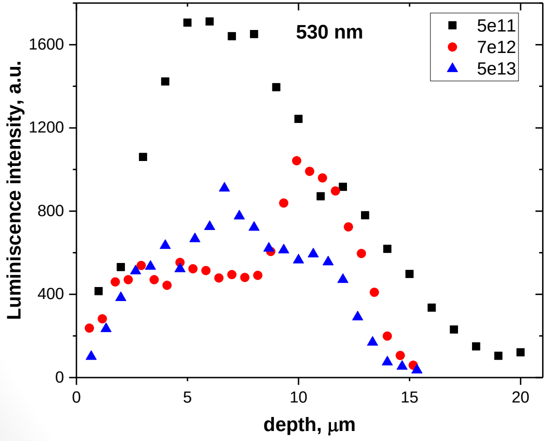
$\Phi = 10^{12}$ ions/cm^2

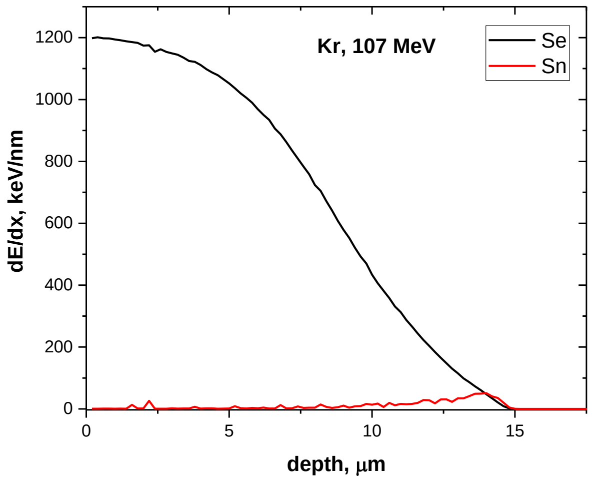


$\Phi = 10^{13}$ ions/cm^2

Results And Discussion – Kr, 107 MeV

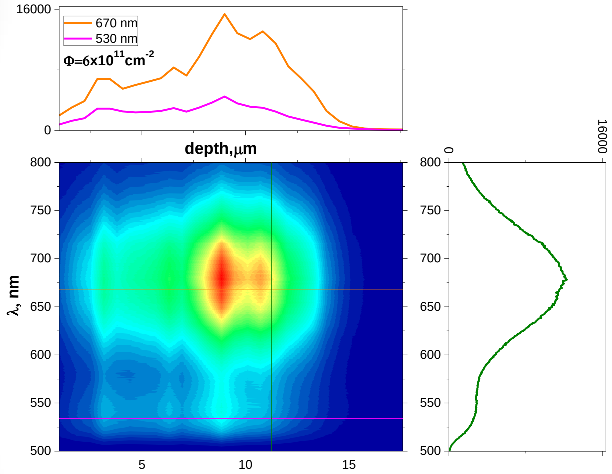


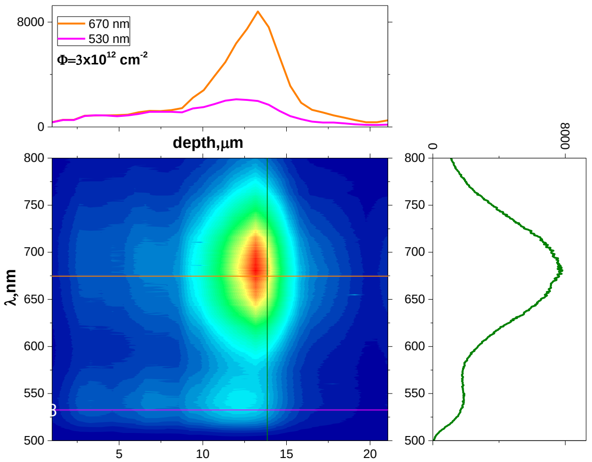


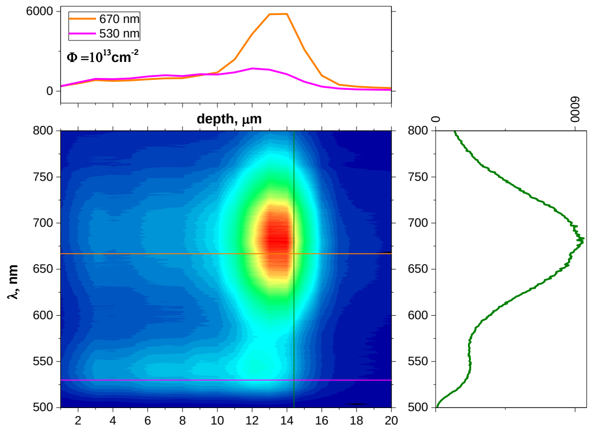


Ion	Ion energy, MeV	dE/dX Elect., keV/nm	dE/dX Nucl., keV/µm	Projected range, µm
Kr	107	12.03	0.029	14.22

Results And Discussion – Xe, 167 MeV

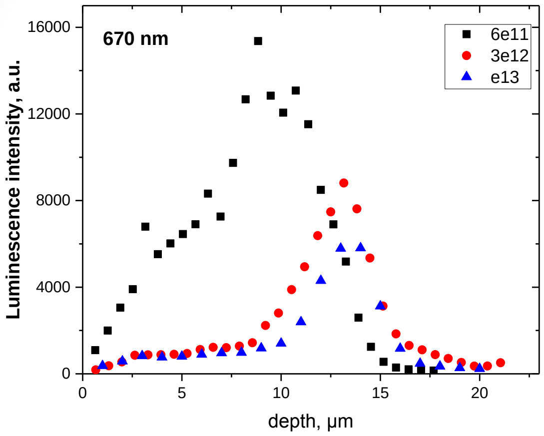


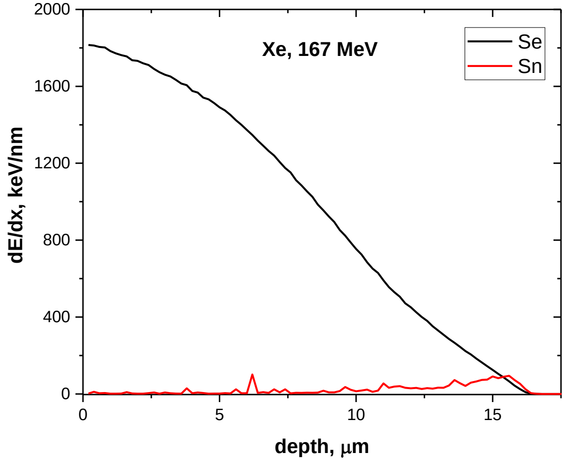


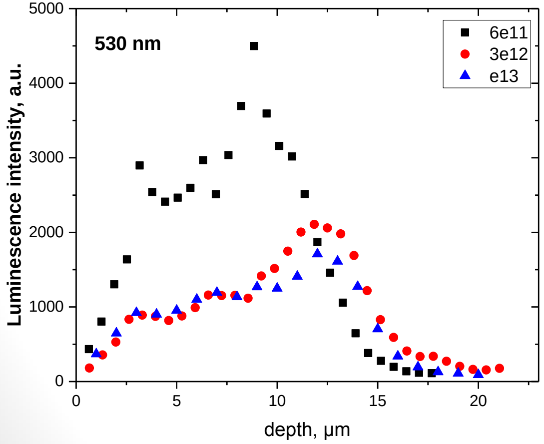


$\Phi = 10^{11}$ ions/cm^2 $\Phi = 10^{12}$ ions/cm^2 $\Phi = 10^{13}$ ions/cm^2

Results And Discussion – Xe, 167 MeV

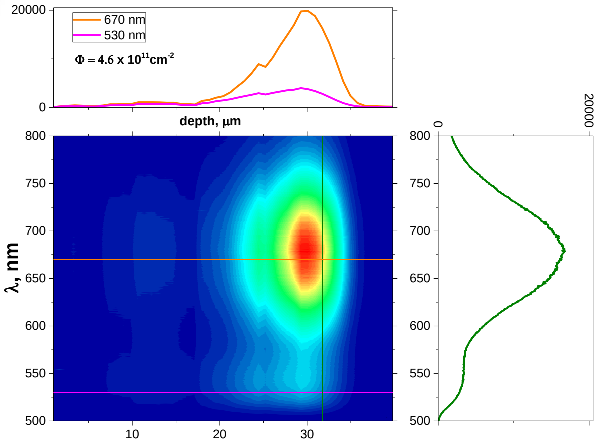




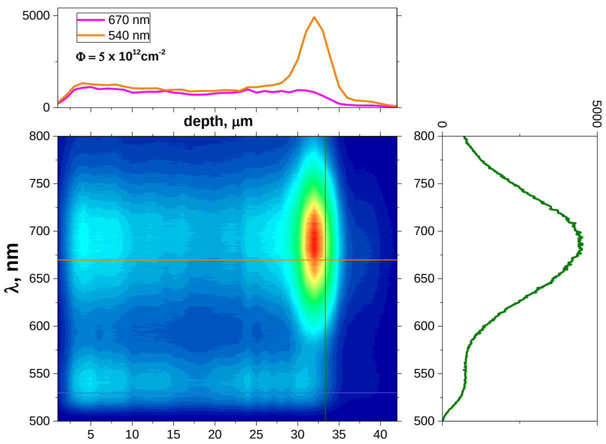


Ion	Ion energy, MeV	dE/dX Elect., keV/nm	dE/dX Nucl., keV/μm	Projected range, μm
Xe	167	18.24	0.061	15.79

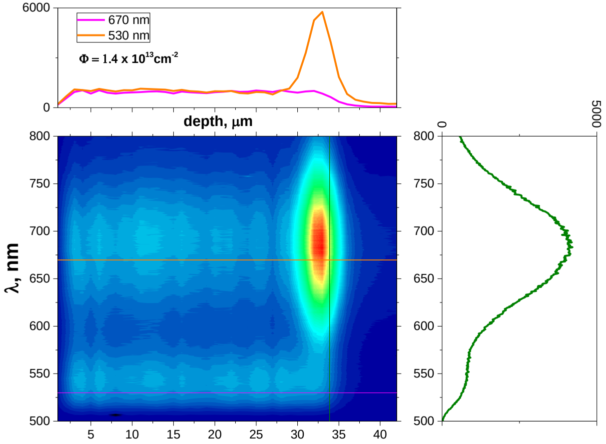
Results And Discussion – Bi, 710 MeV



$\Phi = 10^{11}$ ions/cm^2

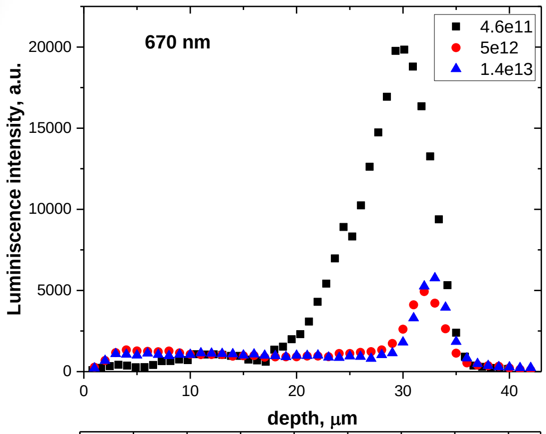


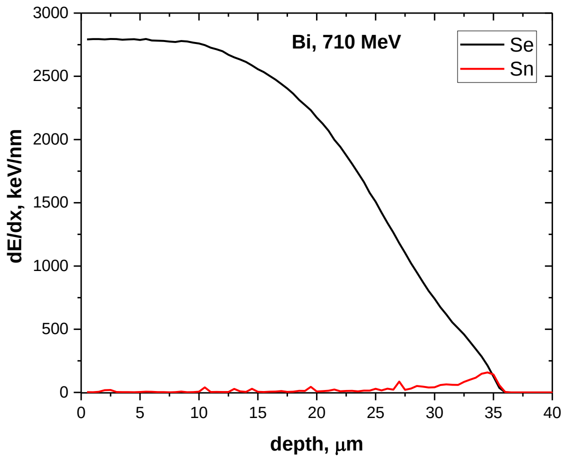
$\Phi = 10^{12}$ ions/cm^2

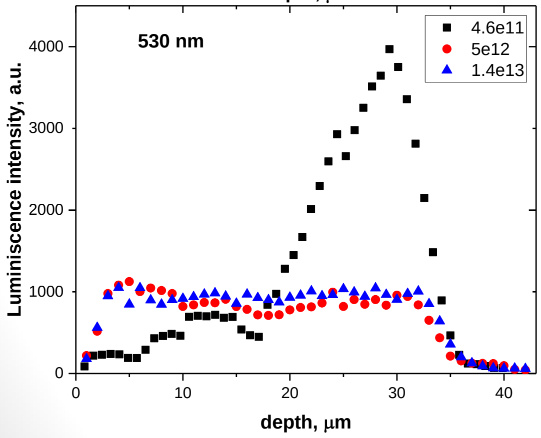


$\Phi = 10^{13}$ ions/cm^2

Results And Discussion – Bi, 710 MeV







Ion	Ion energy, MeV	dE/dX Elect., keV/nm	dE/dX Nucl., keV/µm	Projected range, µm
Bi	710	27.77	0.058	35.03

Conclusions

- We were introduced to microluminescent technique.
- Depth distribution of the luminescence intensity of F-type aggregate centers in LiF single crystals irradiated with swift heavy ions in track non-overlapping regime correlates with ionizing energy loss profiles.
- It can be seen that for samples irradiated with same ions but with higher fluences most of the defects are distributed in narrow part at the end-of-range in region and that depth distribution correlates with nuclear energy loss profiles.

References

- [1] W. Wesch, E. Wendler, Ion Beam Modification of Solids: Ion-Solid Interaction and Radiation Damage, Springer International Publishing 2016.
- [2] H. Benhacine, S. Kadid, Damage creation in lithium fluoride by Swift heavy ions in the electronic energy near the maximum of the Bragg peak, Materials Science: An Indian Journal **12** (2015) 438-443.
- [3] M. Kumar, F. Singh, S. Khan, A. Tripathi, D. Avasthi, A. Pandey, SHI irradiation as a tool for controlled creation of optically active F_2/F_3 color centers in LiF thin film.
- [4] V. Skuratov, N. Kirilkin, Y.S. Kovalev, T. Strukova, K. Havanscak, Depth-resolved photo-and ionoluminescence of LiF and Al 2 O 3, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms **286** (2012) 61-66.
- [5] http://www.frascati.enea.it/fis/lac/solidstate/solidstateing.htm.