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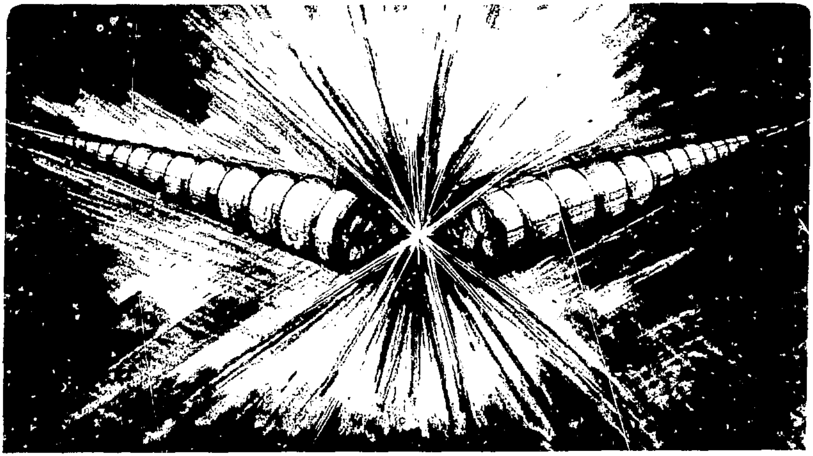

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Summary

The LBL Wideroe-based high-intensity heavy-ion injector for the SuperHILAC will be operational by April 1981. It will provide several emA of low charge state ions up through uranium at high duty factor to the SuperHILAC. Several of the subsystems have already operated to specification and will be described.

Introduction

The LBL Abel injector for the SuperHILAC will provide large fluxes of ions from Argon to Uranium at a high duty factor for injection into the SuperHILAC, increasing the intensity over that provided by the present heavy ion dynamatron (Adam) and the light ion Cockcroft-Walton injector (Eve). Substantially better ion source intensities than predicted in our original estimates will increase the average beam current over the highest presently available mass (lead) by almost two orders of magnitude over our present capability and extend the mass capability to uranium. A substantial increase in overall system reliability is also expected.

The Abel (Third) Injector Project has been described previously[1,2]. The injector system consists of a 750 kV Cockcroft-Walton preinjector with a high-power PIG ion source and a moderate gradient column. The LEBT from the preinjector to the Wideroe linac has a mass discrimination of 0.3% to provide monoisotopic beams from unenriched source feed material. The Wideroe linac accelerates a q/A = 0.021 ion from 15.87 to 113 keV/n over a length of 4.6 m. The linac closely resembles the first Wideroe used at GSI, Darmstadt, and operates at 23.4 MHz, one-third of the operating frequency of the SuperHILAC. The Wideroe is followed by a Fomblin vapor stripper to strip to U^{11+} (q/A = .0294), at an efficiency of 12% with a higher efficiency for the lower mass ions.

The Abel injector will be used, along with the Adam and Eve injectors, in a time-multiplexed beam sharing configuration, providing one of three independent ion species whose intensity and energy are individually selectable on a 36 pulse-per-second basis. This wide selection of beam characteristics serves the several experimental caves at the SuperHILAC, as well as the Bevalac, the coupling of the SuperHILAC to the Bevatron, a large-aperture weak focusing synchrotron with a peak energy for q/A of 0.5 of 2.1 GeV/n. Concurrent with the Abel Injector Project, an improvement program at the Bevatron will improve its present vacuum of $2 \cdot 10^{-7}$ T to $1 \cdot 10^{-10}$ T by the addition of an inner vacuum liner and additional cryopumping facilities [3]. When this modification is complete in 1982, 2 GeV/n uranium will be available.

Several subsystems have already operated and their performance will be reported below.

Ion Source

The injector performance is limited by the available ion source current within the normalized acceptance phase space area of .6π mm-mrad of the following accelerator. A recent ion source development program has resulted in sources whose extracted current of Xe^{3+}, Au^{4+}, and Pb^{5+} have far exceeded our original expectations: instantaneous intensities of 3-4 emA of these ion species have been observed in a normalized emittance area of 0.5π mm-mrad[4]. The space charge limit of the accelerating column, the Wideroe accelerator, and the SuperHILAC prestripper accelerator is on the order of 10 emA, which then represents the ultimate intensity limit.

The available uranium flux from the SuperHILAC using U^{5+} from the ion source and including a 12% stripping efficiency in both the stripper following the Wideroe and the stripper following the first Alvarez tank will be $4.4 \cdot 10^{12}$ sec^{-1} at the exit of the poststripper accelerator at 8.5 MeV/n. To date, we have not accelerated uranium in the SuperHILAC, but this is about 50 times greater than the best obtained fluxes of ^{208}Pb. Another gain from a performance standpoint is the increased availability of the ion source. Our present heavy ion injector is a pressurized dynamatron which requires approximately 8 hours to depressurize and repressurize, which is a large overhead for a typical ion source lifetime of 10-40 hours. The Abel injector is air insulated, and uses a dual-headed ion source which can be changed remotely in a matter of seconds. The replacement of the entire dual-head module is facilitated by quick disconnects and a fast pumpdown system, allowing a complete changeover time of less than a half hour.

Cockcroft-Walton Preaccelerator

The ion source is located in the terminal of a series-fed voltage multiplier excited at 90 kHz[5]. The design operating voltage is 750 kV, with a maximum average drain of 10 mA. We have operated the power supply at 890 kV without the accelerating column in place at which point a discharge occurs from the terminal outer structure to the building wall, located seven feet away. The accelerating column, constructed from three one-foot NEC column sections, is insulated by SF_6 at ambient pressure.

The power demand on the high voltage platform is provided by a 100 kVA motor-generator set using a 60 Hz and a 400 Hz permanent magnet generator which are driven by a 200 hp motor at ground potential. We have operated the MG set with nearly full load without apparent difficulty or vibration problems.

Wideroe Accelerator

The accelerator is a π-3π Wideroe structure patterned after the first tank of the Unilac accelerator[1,2,6]. The Wideroe, containing 34 drift tubes, accelerates a q/A = .021 ion from 15.8 to 113 keV/n. The drift tubes for the short cells without focusing quadrupoles are excited to a peak potential of 100 kV at the first cell to 250 kV at the last cell by an eccentric coaxial line supported

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on three coaxial stubs. The electrical length of these three stubs is individually adjustable to fix the nominal 23.4 MHz resonant frequency and voltage profile along the tank.

The accelerator has been assembled and the resonant frequency and voltage distribution has been measured by a bead perturbation technique. The initial resonant frequency was obtained with less than a 0.6% error, well within the range of the adjustable shorting plate coarse tuners. The next higher mode was also observed and was within 2.5% of expected. The r.f. structure was modeled at six points along the accelerator with a dispersive transmission line technique using data obtained from a 1/7 scale constant-velocity model.

The accelerator is excited by a 250 kW r.f. amplifier loop coupled to the middle support stub[7]. The nominal power demand of the accelerator is 70-100 kW with a duty factor as high as 0.5. The amplifier has been tested at full power into a dummy load whose impedance approximates that of the Wideroe. The amplifier operates at one-third the SuperHILAC operating frequency and is phase locked to it with a maximum phase error of 0.5 degree.

Quadrupoles

The sixteen outer wall drift tubes and the two end wall half drift tubes each contain a focusing quadrupole magnet. The magnets were fabricated using the tape wound coil technology reported previously,[8] and provide an integrated field strength of 97.5 kG. They are grouped into four sets with apertures and poletip lengths varying from 1.6 cm dia., 7 cm long to 2.7 cm dia., 15.8 cm long. The magnets operate at a magnetic efficiency of greater than 85%. The strength and harmonic content of each unit was measured with typical error terms for higher order ($< n=14$) multipoles of less than 0.5% at the poletip radius.

The drift tube fabrication uses the magnet yoke as the outer wall, with type 304 stainless steel formed shells 0.109" thick welded to the yoke ring and bore tube. The single vertical stem provides current lead penetrations as well as coolant (Freon TF-113) supply and return passages. The entire drift tube is copper plated to the desired thickness (approximately 0.5 mm) and the adjustment brackets were mounted. All sixteen drift tubes have been installed and will be magnetically aligned using the pulsed wire alignment technique used earlier at the SuperHILAC[9].

Fomblin Vapor Stripper

The stripper following the Wideroe strips U^{5+} to U^{11+} at an energy of 113 KeV/n at an average particle flux of 500 pμA. The optimum stripper mass in the beam is less than 10 $\mu g/cm^2$ for minimum scattering and energy straggling. Carbon foils this thin are difficult to obtain, and the lifetime would be unacceptably short. We have therefore decided to use a vapor stripper based on the Fomblin perfluoropolyether materials, which are high molecular weight linear chain fluorocarbons[10]. At higher energies, the fluorocarbons show little increase in average charge state produced over gas strippers. However, at these low energies, a considerable improvement in average charge state is obtained, and furthermore, the resulting charge state distribution is highly skewed, with substantial fractions of high charge state ions being produced. The stripper is found to contribute only a small amount of scattering to the beam.

We have installed the Fomblin vapor stripper following the Wideroe. This stripper uses a supersonic nozzle to generate the required pressure in the beam over a 4 cm interaction length. Differential pumping reduces the pressure in the beam line to an acceptable level, and no optical path exists to either the Wideroe or the following Alvarez for direct transport of Fomblin vapor. The Fomblin molecule has the desirable property of cracking rather than polymerizing in the presence of ionizing radiation, preventing build-up of heavy deposits in the stripper area.

Computer Control

The Third Injector is controlled by a new microcomputer system tailored to its specific requirements[11]. This system uses a distributed (star-type) structure with fiber optic data links; multiple CPU's operate in parallel at each node. A large number (20) of the latest 16-bit microcomputer boards are used to get a significant processing bandwidth. This allowed us to write simpler software, because it could be less "real-time" critical. All programs are written in a high level language.

Accelerator parameters are connected to the "points" of the star structure. These distributed I/O micromodules each have their own database and programs stored in read-only-memory (ROM). Thus they can be operated independently for local control or maintenance. Data travels simultaneously to and from these points to a central collector. Operator stations then have access to this data.

Dynamically assigned and labeled knobs together with touch-screens allow a flexible and efficient operator interface. An X-Y vector graphics system provides display and labeling of real-time analog signals as well as general plotting functions. Both the accelerator paramenters and the graphics system can be driven from "BASIC" interactive programs in addition to the pre-canned user routines.

The control system provides for attachment of a powerful auxiliary computer for scientific processing and access to accelerator parameters.

Schedule and Costs

Detailed engineering and design work for the Third Injector Project started in February 1979 and actual fabrication and construction was authorized to begin in June 1979. The construction work for the Cockcroft-Walton preinjector tower enclosure and a power supply building was completed in April 1980 and some of the initial large special fabrications (high voltage terminal shell, insulating legs and elevator service platforms) were ready to be installed at that time. The Cockcroft-Walton power supply was assembled during the summer with first initial high voltage tests reaching 890 kV in September 1980. The ion source analysis magnet, vacuum system and high voltage power supplies were all installed and tested in the fall of 1980, with the first analyzed beams of up to 4 mA peak lead and gold ions being studied in early January 1981. The motor-generator set is now also operational, as are all other magnet power supplies. The high gradient column is now completing its assembly and checkout tests with full operational tests of the preinjector scheduled for April 1981.

The Wideroe linac tank was installed in May 1980 and all internal components have been mounted and aligned. The large component copper plating operations (end walls, stub flanges, inner conductor and drift tubes, and outer wall drift tubes) were done in the LBL mechanical shops and all final assembly, tests and installation steps were carried out by SuperHILAC technical personnel. The linac is now complete, the initial resonant frequency tests are very satisfactory, and the first bead pulling measurements have just been completed. High level r.f. power testing is scheduled for March/April 1981.

The control system development has continued throughout the project and the new system has already sucessfully been tested to control preinjector components. The full control capability will be available during initial full injector system tests in April 1981.

The entire Third Injector Project costs are approximately 3.57M including $0.47M for conventional facilities construction. The $3.1M special facilities portion costs include both fabrication as well as engineering and design costs with nearly equal portions being used for the 750 kV preinjector, the Wideroe linac, and the necessary beam transport and controls.

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