MODIFYING A RESEARCH LINAC LABORATORY INTO AN APPLIED RADIATION FACILITY

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Abstract

What does one do with a powerful accelerator that has performed well for a quarter of a century and is still in excellent condition? At Rensselaer in the Department of Nuclear Engineering we have such an accelerator: a 9-section travelling wave L-band linac with maximum energy of 100-MeV and maximum (average) beam power of over 40 kw. In response to the decreasing funding of neutron physics research, for which the laboratory was established, we have modified the accelerator to provide intense ionizing radiation fields for such diverse applications as coloring topazes, measuring transient radiation effects in advanced semi-conductor devices, simulating radiation levels in commercial-size reactors, etc., while at the same time maintaining the capability to carry out neutron physics research. Radiation fields of over 1.0E+11 rad/sec and integrated doses in the Gigarads range are now routinely available.

I. Introduction

What should one do with an accelerator laboratory that began over a quarter of a century ago and for which the 'traditional' sources of funding have been shrinking away? This paper attempts to answer this question within the context of transforming the laboratory to pursue new areas of sponsored research pertinent to the educational objectives of a Nuclear Engineering Department.

The electron linear accelerator at Rensselaer Polytechnic Institute began operation 25 years ago and has served as a research tool for reactor physics,[1-5] neutron physics[6-11] and photonuclear physics[12-14] experiments. The accelerator consists of nine waveguide accelerating sections operating as a travelling wave 1300 MHz L-band linac with an unloaded energy of 100 MeV and which can deliver over 25 kw of average beam power at an energy of approximately 50 MeV. The linac was designed in the late 1950's for pulsed neutron research and as a result the objective was an intense pulsed beam with little emphasis on tight energy spread or beam emittance. However, the accelerator has been continuously upgraded since it began operation to take advantage of developments in electronic and vacuum technology and today it is still representative as a powerful machine in its class.

The problem faced several years ago was brought about by ever diminishing funding for reactor and neutron physics research. Either the research program had to be expanded into other 'fundable' areas or the laboratory would have to be closed down. Many similar laboratory facilities were visited and compared with the strengths/weaknesses of the RPI laboratory, and it was finally decided that our laboratory was still a viable research tool and that new research areas could be developed that would be compatible with the education objectives of the Nuclear Engineering Department. As a result, in addition to continuing basic research in neutron physics, the research program has been broadened into the area of applications of intense ionizing radiation for research and development of industrial-related problems. Today the research program has been expanded to include radiation effects in semiconductors, production of color centers in crystalline materials, electrical effects of radiation in insulating materials and the simulation of ionizing radiation inside of a commercial power reactor. Although funding was a problem and had to be of the bootstrap variety, the linac has recently been modified to extract an intermediate energy beam and to provide electron injection over the range of pulse widths required for this diverse set of research needs. Modifications are still being implemented to further improve the accelerator and associated laboratory equipment.

II. Three Section Configuration

The study of radiation effects in semiconductors and the production of color centers in crystalline materials require intense electron beams of the order of 15 MeV; electrons of this energy can simulate the type of radiation anticipated in semiconductors in space or defense environments and also represents a tradeoff between optimal production of color centers with minimal production of radioactivity in crystalline materials. The originally configured 9-section linac could not deliver any appreciable beam power below 25 MeV as a result of losses by a low-energy beam going through all nine sections, and thus it was decided to reconfigure the accelerator to extract a beam after the third accelerating section. The easiest and least costly method to achieve this was to remove section number 4 and replace it with an existing 30-degree bending magnet. This was done and now the electron beam can either be magnetically extracted from the 3-section configuration or, by turning off the magnet, sent forward through 8 sections. At a future time the removed section number 4 will be placed just after the original 9th section to again provide a full-energy 9-section linac.

A planar-triode-driven gun-pulsing circuit was constructed to drive the Arco Model 12 gridded gun with a continuously variable pulse width from 100 nanoseconds to 4.5 microseconds; another pulser is now under development to extend the range to below 10 nanoseconds. Since the gridded gun operates at a potential of -90 kv, a photo-resistor driven by means of a quartz (radiation resistant) fiber optics light guide was used to control the pulse width. An average power of just over 10 kw has been obtained for a 17-MeV electron beam with the 4.5-microsecond pulse width and a repetition rate of 300 pps. This output was achieved with a low-emission Model 12 gun, and it is anticipated that when a gun with a fresh cathode coating is installed the power level can be raised by at least 50%.

For the production of color centers in crystalline materials, the high average power electron beam is transmitted through our standard Al-water-Al output window and impinges upon a mechanically-moved, water-cooled container which holds several kilograms of crystals. To date large quantities of natural colorless topaz (aluminum silicate with F and OH substitution) have been irradiated to produce a deep blue color which is currently favored as a semi-precious gemstone. A research program has been initiated to study the physics of these color centers and the mechanism(s) by which they are produced. Optical spectroscopic, thermoluminescent and electron paramagnetic studies are now being conducted on topazes at various stages of their irradiation to help identify the responsible color mechanisms.

For the study of ionizing radiation effects in semiconductors, a subject of importance to nuclear power, space and defense electronics, both high instantaneous dose rates and large integrated doses are required. Instantaneous dose rates (dose rates during the electron pulse, but averaged over the pulse microstructure) in excess of 1.0E+11 rads/sec are obtained during an electron pulse while integrated doses in excess of megarads can be obtained in less than one second. Research on radiation effects in semiconductors is not a new field, but for the most part it has been carried out at either defense or industrial laboratories. We have initiated a new analytical/experimental research program in this area at RPI and it is our objective that such research which involves faculty and graduate students can lead to a deeper insight into the basic interactions in this field.

III. Eight Section Configuration

Neutron physics research is still carried out typically with a few kw beam of 60-MeV electrons striking a thick (>5 radiation lengths) Ta photoneutron target. A thinner Ta target designed to optimize bremsstrahlung production is used to produce the ionizing radiation levels found inside of a power reactor. In particular, a General Electric Co. boiling water reactor operating at 3000 Mwt has an internal gamma ray environment of about 50 Mrad/hr, a dose rate beyond the level obtainable from Co-60 facilities. It is, however, relatively easy to produce this magnitude of dose rates with the linac. For this simulation of reactor dose rates, a 10 kw beam of 60-MeV electrons strikes the Ta target to produce the forward-directed bremsstrahlung, and this bremsstrahlung is allowed to impinge on and penetrate a thick-walled stainless steel pressure tube which contains water at operating reactor conditions (1000 psi, 550 degree F). Thus a 'test tube' of simulated reactor water and intense ionizing radiation is obtained in a laboratory experiment, and this simulated environment is now being used to study the operation of corrosion potential electrodes prior to their selection for use inside of a power plant.

The intense ionizing radiation provided by the high-power bremsstrahlung has also proved useful in exposing large area arrays (>1000 square centimeters) to doses in excess of 1.0E+08 rads over a period of only several hours. This proved useful to rank-order the electrical properties of conductors encapsulated in organic insulating materials[15,16] and this high-dose radiation facility is now available for a wide range of applications.

IV. Conclusions

Although this paper does not contain much new technical information, it does provide an insight of how a large and expensive facility like the RPI linac laboratory can be made viable in today's tight basic research sponsorship environment. The technical and economic problems are considerable; for example, just obtaining replacement parts for a quarter century old machine is not easy. However, the challenges have been rewarding and the students are seeing a 'realworld' class of problems which will stand them in good stead when they graduate and when most of them go into industry. Another positive result is that the increased budget obtained from the industrial radiation applications has added to the overall improvement of the accelerator and the availability of more time and equipment which can be used for basic research. Indeed, the basic research level in many respects is at a higher level now with less direct funding than a decade ago, thanks to the increased activity level at the laboratory. We have found that applied research actually complements and assists basic research, and the combination has been very good for our students' educational objectives.

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