STATUS REPORT ON THE UNIVERSITY OF MANITOBA ACCELERATOR LABORATORY

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Summary

The University of Manitoba cyclotron completed an extensive upgrading program in late 1984[1,2]. Since then, the cyclotron has operated very reliably and has realized the upgrading objectives for acceleration of H^- ions. Future plans for upgrading and operation will be discussed.

Recent trends in the funding of small accelerator laboratories have necessitated a search for financial support in fields not directly related to nuclear physics. Some facilities and services for use in these areas of research will be described.

Operation of Cyclotron

Review of Upgrading

An extensive upgrading of the University of Manitoba cyclotron was carried out between 1983 and 1984. The objectives and results of this project have been discussed in detail elsewhere[2,3]. Briefly, the upgrading consisted of shimming the magnetic field in order to make it isochronous for both H^- and D^- acceleration, and redesigning the dees, center region and the RF power supplies and coupling. The objective was to produce more extracted current with improved quality and reliable operation to 50 MeV for H^- ions. For D^- ions, a higher extracted current with much improved beam quality, reliable operation to 27 MeV, single turn extraction to 15 MeV and reliable operation of polarized beams was called for.

Operating Experience

Performance of the cyclotron has, in general, exceeded the expectations prior to the upgrading. Stable, reliable operation has reduced the maintenance requirements and has allowed the technical staff to concentrate on providing more services to users. Operation of the cyclotron is usually handled by the user after a short training course. The user is trained to turn on and turn off the cyclotron and to change the energy of the extracted beam. Once the required current and energy settings are obtained, the machine requires virtually no attention. This reliability and ease of operation is largely attributable to the new dee and dee liner system with substantially improved cooling and mechanical stability.

Due to a heavy demand for H^- beams, operation in the deuteron mode has not been tested. The range of available energies for proton beams is extended to 50 MeV from effectively 42 MeV. A current of 2 μA at 49 MeV is now possible whereas in the past protons with energies greater than 42 MeV were very difficult to extract. The energy spread of unanalyzed beam has also improved and is measured to be ±0.6% at an energy of 43.8 MeV. The lowest extractable proton beam energy is about 20 MeV but a 10 MeV beam of reasonable quality has been produced by degrading a 25 MeV beam and analyzing it with a magnet dipole[4].

Future Plans for Upgrading and Operation

Future plans include injection of H^- beam into the cyclotron from an external Ehlers source. A factor of three increase in beam current is possible with this source as it is approximately three times as bright as the currently used duoplasmatron. Further improvements in beam current will be realized when the main vacuum pumps are upgraded. This will entail the replacement of two Balzers 16" diffusion pumps and Freon cooled baffles with two Varian VHS-10 diffusion pumps or equivalent with cryo-cooled baffles. A high partial pressure of water vapour is responsible for the gas stripping of a significant portion of beam inside the machine. In fact, the first neutral beam for experimental use was produced by this method[5]. Beam loss could be reduced by as much as 50%, resulting in greatly increased beam currents. More importantly, it will decrease the activation of the vacuum chamber so that maintenance will be easier.

Conversion to deuteron acceleration will take place on a periodic basis. To convert to deuterons, the machine has to be opened and the center region replaced with one suitable for these particles. The RF will operate at the second harmonic of the cyclotron frequency in a push-push mode. Changeover is expected to take less than one week.

The polarized Lamb-shift source[6] is scheduled to be refurbished and upgraded. Deuteron beam currents of up to 60 nA with a polarization of 80% are expected to be extracted at energies between 10 and 27 MeV.

Accelerator Laboratory Facilities

Recent trends in the funding of low to intermediate energy nuclear physics facilities have driven the laboratory to consider alternate options for funding. Before these options were considered, it was necessary to identify the Laboratory's resources in terms of the facilities and services it can offer to outside users in the research community.

Various applied facilities and services are ongoing or have been available for many years. The most prominent are the protein content analysis of samples of grain, the production of radioisotopes and licensed radiopharmaceuticals and the analysis of samples for trace elements by the PIKXE (Proton Induced K X-ray Emission) technique[7,8,9]. This latter method is especially useful for the detection of trace quantities of heavy elements at the energies of the spiral ridge machine.

A variety of new facilities either existing or under development are described below. These include a neutral beam production facility, a 35 MeV proton microprobe to be used in conjunction with the PIKXE technique, and a proton radiotherapy beamline.

There are two resources which should not be overlooked in any accelerator laboratory. One of these is the data acquisition and computing facility. This facility at the University of Manitoba Accelerator Laboratory is based on a VAX11/750 with CAMAC computer hardware and TUNL XSYS software. Associated with this is a modest inventory of CAMAC and NIM electronic modules. The second and possibly the most important resource, is the cadre of accelerator physicists and professionals without which the laboratory would not operate. A brief description of the accelerator physics research and educational program will be given below.

Applied Research Facilities

Neutral Beam Production. A variable energy neutral hydrogen beam facility has recently been developed at the University of Manitoba Accelerator Laboratory[10]. H^o beams are produced by stripping a single electron from the circulating H^- beam in the cyclotron using a number of methods. Initially, the H^- beam was stripped using the residual gas within the cyclotron. The efficiency of this process was of the order of 0.01% for a 10^{-6} torr residual gas pressure in the cyclotron.

The second stage of development involved stripping the H^- beam with a thin Carbon foil (thickness = 5 micrograms/cm^2) which yielded a stripping efficiency of approximately 5% at 40 MeV. Using this method, neutral hydrogen beams with energies between 30 and 50 MeV and fluxes on target of up to 4 x 10^{12} H^o/sec/cm^2 were extracted from the cyclotron and employed in a number of experiments which use the H^o beam as a probe to study optical radiation emitted from metallic and non-metallic surfaces[11]. Due to difficulties associated with transporting a neutral hydrogen beam of this energy to an experiment, all experiments to this point have been carried out in the vault area.

In the final stage of development of the Neutral Hydrogen Beam Facility the carbon stripping foil is to be replaced by a variable thickness metal vapor stripper. With the use of such a system stripping efficiencies greater than 80% are anticipated for all H^- energies[12]. Since the cyclotron is potentially capable of accelerating up to 20 μA of H^-, we expect to achieve H^o flux intensities of greater than 10^{14} H^o/sec/cm^2. Work is well under way on this stage of development. The metal vapor stripper has been constructed and is being assembled. Software is being written and tested to implement computer control of the H^o production system. A micro-computer system (PC/XT type) will be used to monitor and control some 15 parameters affecting the beam and its use.

Proton Microprobe. A high energy transmission microprobe, operating in the proton energy range between 20 and 50 MeV is currently under construction at the cyclotron laboratory. The magnetic lenses and beam transport system are being completely manufactured, wound and assembled `in-house´. It is now believed that this facility can provide focussed beams as small as 20 microns in diameter which can be used for analytical studies. Research into such varied topics as the elemental uptake of heart tissue and the composition of thin and powdered rock samples is planned. Scanning of samples through the beam will enable variation in concentration to be determined as a function of position, and the transmission nature of the instrument will allow self-absorption in the targets and background contamination to be minimal. It is expected that the full facility will become operational in 1987.

Proton Radiotherapy. Measurements of the characteristics of the proton beam as it pertains to the treatment of surface and ocular melanomas, have been made at 49 MeV[13]. The parameters of most interest to this project were the "flatness" of the beam (uniformity of beam intensity in the plane perpendicular to its axis), the depth dose distribution of the beam, and the relative amount of contaminants (particles other than protons) in the beam.

The experiments were carried out at the end of a beamline approximately 5 meters downstream from a quadrupole doublet. The doublet was used to defocus the beam onto a phantom. The proton beam exited the beam line through a thin Kapton window and entered the phantom after travelling 10 cm. Measurements of the depth dose distribution were made in water using a silicon diode (1N4007) to measure the relative dose. The results clearly show the Bragg peak and the range of the protons which is close to the 22 mm. predicted. [R.R.Wilson, "Radiological use of Fast Protons.", Radiology 47,487-491(1946)]. Field flatness was measured using a Lucite phantom and LiF thermoluminescent dosimeters (TLD´s). Results indicate a variation of dose by 9% over a distance of 10 mm. During the depth dose measurements, a TLD was placed 50 mm from the surface of the phantom and axial to the beam. The dose recorded was less that 0.1% of that in the plateau region of the Bragg peak indicating that photon and neutron contamination is unlikely to be significant.

These measurements confirm that a viable eye irradiation facility may be based on the University of Manitoba cyclotron. However, more effort in developing the proton beam is required.

Nuclear Physics Research Facilities

High Resolution Beam Line. Momentum analyzed beams of dE/E=0.05% can be obtained at most energies. Beam currents of protons of up to 100 nA can be realized. It is anticipated that a much higher current of momentum analyzed deuterons can be obtained at all extractable deuteron energies. Higher currents and better resolution will be possible with deuteron beams which are "single turn extracted" up to an energy of 15 MeV.

Neutron Spectrometers. Compact neutron spectrometers using a proton radiator have been built and tested at this laboratory. Neutron production cross-sections have been measured using this technique and the results are very promising[14]. These facilities are available for further cross-section measurements.

Targetry. The resources of the laboratory include a variety of target chambers and beam lines for specialized uses. These include a radioisotope production chamber, a target chamber for samples analyzed by the PIXE technique, a neutral beam target chamber, as well as an assortment of chambers with movable detector tables with precision angular positioning.

Training and Research Programs in Accelerator Physics

Accelerator Physics Program

The Department of Physics at the University of Manitoba is currently offering a Masters degree program in Accelerator Physics. This 16 month course has been held for 5 years and has attracted students from around the globe. The laboratory portion of the program is an opportunity for the students to become involved in accelerator based research and development projects in the laboratory. Much of the work described in this paper has been performed with the assistance of these students.

Princeton Injection Line and Central Region Studies

In addition to designing `in-house´ facilities and programs, various projects are being carried out for other laboratories.

The conversion of Princeton University cyclotron to axial injection is a particular consultancy project[15] which started in 1984. Here it is aimed to design an axial injection system and predict the total transmission efficiency of beams of various particle (high charge state heavy ions from an ECR source, and polarized ions of proton, deuteron and $^3He^{++}$) for both n=1 and n=2 modes of acceleration.

Design of Mini-Cyclotron for PET Isotope Production

The preliminary design study of a mini-cyclotron for the production of radiopharmaceuticals for use in Positron Emission Tomography (PET) is proceeding in collaboration with TRIUMF. The design parameters of the cyclotron should be such that it can produce a 50 μA beam of protons at an energy of 11 MeV. It must be simple to use, be very reliable, and cost about 1M$Cdn. A proposal and cost estimate will be submitted to an appropriate funding agency by the fall of 1986. The impetus behind this proposal comes from a very active group of clinicians using advanced PET techniques in clinical trials at the University of British Columbia Health Sciences Centre Hospital. They intend to install an easily accessible PET isotope production facility at the hospital.

Laboratory Outreach

In a determined effort to introduce the research facilities available at the University of Manitoba Spiral Ridge Laboratory to a wider technological community, a brochure giving details of these basic and applied physics research and consulting services has been generated and widely circulated. The cooperation of the private sector in joint research and development projects is welcomed and applied research in a variety of fields already under way.

Copies of this brochure and further information can be obtained from the Accelerator Laboratory at the University of Manitoba.

References

1. J. Anderson et al., 10th Int. Conf. on Cyclotrons and their Applications, East Lansing (1984) 461.
2. I. Gusdal et al., IEEE Trans. on Nucl. Sci., NS-32 (1985) 2724.
3. H. Uzat, I. Gusdal, V.P. Derenchuk, J. Lancaster, F. Konopasek, IEEE Trans. on Nucl. Sci., NS-32 (1985) 2954.
4. J.S.C. McKee (Ed.), "The University of Manitoba Cyclotron Annual Research Report 1985-86", ISSN 0832-8234, pp. 93-94.
5. Ibid, pp. 152-154.
6. S. Oh et al., "Ninth International Conference on Cyclotrons and Their Applications", Les Editions de Physique 1982, France, pp. 293-295.
7. D.A. Dohan, K.G. Standing, W. Bushuk, Cereal Chemistry 53 (1),(1976) 91-100.
8. M. Billinghurst, J.S.C. McKee and I. Gusdal, Int. J. Appl. Radiot. Isot., 34, (1983) 1655-1656.
9. J.S.C. McKee et al., Cancer Detection and Prevention 8 (1985) 87-93.
10. J.J.G. Durocher, G.R. Smith, V.P. Derenchuk and J.R. Anderson, "Extraction of Variable Energy Neutral Hydrogen Beams from the University of Manitoba Cyclotron", To be published in Nuclear Instruments and Methods in Physics Research, Section A - Nuclear Accelerators, Instrumentation and Techniques with Related Research in Physics.
11. J.J. Guy Durocher, G.R. Smith and D.R. James, "MANOR - Experiments in Collaboration With Oak Ridge National Laboratory", University of Manitoba Accelerator Laboratory Annual Research Report 1985/86.
12. J.J. Guy Durocher, C.S. Bohun and G.R. Smith, "Production of 20 to 50 MeV Neutral Hydrogen Beams", submitted to the IEEE 1987 Particle Accelerator Conference.
13. J.S.C. McKee (Ed.), "The University of Manitoba Cyclotron Annual Research Report 1985-86", ISSN 0832-8234, pp. 212-223.
14. R.R. Tkachuk, "Preliminary Analysis and Simulation of the University of Manitoba Neutron Beam Line". M.Sc. Thesis, University of Manitoba, 1984.
15. R. Kouzes et al, In proceedings of this conference.

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