

EXPERIMENTAL FACILITIES DEVELOPMENT

RADIATION-EFFECTS RESEARCH FACILITIES

C. Foster and T. Rinckel

Indiana University Cyclotron Facility, Bloomington, Indiana 47408

K. Murray

KM Sciences, Beech Grove, Indiana 46107

There are a variety of electronic devices and radiation detectors that are flown in the harsh radiation environment of space. High energy protons which penetrate spacecraft shielding are the major cause of single event and other radiation effects in microelectronic devices and a major component of signals in detectors. Accelerator-based irradiations of electronic components and detector studies are used to provide information essential to understanding the performance of these devices in the space radiation environment. Facilities and software needed to support radiation-effects studies, detector calibrations and detector background measurements have been developed and used at IUCF. This report describes the facilities and beams available, outlines the radiation-effects research program (which encourages use of the facilities by the radiation-effects research community and participation in appropriate improvement of the facilities) and lists recent users of the facilities.

Figure 1 shows the radiation-effects research station (RERS) which is used in beam line 4 when sharing beam with users of the K600 spectrometer, the beam swinger/neutron time-of-flight facility, the polarized-neutron facility or the beam line 5 general purpose station, or in the beam line 5 general purpose station when sharing beam with users of the Cooler. The research station is used in beam line 4 if not using beam shared with another user. The RERS uses a carbon target (not shown) to spread the beam by multiple scattering. The target thickness is chosen so that about 60% of the beam passes through a 6-cm-diameter by 5-cm-thick copper collimator (shown) located about 2.5 m downstream of the target. This results in a circular beam intensity profile which falls off by about 30% from the center to the edge. The beam profile is determined by exposure of GafChromic film, which is read by a photometer.

Immediately downstream of the collimator is located a secondary-electron monitor (SEM) followed by a removable copper block, with magnetic electron-emission suppression, which is used as a Faraday stop to measure the beam current through the SEM. Calibration of the SEM is accomplished by measuring the ratio of the Faraday stop current to the SEM current. This ratio is then used in dosimetry calculations. About 10 cm downstream of the Faraday stop is a 5-mil thick Kapton window 9 cm in diameter, through which the beam passes into an air gap of 50 cm before passing through a similar Kapton window into an evacuated beam-dump Faraday Cup. The device under test (DUT) is placed in the air gap

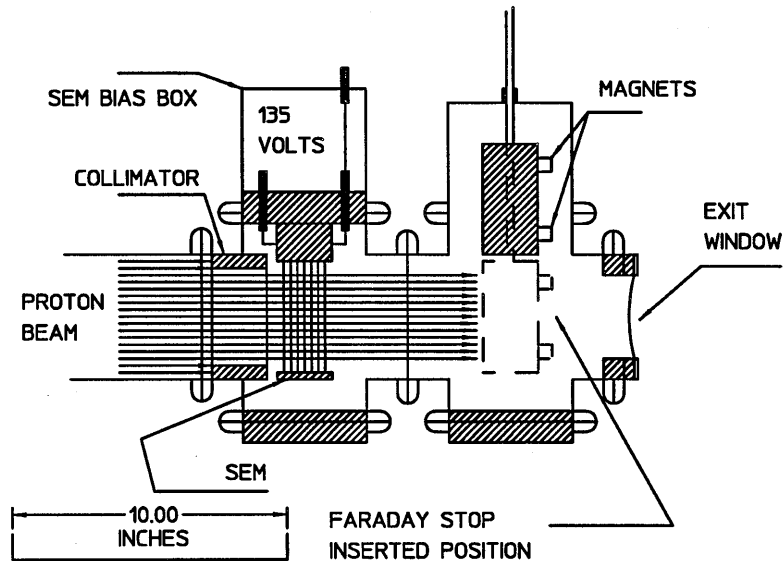


Figure 1. Schematic drawing of the downstream end of the radiation-effects research station.

just behind the upstream Kapton window. It is mounted on a device that allows vertical, horizontal and rotary positioning of the DUT. There is a remotely-operable beam stop located well upstream of the carbon scatterer that is used to control the time of device exposure.

The upstream stop and the Faraday stop are controlled by a personal computer, which also records the measured currents from the SEM and Faraday stop, computes the SEM calibration and monitors the dose that is corrected for the actual measured beam profile. User-friendly software provided by Ken Murray of KM Sciences allows exposure of the DUT for a preset dose. Data from each exposure are stored on disk and a printed run log is maintained as well.

A prototype SEM has been developed and tested that has a Faraday-stop-current-to-SEM-current ratio of 2.0 at 200 MeV, leakage currents less than 0.5 pA, and noise less than ± 0.02 pA. This would allow measurements with fluxes of 200-MeV protons as low as 1×10^6 protons/s/cm² with a 10% uncertainty in dose. Scaling this SEM to one with 80 foils is possible in the available space. This would allow measurements in the 10^4 protons/s/cm² range with somewhat increased uncertainty in the dose. Such low fluxes are necessary for exposures of certain radiation-sensitive devices. Usual exposures require fluxes in the 10^6 to 10^9 protons/s/cm² range. Proton fluxes as high as 10^{11} protons/s/cm² are available.

The energy of the protons incident on a DUT is controlled either by changing the energy of the beam through retuning the cyclotron and beam lines at the cost of several hours, or by degrading the beam energy by placing copper degrader plates in air just in front of the DUT at a cost of increased beam energy spread. The latter technique is usually acceptable and has been used to degrade the beam energy from from 200 to 30 MeV. See Table 1 for a summary of the proton capabilities of the RERS.

Table 1. Proton Capabilities of RERS

Energy Range: 30 to 200 MeV
Flux: 10^4 to $> 10^{11}$ protons/s/cm ²
Area: Less than 2 cm to 7 cm diameter
Uniformity: < 30% variation over area
Absolute dosimetry: Better than 10% routinely
Exposure durations: A few seconds upward routinely

This radiation-effects research station is fully operational and has been used by groups from the Johns Hopkins Applied Physics Laboratory, Sandia National Laboratories, the Naval Research Laboratory, the Crane Naval Surface Warfare Center, Clemson University, and NASA.

In order to provide funds for automation and other improvements of the research station, the Indiana Radiation Effects Research Alliance has been created. Users are given the opportunity to join the Alliance by making an "up front" investment of a minimum of \$20,000. This provides them access to beam at IUCF for two years at a much reduced cost, participation in planning improvements to the research station, priority consideration during beam scheduling, dosimetry and technical consultation. A group from NASA has joined the Alliance and several other groups are considering doing so.

When fluxes less than 10^5 protons/s/cm² are required for detector studies or device tests, it is difficult to use the RERS described above because the SEM and Faraday stop currents become comparable to leakage currents and rapidly changing noise currents create significant uncertainties. The "tagged proton" technique described below has been effectively used for such purposes.

As shown schematically in Figure 2, protons scattered from protons in a polyethylene (CH₂) target (about 1 mg/cm² thick), pass through a 5-mil-thick Kapton foil and 10 cm of air into a collimated $\Delta E - E$ telescope, which is used to identify them as protons. Recoiling protons, which scatter at an angle of about 90° from the telescope, are tagged by the protons detected in the telescope. This flux of tagged recoil protons, which passes through a 5-mil Kapton window and are incident on the DUT located 90° from the telescope, is determined by the collimator aperture, the target thickness, the beam intensity, reaction kinematics, and the proton-proton elastic-scattering cross section. Kinematics of the scattering determines energies of the recoiling protons from knowledge of the energy of the beam protons and the scattering angles. Correction can be made for the small loss of energy in the exit window and air. Therefore, events occurring in the DUT in coincidence with the tagging protons are the result of a known flux of protons of known energies. Other particles produced as reaction products in the carbon target, window and air, which may cause events in the DUT, will not satisfy the coincidence requirements. Fluxes in the range from 1 to 10^4 protons/s/cm² are readily obtained with this technique.

The energies of the tagged protons may be readily varied in the range from about 25 to about 180 MeV by varying the angles of the telescope and the DUT while maintaining the 90° angle between them. This technique has been used to measure detection efficiencies of scintillator, wire chamber, phoswich and other detectors. The hardware for this technique

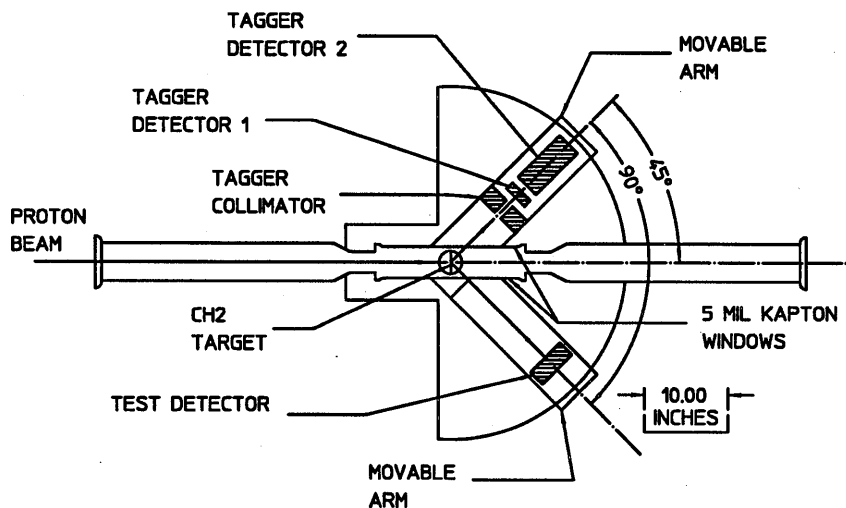


Figure 2. Schematic plan-view drawing of the tagged-proton facility.

can be set up at the same time as the RERS and in the same beam line to allow rapid change between use of the two techniques.

IUCF has implemented two techniques, direct exposure to the beam and exposure to a tagged proton beam, for the study of radiation effects in electronic devices and detectors. These techniques have been used several times and have served several user groups. They are user friendly and cover a wide range of energies and fluxes with accurate dosimetry. A program to encourage commercial and other users to use and help improve these facilities is being offered to and is being accepted by the radiation effects community.

STATUS OF TWO SUPERCONDUCTING SOLENOIDS

Kevin Komisarck

Indiana University Cyclotron Facility, Bloomington, Indiana 47408

The new spin-precession solenoid manufactured by Cryomagnetics, Inc. arrived in December, 1994. Its purpose is to replace the magnet in beam line 3 which developed a large leak in its helium cryostat. The new magnet has an integrated field of 2 T·m at 90 A, slightly larger than the BL3 solenoid (1.6 T·m). The helium boiloff rate is approximately 1.1 l/hr, similar to the boiloff rate of the BL3 solenoid. This translates into a 20 hr refill period for both beamline magnets. The new magnet has a 10 cm diameter bore. This will allow it to be used not only in the high energy beamlines but also the Cooler if necessary. So far, the new magnet has been used successfully by E368, E378 and in several INPOL runs.