RADIATION EFFECTS TESTING FACILITY IN PSI LOW ENERGY OPTIS AREA

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Irradiation facility for parasitic testing of electronic components was developed and is installed in PSI OPTIS area. Radiation effects experiments and testing are performed using protons beams with energies up to 65 MeV. The facility, constructed as a low energy extension to the PSI Proton Irradiation Facility PIF, is designed in a similar, user friendly manner.

Many modern electronic components exhibit increased sensitivity to low energy proton radiation. In several types of DRAMs, a threshold for Single Event Upsets (SEUs) was found to be below 10 MeV [1]. The market of commercial-off-the-shelf devices (COTS) offers large assortment of components that can perform similar tasks. Nonetheless, radiation characteristics of them are frequently dramatically different. To qualify such devices for space applications a testing in a full range of interesting energies is needed.

1. PSI ACCELERATOR FACILITIES

Three cyclotrons deliver the PSI beams: two low energy injectors and the main ring, separated sector, accelerator [2]. Usually the ring is coupled with the high intensity, fixed energy (72 MeV) injector cyclotron. They provide proton beams with energies of 590 MeV and intensities above 1.5 mA. The main beam passes through two meson production targets. Secondary pion and muon beams from the targets can be simultaneously used in seven experimental stations. The rest of the proton beam is refocused to feed a high flux spallation neutron source SINQ.

Before the beam reaches meson targets, a small fraction of it is split to a nucleon area for parasitic use. The area contains following installations: Proton Irradiation Facility (PIF) [3], Proton Irradiation Experiment (PIREX), proton therapy facility, and neutron beam line.

The Philips cyclotron (also used as an injector) serves to produce low energy beams of protons, deuterons and different types of heavy ions. It is a variable energy accelerator - up to 72 MeV for protons and up to 120 MeV•Z^2/A for ions. A medical irradiation facility Opthalmological Proton Therapy Installation SIN - OPTIS [4], some experimental installations in two other areas (one with a neutron production target), and isotope production station are supplied with particles from this cyclotron.

The irradiation experiments and components tests with protons of energies between 35 and 590 MeV are conducted in the Proton Irradiation Facility. For certain experiments, the intensities of the mono-energetic beams below 50 MeV are sometimes insufficient. Parasitic low energy facility developed recently in the OPTIS area allows for high proton fluxes and makes possible to conduct radiation tests with energies down to about 6 MeV. The general design is similar as for the PIF with respect to the sample holder, positioning tools as well as the run control and data acquisition systems.

2. LOW ENERGY OPTIS BEAM LINE

The OPTIS installation for treatment of the ocular tumours with a proton beam is in permanent use since 1984. It has simple and immutable beam optics designed in accordance with safety operation conditions. In last stages of the beam-line, the protons pass trough a series of scattering foils and collimators. It ensures an easy beam set-up and control as well as guarantees a low current intensity required during patients exposures. The beam profile has a homogenous distribution over the eye surface. Additionally, a neutron and gamma shielding are mounted along the beam pipe in front of the patient chair to reduce the secondary radiation to minimum.

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3. TEST AREA

A schematic layout of the component radiation test facility in the OPTIS area is shown in Fig. 1. Experimental instruments and devices are mounted on the portable stage (100 cm long, 80 cm wide) that can be easily moved and aligned on the beam line. The arrangement consists of energy degrader, XY-table with a sample holder and a beam dump behind which a laser positioning tool is mounted. Two ionisation chambers (or CsI(Tl) crystals) used for flux/dose monitoring are located behind the beam exit window. Irradiation tests are performed in air.

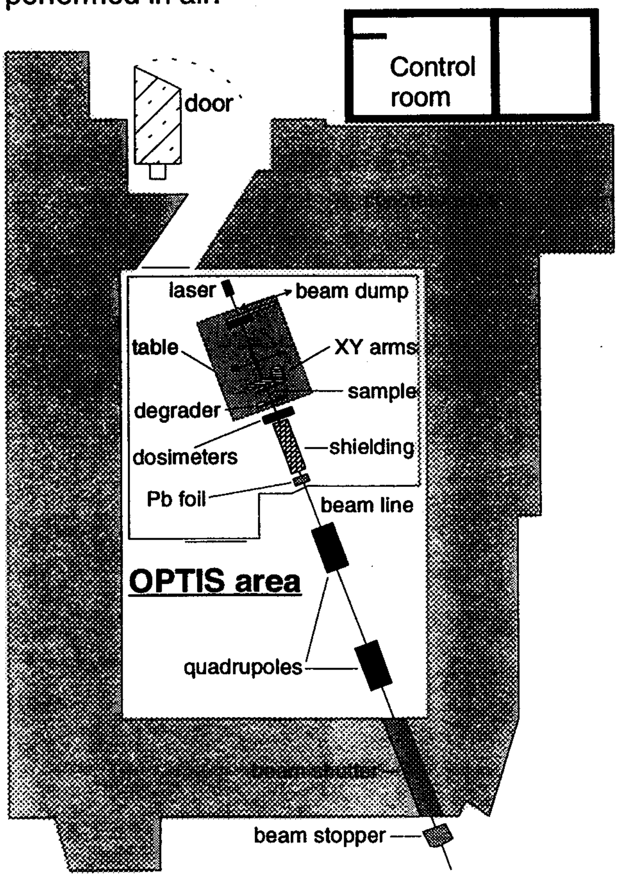

Fig. 1. Layout of the test facility and OPTIS area.

3.1 Energy degrader

Copper cylinders of different thickness are used to lower the initial proton energy. Eight of them are mounted perpendicularly to the beam direction on an Aluminium ring that is directly fixed on the axis of a step-motor - see Photo. 2. A PC with a RS232 interface remotely controls positioning of the ring. The energy can be selected between 6 and 64 MeV by placing a proper cylinder on the beam axis.

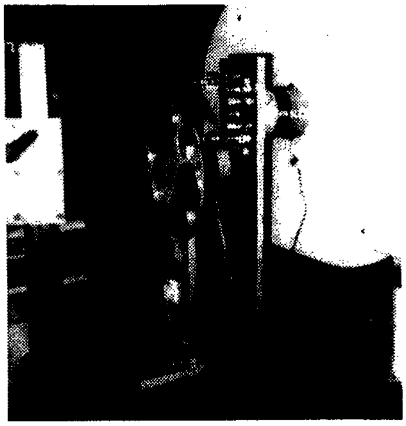

Photo. 2. Energy degrader mounted to the beam line exit.

3.2 XY-table and sample frame

Irradiated devices are mounted on the standard holder frame that is also used in PIF/PSI, SEU/Brookhaven and HIF/Louvain la Neuve [3,5,6]. The frame is fixed on movable arms of the XY table that is mounted perpendicularly to the beam line. The frame position can be changed in a vertical and horizontal direction using step-motors.

Photo. 3. Experimental table with XY-movable arms and sample frame.

The distance between the holder and the beam exit can also be varied (manually). It provides easy access to the front side of the test frame either during set-up or system verification. The XY table with arms and the sample frame is shown in Photo. 3.

3.3 Flux measurement and calibration

Typical monitoring system consists of two ionisation chambers working in a transmission mode. They are mounted perpendicularly to the beam line directly in front of the degrader. Each proton passes through the chamber depositing small amount of energy by ionisation. The total ionisation current is proportional to the proton flux.

Another, frequently used dosimeter system consists of two small CsI(Tl) scintillators mounted at the end of the beam pipe. They are located in a horizontal plane about 1.5 cm left and right from the beam axis. Both detectors are coupled to the photodiodes that provide current signals proportional to the particle flux/dose rate.

Conversion factors between the flux and signals from dosimeters are determined for all energies during calibration procedure. The plastic counter of known area located exactly in a place of the test sample is used to measure the flux.

3.4 Run control and data acquisition

Irradiation procedure, supervised by the computer, is fully automatic. Both, position of the sample on beam and selection of the proton energy with the degrader are set from the measurement room. For each run the most important parameters (sample id, position, energy, flux and accumulated dose) are updated periodically on the computer screen and stored into a file. Alarm signals are provided in case of any malfunctioning of the devices. A user panel displayed on a computer screen for monitoring and control of the run is shown in Fig. 4.

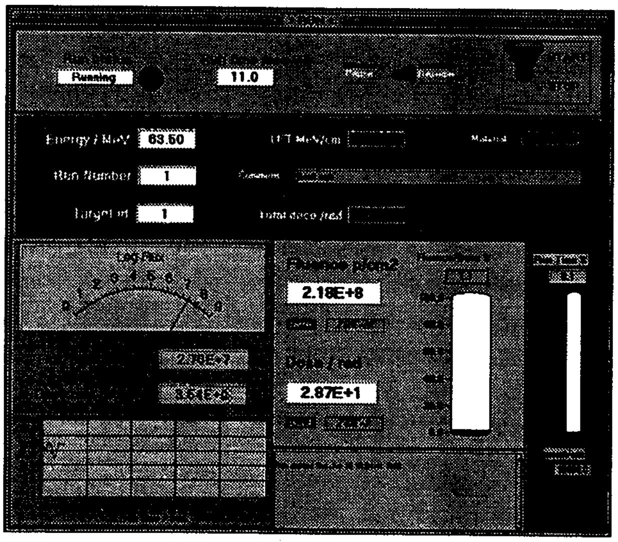

Fig. 4. User interface with the run control panel.

3.5 Laser positioning tool

Test samples are centred on the beam with a help of the laser system. The laser is mounted separately, about 50 cm downstream from the irradiation platform. The laser beam, aligned to the proton axis, illuminates rear side of the sample.

3.6 Beam dump

Protons passing behind the test sample are deposited in the beam dump that is located at the end of the platform. It consists of a copper plate with rolls and is mounted on rails. During runs the plate is placed on the beam to decrease air activation and to shield the experimental apparatus in the area against direct proton exposure.

4. ENERGY SPECTRA AND BEAM PROFILES

Energy spectra and beam profiles for various energies and distances from the degrader were calculated with a GEANT code from CERN. Examples of the spectra for 44 MeV and 12 MeV proton energies are shown in Fig. 5. Calculations agreed with measurements done using plastic scintillator NE102.

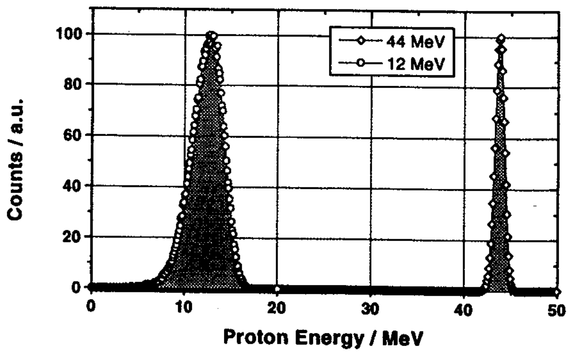

Fig. 5. Proton energy spectra behind 2.8 (44 MeV), and 5.7 mm (12 MeV) Cu degrader.

At the initial energy, the beam profile is flat over the collimator opening of 34 mm. For lower energies the beam homogeneity is preserved up to 3-4 cm behind the degrader - see examples in Fig. 6.

5. SUMMARY

Low energy proton irradiation facility was developed and is located in the OPTIS area. It operates in a parasitic mode, during nights and

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weekends, after biomedical exposures. Main characteristics are shortly presented below.

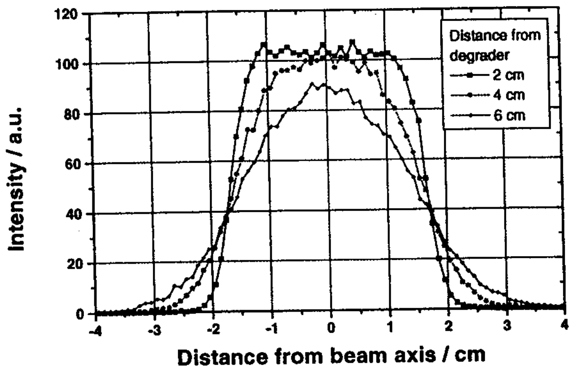

Fig. 6. Beam profiles for various distances from the 0.56 cm thick Cu degrader (E=16.5 MeV).

Features of the low energy PIF-OPTIS facility

- Energy range: 6 to 65 MeV
- Proton flux: < $5 \cdot 10^8$ p/cm^2/sec
- Beam spot: circle, 34 mm diameter
- Beam uniformity: > 9 0% 2 cm from degrader
- Flux/Dosimetry: ≅ 5 % absolute accuracy
- Irradiation take places in air
- Sample frame Brookhaven and HIF compatible is fixed on the XY table
- Irradiation procedure: device positioning, energy selection, stop criteria are supervised by the computer.

With this facility the energy range offered by PSI for irradiation tests extends from 6 MeV to 590 MeV. In 1997, 8 research groups from industry and space agencies used the installation. The experiments served to characterise electronic components (e.g. SEUs sensitivity), test different devices (e.g. opto-couplers) in a proton environment and calibrate newly developed dosimeters. Easy access to the facility makes possible to qualify/test new devices and products for space applications in a very short time.

6. REFERENCES

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