LABORATORY EQUIPMENT AND COMPUTER DEVELOPMENT

ION SOURCES, OPERATION AND DEVELOPMENT

V. Derenchuk, R. Brown, R. Kupper, and H. Petri
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

Introduction

During the 1995 running period, HIPIOS has delivered beam for about 70% of the scheduled operating shifts. Experiments using the Cooler Ring and high intensity polarized beams with 1:12 pulse selection (375 ns period) for INPOL were the primary source of the demand. Low intensity polarized beam from HIPIOS was delivered to users in the K600 area and has taken the place of polarized operation with the Terminal-A ANAC source. The HIPIOS ECR ionizer has also provided doubly charged ^{3}He and ^{4}He beams to the ISIS 4π detector and to experiments using the K600.

Beam from the ANAC source in Terminal A was used for three runs totalling less than 10% of scheduled operation. In 1996, K600 operation has been exclusively with HIPIOS. The ANAC source will be decommissioned and parts used in the new CIS pulsed polarized ion source. The terminal B sources have been used to deliver H_2^+, He^+ and Li^+ beams from a duoplasmatron and a β-Eucryptite source. This terminal has been used for more than about 20% of the scheduled operation.

Construction and development continue on a pulsed unpolarized ion source for CIS in preparation for the arrival of the RFQ/DTL this year. A technical review committee consisting of W. Haeberli and T. Clegg has met and considered polarized-ion-source options for CIS.[1] As a result of their recommendations and the needs and expertise of the IUCF facility, planning has begun for a pulsed-atomic-beam source which will be mated to a resonant charge-exchange ionizer. This source is expected to produce a peak current of several hundred μA into the acceptance of the RFQ/DTL.

HIPIOS Operation and Development

Polarized protons from HIPIOS have been delivered for 58% and doubly charged He beams have been delivered for 12% of the scheduled operating time. Proton and helium beam stability from HIPIOS has benefitted greatly from extraction-system design changes made during the middle of 1995. The polarized beam extraction system has been modified so that there is only a single grid at the ECR plasma potential followed by three tube electrodes that focus and accelerate the beam to local ground potential. With a two grid system, beam intensity at Stop 5 in Terminal C would exceed 200 μA for several days following a maintenance period, after which the intensity would drop to about 150 – 175 μA. After fewer than 6 weeks of operation, insulators in the ionizer would become coated with grid material and the beam would be unstable. Removing the second grid dropped the average beam intensity to about 150 μA but the ionizer requires maintenance only after more than two months of operation.

A gas-pressure-regulation system that maintains the ECR pressure by varying the buffer gas flow has been installed. This system has eliminated slow drifts in the energy and intensity of the extracted beam. The buffer gas has been changed to N_2 from D_2 in order to eliminate unpolarized background for deuteron beam operation. Further developments and a study of the source emittance has been presented at the 1995 International Workshop on Polarized Beams and Polarized Gas Targets.[2]

A new extraction system for He^{++} beams has greatly increased the time between required cryopump regenerations from 1.5 days to 5 days or longer. The total He^{++} beam intensity has been reduced to about 15 μA, but the emittance was improved and the beam intensity from the cyclotrons has remained the same. This extraction system has been modeled using the TRAK/EMP[3] package of programs purchased from Field Precision in Albuquerque, NM.

HIPIOS reliability, beam quality and polarization have been major development goals for the atomic beam section (ABS). Several nozzle designs were tested. It was found that an Al nozzle can operate for two-week intervals without cleaning and maintain a consistently high flux at the ionizer. This nozzle easily recovers from short power failures. Proton polarization, measured on the BL2 polarimeter, has averaged 70% or higher, but the weak-field state is usually several percent higher than the strong field. The strong field 2$\rightarrow$4 transition efficiency is improved when the RF cavity is tuned for the best power ratio. Also, gradient coils have been designed and will be installed in place of the tilted pole tips for the static field. An optimum gradient field should result in good transition efficiency over a wide range of magnet settings. During a development run in July 1995 deuteron polarization was measured to be about 50% of the maximum possible. This low polarization was attributed to an unpolarized deuteron background in the ionizer and to inefficiencies in the transition units. It is expected that replacing the ECR buffer gas with N_2 will decrease the unpolarized background, and adding the strong field transition magnet gradient coils will improve transition efficiency.

The average polarization measured by the BL2 polarimeter and the magnitude of the polarization calculated from measurements in three planes using the BL3 and BL5 polarimeters is frequently observed to disagree by as much as 5% to 8% and can vary over a several day run. Typically, the polarization is higher in BL3 and BL5 and remains relatively constant. The BL2 polarization, measured using the ^{4}He(p,p)^{4}He reaction in only one plane, varies from day to day and has changed by up to 8% over a 12 hour period. To investigate this effect further, a spin-rotation solenoid will be installed in BL1C after the first 45° bend following the acceleration column. Any longitudinal polarization that remains after the spin-rotation solenoid in Terminal C is optimized will be precessed by about 85° after passing through the 45° bend. The new solenoid will then be able to correct any off-vertical component that arises from inside Terminal C. It is expected that there is some unanticipated magnetic field in HIPIOS or the beam transport line that is precessing the quantization axis in such a way as to add the longitudinal component at the acceleration column.

Sources in other Terminals

With the improvement of beam stability and polarization from HIPIOS, there is no longer a demand for beams from the ANAC source in Terminal A. The ANAC source has worked reliably during the last year, but high-voltage power-supply problems on Terminal A and the ease of tuning with higher intensity beam has made Terminal C a more attractive option. Terminal A will be kept operational until the construction of a new H^- polarized ion source for CIS (CIPIOS) begins. Parts of the ANAC source will be used for the new source as required.

Terminal B duoplasmatrons have been running reliably with few upgrades. During INPOL runs that require unpolarized beam, an F/6 buncher replaced the F/3 buncher and with chopping in BL1-common and pulse selected 1:12 and 1:10 (F/6 buncher tuned to F/5), beam was delivered for the first time from Terminal B. The β-Eucryptite Li^+ source has continued to provide beam for Cooler runs during which dielectric recombination is measured. Singly charged He was also delivered from Terminal B.

Unpolarized Ion Source for CIS

The development of a pulsed H^- source for CIS began in February 1995, using a duoplasmatron that formerly delivered H^- beam to the IUCF stripper loop. Some minor modifications were made to the source before it was installed and operated on a 25-kV test stand. As a result, 125 μA to 150 μA of H^- beam was extracted and transported to a stop two meters downstream.

An exhaustive study of the DC beam properties of this source was undertaken in order to design a 25-keV beam-transport line. The duoplasmatron extraction optics and beam transport through to the RFQ were modeled using the TRAK/EMP[3] programs. Measurements of the DC source emittance matched the modeled emittance within 25% of the phase space area and angular divergence. Matching the beam to the RFQ acceptance will be made by an Einzel lens pair. This final lens pair, at the entrance to the RFQ/DTL is critical and must be accurately designed in order to focus the beam within the constraints of the entrance channel of the RFQ, 125 mrad half-angle and 1.3 mm radius within a phase-space area of 1.0 π-mm-mrad. The measured emittance of the DC beam is much smaller than the acceptance of the RFQ and so no problems meeting this requirement are anticipated. The final beam transport line design is shown in Fig. 1 of the contribution to this report on CIS.

A pulsed arc supply and gas valve have been added and will be timed with the RFQ and CIS pulsing. It is expected that the pulsed beam current will increase by more than factor of 3 over the DC operating value and average more than 300 μA of peak current. A new emittance scanner using a moveable slit and harp mechanism is being designed to measure the properties of the pulsed beam from the source.

1. See “A Source of Polarized Ions for CIS”, this report.
2. V. Derenchuk, R. Brown, and H. Petri, in the *Proceedings of the Int'l. Workshop on Polarized Beams and Polarized Gas Targets*, Cologne, Germany (1995), eds. Hans Paetz gen. Schieck and Lutz Sydow (World Scientific, 1996) p. 180.

3. Stanley Humphries, Jr., TriComp System, Field Precision, PO Box 13595, Albuquerque, NM (1996).

RF SYSTEMS

A. Pei, S. Anderson, D. Jenner, and D. McCammon
Indiana University Cyclotron Facility, Bloomington, Indiana 47408, USA

The RF systems of the IUCF Cyclotrons, Cooler, ion sources and the associated beamlines have been operating reliably in the past year. Routine maintenance was conducted and minor upgrades were made to meet the operation specifications.

At certain operating frequencies, the main cyclotron D-cavities experienced amplitude and phase jitters. It was verified that the feedback control loops were operational. The problem was then traced to the poor suppression of harmonics of the D-cavity at certain harmonic frequencies, caused by high order mode resonances being too close to the harmonics. In the case of the second harmonic perturbation, for example, the peak RF voltage is:

$$|V_p| = \sqrt{(cos\,\omega t + \alpha(t)\,cos\,(2\omega t + \phi))^2}$$

where $\alpha(t)$ is the second harmonic perturbation amplitude. While the non-mixing terms of the above only contribute 2ω terms, the mixing term produces the fundamental frequency term at ω, effectively breaking the symmetry of the negative and positive cycles, which is a fairly general case of non-pure-tone periodic signals. A peak detector based RF feedback loop can effectively regulate either the positive or the negative peak signal, but not both, resulting in an RF signal that is well regulated in one half of the "sine wave", but not the other. A practical solution to this problem was to alter the D-cavity geometry by repositioning the two tuning panels to move the high order mode resonances sufficiently away from the harmonic frequencies.

The F/2 beam-bunching system in the cyclotron injection beamline consists of a variable frequency lumped-element RF cavity that operates at approximately 11 to 18 MHz. To maintain a constant voltage step-up ratio, tuning is accomplished by changing the sliding contact of a water-cooled inductive coil. A new mechanical design of the sliding sub-assembly carefully isolates the mechanical stress areas from the RF field path. This greatly reduces heat stress of the tuning element and makes the once-high-maintenance device much more reliable.

Most of the research and development effort was concentrated on the CIS RF system design.[1] It was decided that the CIS RF ramp would use a real-time linear interpolation scheme to generate the required digital control as in the rest of the CIS ramp control system. In this scheme, the operator inputs a number of points in the frequency-versus-time plane to describe a frequency ramp curve adequately. These vector points are then down-loaded into the RAM of a digital signal-processor board. The digital control value