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MODERN HEAVY ION BASED TEST FACILITIES FOR SPACECRAFTS ELECTRONICS QUALIFICATION

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Abstract

For ionizing radiation hardness assurance of space system electronics heavy-ion SEE tests shall be performed. This type of radiation is the most critical for modern digital VLSICs and power devices, and the susceptibility to heavy ions limits the space systems active lifetime in general. To perform the tests, the test facilities created by ISDE and JINR collaboration on the base of U-400 and U-400M accelerators are used. The facilities are equipped with the advanced hardware and measuring instrumentation. Currently our test facilities provide tests of all electronic component functional classes on hardness to all types of SEE.

GENERAL DESCRIPTION OF TEST FACILITIES

The test facilities has a number of advantages and allow us to irradiate items with a wide range of ions (from C to Bi) with initial energy from 3 to 60 (for light ions) MeV/A, and provide LETs from 1 to 100 MeV×cm²/mg and ranges in Si from 30 to 2000 µm, flux densities from 10 to 10E+5 particle/(cm² × s) and irradiation area up to 200×200mm with nonuniformity less than 10 % [1]. Thanks to the beam monitoring system allowing for multi-stage beam control and monitoring, we obtain information on the heavy ion fluence with excellent accuracy.

A schematic block diagram of the SEE Test Facility is presented in Fig. 1.

Figures 2, 3 and 4 show the appearance of test benches. Figure 2 is a photograph of the IS OE PP low-energy test facility; Figure 3 shows the IS OE VE-M for high-energy tests; and the low-energy IS OU 400-N test facility is illustrated in Fig. 4.

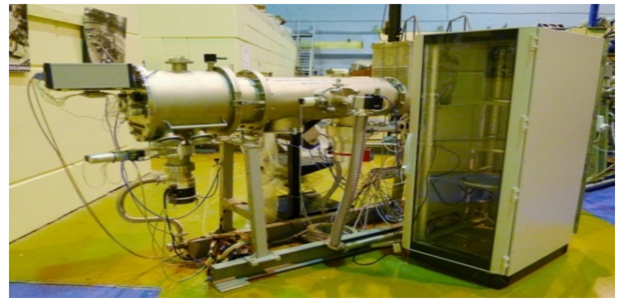

Figure 2: IS OE PP Test Facility.

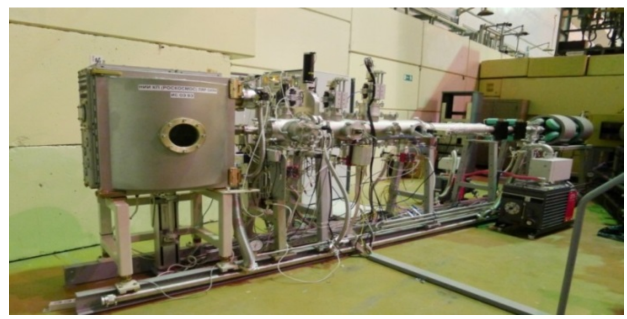

Figure 3: IS OE VE-M Test Facility.

Figure 4: IS OU 400-N Test Facility.

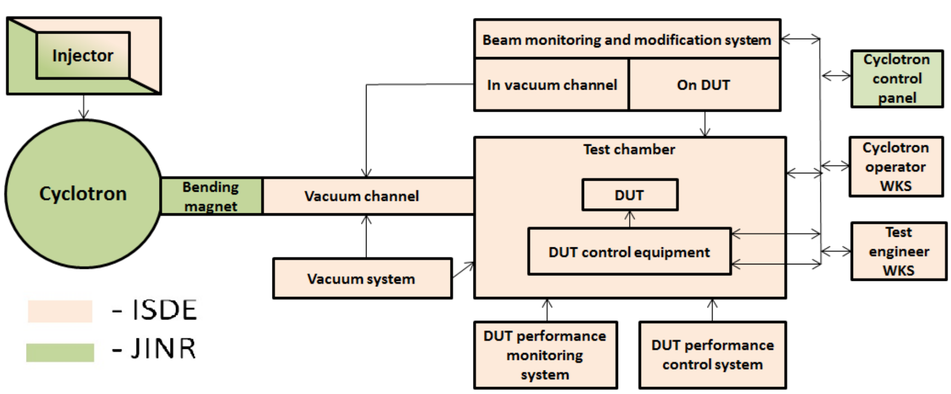

Figure 1: Block diagram of the SEE Test Facility.

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Table 1: Main Characteristics of the SEE Test Facilities

Technical features	IS OE PP (LE)	IS OE VE-M (HE)	IS OU 400-N (LE)
Ion source	Cyclotron U-400M FLNR JINR	Cyclotron U-400M FLNR JINR	Cyclotron U-400 FLNR JINR
Energy, MeV/nucleon	3 ... 6	15 ... 40 (60 for light ions)	3 ... 9
Flux density, particle/(cm^2 × s)	10 ... 10^5	10 ... 10^5 (10^4 for Bi)	10 ... 10^5
Nonuniformity, %	± 15	± 10	± 10
Suite of ions	C, O, Ne, Ar, Fe, Kr, Xe, Bi	Ne, Ar, Kr, Xe (C, O, Fe, Bi)	C, O, Ne, Ar, Fe, Kr, Xe, Bi
LET (Si), MeV × cm^2/mg	1 ... 100	1 ... 98(with using degraders)	1 ... 100
Range in Si, µm	>30	130 ... 2000	> 30
Irradiation area, mm	200 x 200	Ø 60 (Ø 40 for Bi)	150 x 200
Operational pressure, Pa	2,2 x 10^{-3}	Forevacuum/atmosphere	2,2 x 10^{-3}
Temperature range, °C	-40 ... +125	-40 ... +125	-40 ... +125

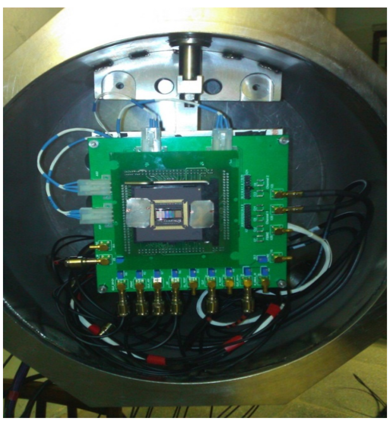

Figure 5: Example of test PCB with mounted device under test (DUT) and placed into the vacuum chamber.

The main technical features of the test facilities are shown in Table 1.

Special test boards were designed and are being used to perform radiation tests of electronics, which allow several samples to be irradiated simultaneously, or promptly replaced between irradiation sessions. Figure 5 shows an example of such PCB test board.

BEAM PARAMETERS MONITORING & CONTROL

The test facility comprises a large number of diagnostic tools for ion characteristics high-precision determination, monitoring and modification [2]. Figure 6 shows the layout of the beam transfer channel with its systems.

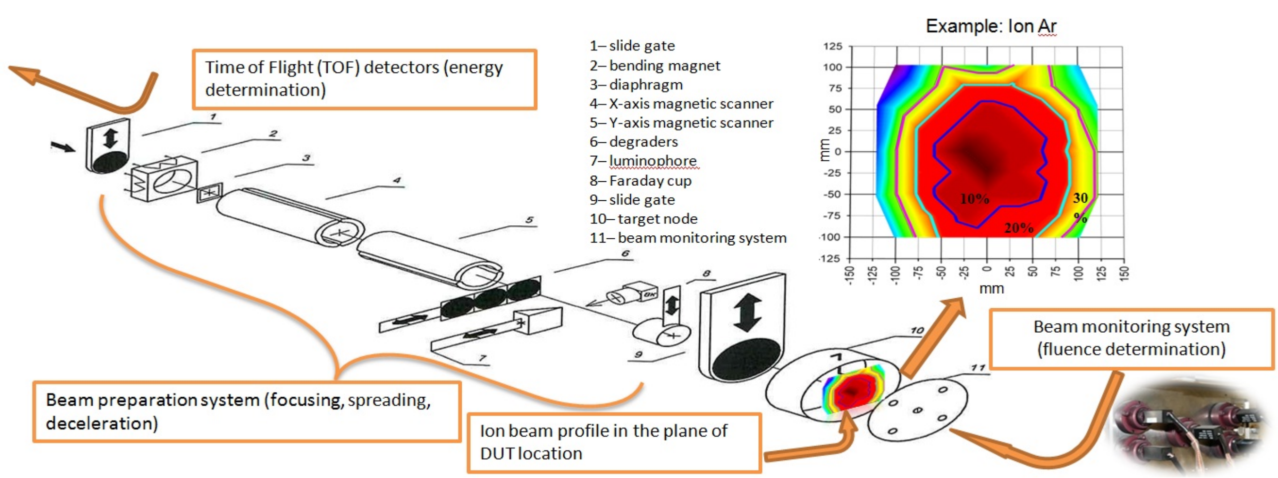

Figure 6: Beam transfer channel layout.

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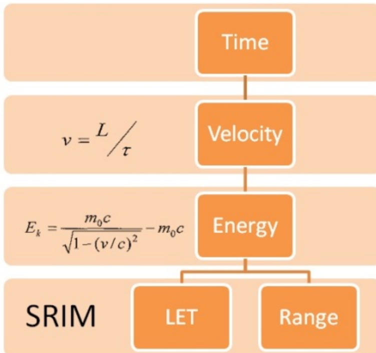

Figure 7: LET & range determination algorithm.

For LET and range determination, the following algorithm shown in Fig. 7 is used. In order to calculate energy, the time-of-flight detectors were used.

Fluence was estimated following the below procedure. The fluence evaluation method is quasi-on-line (on-line are scintillators, off-line are track detectors) and yet it shows excellent accuracy. On-line detectors are used to determine the moment for stopping the irradiation after the fluence reaches >10^7 (3x10^5 for Power MOSFETs). To obtain a precise value, the track detectors placed close to the DUTs are used. If the DUTs are placed in the best location, there is no need to use track detectors, and determine the fluence by on-line detectors. The measurement method is based on the calculation of etched holes formed due to the differences in etching rates of the damaged and undamaged areas of the plastic track detector after its irradiation with heavy ions, and then dividing this amount by the area of field on which holes were calculated (see Fig. 8).

The facility-specific scanning systems provide an increased irradiation area from 4÷10 cm to 11.5÷20 cm, depending on the facility, with minimum nonuniformity. The beam modification (scanning) system layout and its main features are shown in Fig. 9.

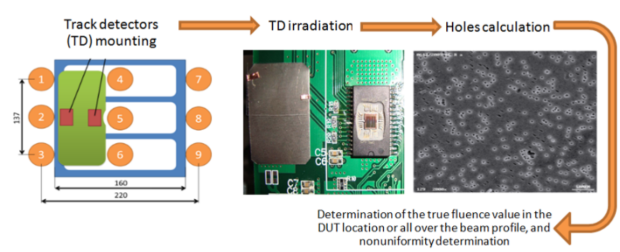

Figure 8: Heavy ion fluence determination procedure.

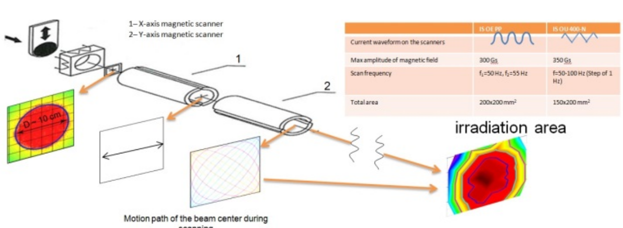

Figure 9: Beam modification system & features.

CONCLUSION

The Branch of URSC – ISDE operates the modern high-quality SEE Test Facilities, which allow to make the best use of up to 4000 hours of the test time per year and provide tests of electronic components of all functional classes to all types of radiation effects, taking into account the specific technical features. The main directions for development of radiation test facilities and joint research were specified:

- Common application of heavy-ion test facilities for electronic components radiation testing and investigations.
- Creation of on-line beam monitoring system (energy, nonuniformity, flux, fluence, etc.)
- Creation of test facilities with milli- and micro-beams for fundamental investigations.
- Creation of technological bench for ensuring de-encapsulation of electronic components.
- Creation of semiconductor detectors for on-board radiation monitoring system.

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