Radiation Effects Facility

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The activity of the Radiation Effects Facility (REF) increased substantially over the previous reporting year. In this reporting period, the facility was used for 1500 hours, which is a 174% increase over the 548 hours used in the 1999-2000 reporting period. Users of the facility (and hours used) over the past year were: Boeing Satellite Systems Inc. (formally Hughes Space and Communications) (828), NASA JPL (375), NASA GSFC (96), Intersil (63), Prairie View A&M University (41), Naval Research Laboratory (32), Motorola (19), NAVSEA (16), Harris Electronics (16) and St. Jude Medical/Sandia National Laboratory (15). From the list above, NASA GSFC, NAVSEA and Naval Research Laboratory were all new customers to the facility.

Table I compares the facility usage by commercial and government customers. The ratio from this reporting year (63% to 37%) is slightly different from the ratio observed last year (76% to 24%) and is due to the proportional increase in the number of government hours. The increase in commercial usage is attributed to the strong US economy and growing satellite-communications market while the increase in government usage can be attributed to many space station projects coming on line. It is expected that the demand for the REF will continue to be as high for several years.

Table I: Radiation Effects Facility usage by commercial and government customers for this and previous reporting years.

Reporting Year	Total Hours	Commercial Hours (%)	Government Hours (%)
2000-2001	1500	941 (63%)	559 (37%)
1999-2000	548	418 (76%)	131 (24%)
1998-1999	389	171 (44%)	218 (56%)
1997-1998	434	210 (48%)	224 (52%)
1996-1997	560	276 (49%)	284 (51%)
1995-1996	141	58 (41%)	83 (59%)

Table II lists the beams used this year and the number of times each was requested. In total, 192 beams were run this year. Several new beams were developed: 15A MeV ^{165}Ho, ^{181}Ta and ^{197}Au; 25A MeV H-D; 40A MeV H-D, ^{20}Ne, ^{40}Ar and ^{78}Kr; 55A MeV ^{16}O and ^{36}Ar. From last year's REF list [1] 30A MeV H-D, 12A MeV ^{12}C, 16A MeV ^{63}Cu, 12A MeV ^{84}Kr, 10A MeV ^{93}Nb and 10A MeV ^{203}Bi were not requested at all and have been dropped from the list. All H-D beams were run to produce proton beams. 40A

Table II: Beams used and the number of times requested. The asterisks indicate beams that were developed this year. 192 beams were run this year.

Particle Type	A MeV	New beam	Requests
^{197}Au	10.5		4
^{4}He	12.5		1
^{20}Ne	15		1
^{40}Ar	"		4
^{84}Kr	"		6
^{129}Xe	"		5
^{165}Ho	"	*	3
^{181}Ta	"	*	4
^{197}Au	"	*	12
H-D	25	*	1
^{22}Ne	"		27
^{40}Ar	"		31
^{84}Kr	"		32
^{129}Xe	"		25
H-D	40	*	1
^{20}Ne	"	*	5
^{40}Ar	"	*	12
^{78}Kr	"	*	13
H-H	55		2
^{16}O	"	*	1
^{36}Ar	"	*	2

MeV H-D was developed to replace 55A MeV H-H. The 40A and 55A MeV noble gas and 15A MeV Au beams were developed to increase the penetration depth of these ions; for example, the range of Ar ions in silicon at 15A, 25A, 40A and 55A MeV is 229, 500, 1079 and 1673 microns, respectively. The 15A MeV Ho and Ta beams were developed to provide a linear energy transfer (LET) between 63 and 82 MeV/mg/cm^2 with 100 microns of range in silicon. Ho and Ta have filled in the "LET gap" between Xe and Au. Beams that may be developed over the next year include 55A MeV Ni and Kr and 25A MeV Ho, Ta and Au. The development of these beams depends entirely on the success of the ECR-LS project.

Hardware and software improvements have been made to the facility. The features that have been implemented since last year's report include the following listed below.

Hardware:

An "in-air" positioning system was added to the REF beam line, as shown in Fig 1. This setup consist of a 10" x 10" mounting frame placed on a round rotating platform at the rear of the line. For accurate positioning, the frame and table are movable in x-, y-, and z-directions. The setup also allows for counter clock-wise and clock-wise rotations about the central axis. Movement in all directions is controlled through the user interface software SEUSS. Previously the in-air setup consisted of a manual pneumatic stand for vertical placement and provided no means for accurate rotation or placement in the x-, y-, and z- planes.

The in-air testing system provides many advantages over the existing vacuum test chamber. Cabling is more feasible with no need for vacuum feed-through connections. The heat issues associated with vacuum testing of electrical components are less of a problem.

Figure 1: In-air positioning system at the end of the REF beam-line.

Test components may be quickly changed with no time lost with the need to vent and then evacuate the test chamber.

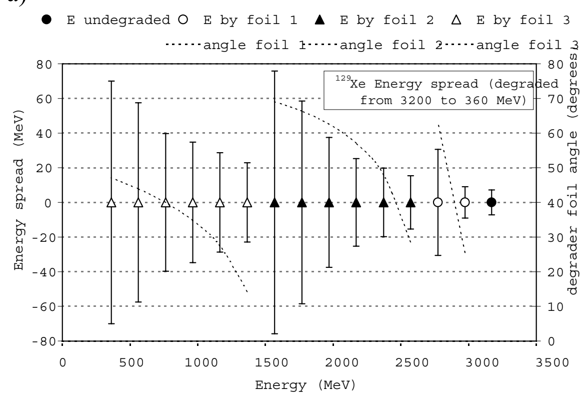
With the in-air setup placed at the rear of the radiation effects line, it is necessary to conduct dosimetry and uniformity measurements closer to the end target. Following a similar design of the set of detectors in front of the vacuum chamber, a new set has been placed at the front of the in-air setup. As with the old, four scintillators are placed at the corners of an approximately 2" x 2" square with a removable scintillator placed central to the beam axis. The central scintillator is placed on a pneumatic valve along with a camera to allow for target viewing. Both the scintillator and camera are removed remotely while testing is conducted.

A plan for a new beam degrader system has been developed. The present degrader system allows for three foils of various thicknesses to rotate up to 71°. Degrader rotation allows for complete thickness coverage of up to three times the thickness of the degrader. In addition there are two non-rotating degraders that may be used in combination with the rotating degraders to allow for necessary beam energies. The present system presents various problems. First, the degraders do not degrade the entire usable beam, only the central portion. When used in combination with the non-rotating degraders an even smaller area of degraded beam is provided. Secondly, the rotation of the degraders up to 71° degrees has proven to be problematic. At rotations above 60° a significant energy spread and corresponding LET spread of the beam is noted. This is illustrated in Figs 2a and 2b. To simplify operation and correct for these problems a new degrader system has been proposed. It will eliminate the need for combinations of degraders by providing a series of ten degraders such that only one degrader will be used at any time. This set of degraders will vary in thickness from 0.001” to 0.512”, doubling in thickness with each degrader. This will require only rotations of up to 60° for complete thickness coverage. Finally the degraders will be large enough in area to degrade the entire beam, not just the central portion

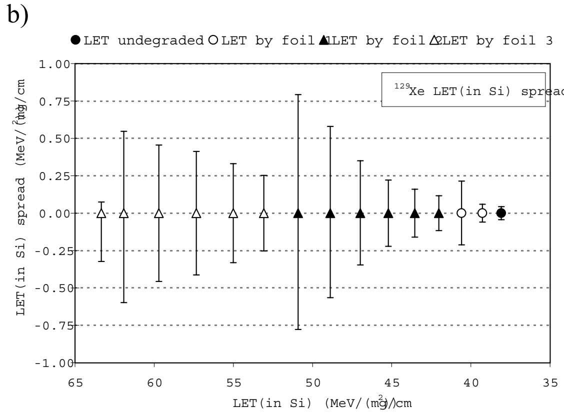
Users can now verify the beam uniformity and fluence by photographing the beam profile with radiographic film. The film is reduced to a software image by a high-resolution transparency scanner. A scanned image is shown in Fig 3a. The uniformity can be analyzed by taking projections of the image. A projection of the image across the solid line in Fig 3a is shown in Fig 3b. The fluence is analyzed by integrating over the entire image. The software used to analyze the scanned images is made by Scion Image Inc. and a

Figure 2 a) Energy spread versus beam energy for 25A MeV ^{129}Xe using foils indicated. The dashed lines and the vertical scale to the right indicate foil angle. **b)** LET spread versus LET for 25A MeV ^{129}Xe using foils indicated.

a)



b)



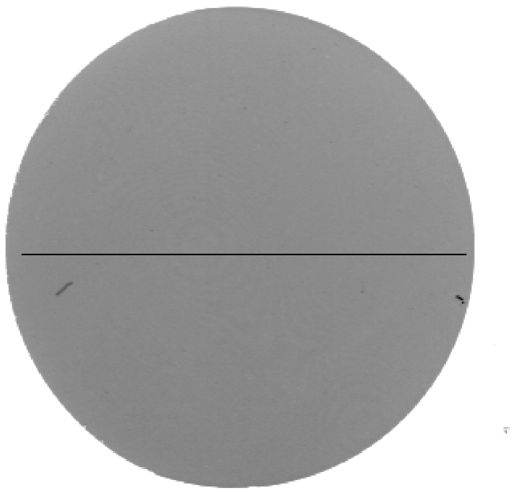
demo-version is obtainable from their website at www.scion.com.

Software:

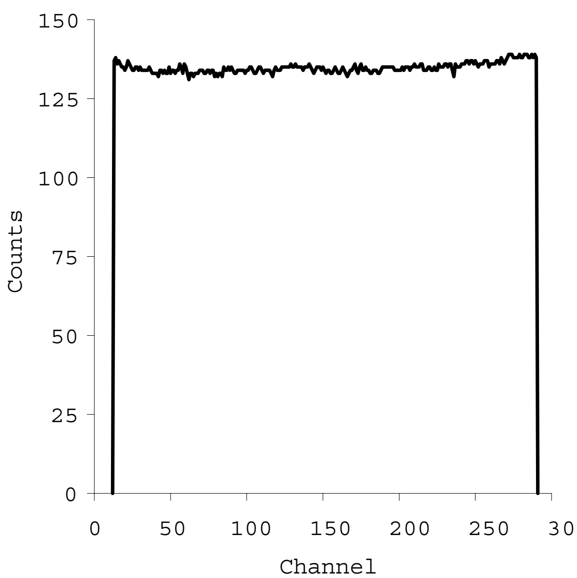
The SEUSS control software has been modified to facilitate the selection of proper energy and/or LET of the beam. This was done by extending the beam energy loss calculations to account for the layers of materials traversed by the beam before it hits the target. For the in-air runs these layers must include the air and the foil that seals the region under vacuum. Additional layers may be present on the device under test in the form of a packaging material or a silicon dead layer. To rely on computer calculations of beam energy/LET, the users have

Figure 3a) Scanned image of the beam profile. The diameter of the beam was 1 inch. (The dark spots are from scratches on the radiographic film and are not beam related.) **b)** Projection of the scanned image across the solid line shown in a).

a)



b)



to list the layers along with their thickness (in sequential order) and indicate which layers rotate when the target angle is changed. This has to be done every time the setup changes. The layer-support-software feature gives the users control over the beam parameters at any given depth inside their devices, which is useful even when they run under vacuum.

Other modifications of the SEUSS control software include the addition of a post-run report generator, providing for a DC level indicator that is set while the beam is on target, and the possibility of replacing the beam energy degrader settings in all preset target position coordinate sets with the current one in a single-step operation.

References

[1] H. L. Clark, V. Horvat, B. Hyman and D. Utley, *Progress in Research*, Cyclotron Institute, Texas A&M University (1999–2000), p. V-5.