Proceedings of the Linear Accelerator Conference 1990, Albuquerque, New Mexico, USA

A NEW 1.4 MEV/U INJECTOR LINAC FOR THE UNILAC

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Abstract

GSI has extended its accelerator facility by a heavy ion synchrotron and an experimental storage ring; the UNILAC has been upgraded to supply beams for these new machines while also serving the low energy physics experiments.

With the installation of two new injector linacs for the UNILAC - a high current and a high charge state injector - fast switching of ion species, beam energy and intensity will become available.

The high charge state injector, presently being assembled, will be described in this paper. It consists of an ECR ion source, a 108 MHz RFQ linac and an interdigital H-type accelerator structure. Highly charged ions (U^{28+}) from the ECR source are accelerated up to 1.4 MeV/u and injected into the Alvarez linac of the UNILAC without stripping. The status of the project will be reported.

Introduction

GSI has extended its accelerator facility by a heavy ion synchrotron (SIS) and an experimental storage ring (ESR). Fig. 1 shows the plan view of the whole accelerator facility. The preparation of the site started in November 1986, first beam was accelerated in the synchrotron at the end of 1988, storage of ions in the ESR started in April 1990. The UNILAC is used as injector for the synchrotron. It has been upgraded to deliver beams for these new machines while also serving low energy physics experiments.

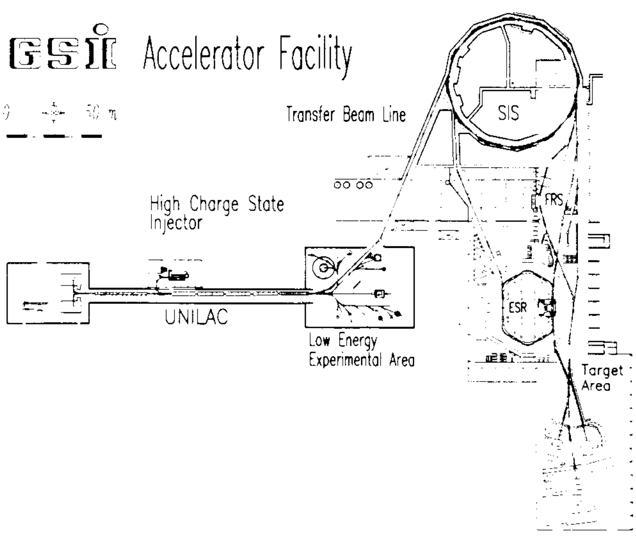

Fig. 1: Plan view of the extended GSI accelerator facility

For efficient operation of the GSI accelerator facility, the scheme of time-share operation has been adopted for the UNILAC: beams of different ion species and currents will be extracted from the injectors, accelerated to the desired energies and delivered into the UNILAC experiment areas or to SIS on a pulse-to-pulse basis.[1]

In a first step, the UNILAC poststripper accelerator was modified for time-share operation.[2,3] With the commissioning of SIS, energy switching was available for routine operation.

Fast switching of ion species will be possible with the installation of a new injector linac which will be described in this contribution.

The present injector linac consists of two DC preaccelerators with PIG ion sources. Four 27 MHz Wideröe tanks accelerate the ions to 1.4 MeV/u. After stripping and charge state selection, the beam (e.g. U^{28+}) is injected into the Alvarez linac operating at 108 MHz. The following intensities (typical peak electrical current) are available after stripping: $^{20}Ne^{7+}$ 100 eμA, $^{40}Ar^{10+}$ 100 eμA, $^{129}Xe^{21+}$ 10 μA, $^{208}Pb^{26+}$ 2 eμA, $^{197}Au^{25+}$ 5 eμA, $^{238}U^{28+}$ 5 eμA. It will be discussed below that the new injector linac will not deliver considerably higher intensities. Therefore, the intensities of both injectors do not allow to reach the space charge limit of the synchrotron for medium and heavy mass ions. An increase of intensity up to three orders of magnitude should to be achieved by a future high current injector. Present concepts favour the modification of the UNILAC prestripper linac. A new RFQ linac up to the energy of 216 keV/u is under discussion. The high charge state linac presently being assembled, will then be used for the continuation of the research program at UNILAC energies.

Design of the new injector

The new injector consists of an ECR (Electron-Cyclotron-Resonance) source followed by an RFQ and an IH accelerator tank. During the last years, ECR sources have been developed continuously. Now this source type can deliver the same charge states of heavy ions at low energy which have been generated so far by gas stripping at 1.4 MeV/u. The intensities are comparable or even higher as delivered by the existing prestripper linac. The high charge state ions from the ECR source allow a very efficient acceleration up to 1.4 MeV/u.

The layout of the new injector - called HLI linac (High Charge State Injector - Hoch-Ladungs-Injektor) - is shown in fig. 2, a summary of the major parameters are listed in Table 1.

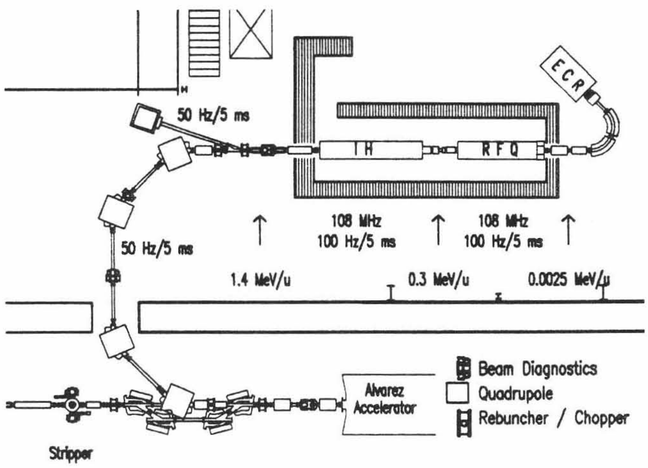

Fig. 2: Layout of the new 1.4 MeV/u injector (HLI)

Table 1: Summary of major injector parameters

Injection	
Ion source	ECR-type, 14.5 GHz
Charge-to-mass ratio	0.105 to 1
Extraction voltage	23.8 kV
Energy	2.5 keV/u (β=0.0023)
Radial emittance (norm.)	0.46 $\pi\cdot$mm$\cdot$mrad
Radial emittance (unnorm.)	200 $\pi\cdot$mm$\cdot$mrad
Mass resolution Δm/m	3×10^{-3}
RFQ accelerator	
Structure type	four rod
Energy, input	2.5 keV/u (β=0.0023)
Energy, final	300 keV/u (β=0.025)
Radio frequency	108 MHz
Repetition frequency	100 Hz
Duty cycle	50 %
Max. RF power (for U^{25+})	125 kW
Max. Voltage	78 kV
Length	3 m
Tank diameter	0.5 m
Radial acceptance (norm.)	$\geq$ 0.75 $\pi\cdot$mm$\cdot$mrad
Longitudinal emittance	30 $\pi\cdot$keV/u$\cdot$deg
Energy spread	$\pm$ 1.0 %
Bunch width	$\pm$ 0.3 ns ($\pm$ 10 deg)
IH accelerator	
Energy, input	300 keV/u (β=0.025)
Energy, final	1.4 MeV/u (β=0.055)
Radio frequency	108 MHz
Repetition frequency	100 Hz
Duty cycle	50 %
Max. RF power (for U^{25+})	110 kW
Max. field strength	150 kV/cm
Length	3.55 m
Tank diameter	0.63 m
Shunt impedance	310 MΩ/m
Radial acceptance (norm.)	1.5 $\pi\cdot$mm$\cdot$mrad
Radial acceptance (unnorm.)	60 $\pi\cdot$mm$\cdot$mrad
Longitudinal acceptance	150 $\pi\cdot$keV/u$\cdot$deg

ECR-Source and Low Energy Beam Transport

The ECR source was developed and manufactured by the "Centre d'Etudes nucléaires" (CEN) in Grenoble. It is an upgraded version of the 10 GHz Caprice source. The excellent performance of ECR sources was reviewed by Geller at the 1988 Linac Conference.[4] The commissioning of the source for the GSI injector took place at Grenoble, the source will be delivered in September 1990. A photograph of the source is shown in Fig. 3.

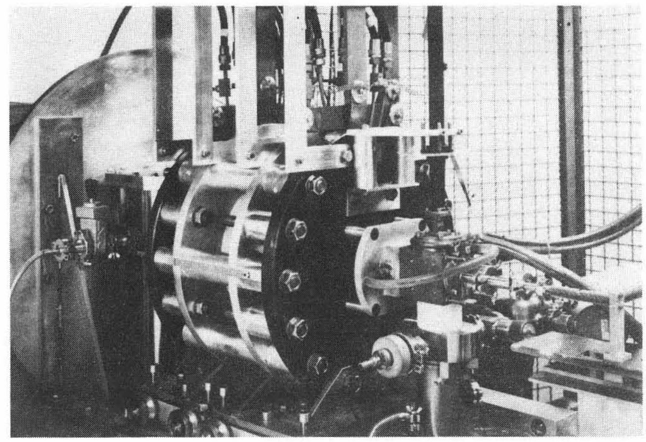

Fig. 3: Photograph of the ECR-Ion Source, taken during the commissioning at Grenoble.

In Table 2, the measured intensities of some ions are listed. A uranium charge state distribution is shown in Fig. 4.

Table 2: Measured ion currents of the ECR Source

U^{28+}	: 5 eµA (max. 10 eµA)
U^{25+}	: 15 eµA
Pb^{24+}	: 5 eµA (10 kV Extr. Volt.)
Pb^{25+}	: 6 eµA (20 kV Extr. Volt.)
Au^{24+}	: 14 eµA
Au^{26+}	: 5 eµA
Xe^{17+}	: 27 eµA
Xe^{21+}	: 15 eµA
Ni^{8+}	: 20 eµA (15 kV Extr. Volt.)

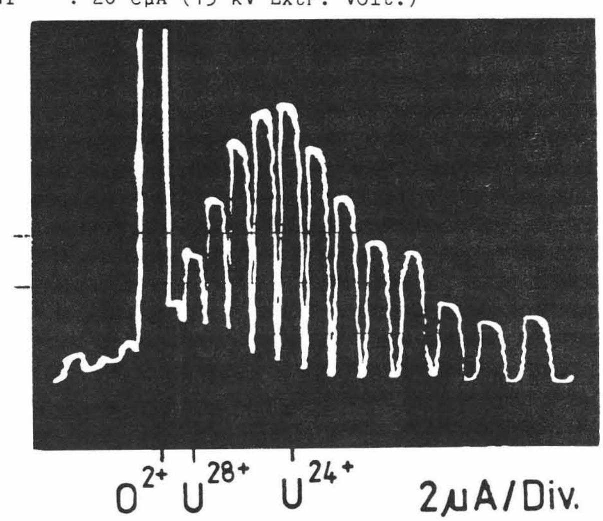

Fig. 4: Charge state distribution for uranium from the 14 GHz ECR source

The power of the klystron was varied in the range 300 - 600 Watt, the maximum hexapole field was 5800 Gauss. For better source operation, the output power of the 14 GHz klystron was stabilized. The long-term stability of the output current is impressive: over 40 hours operation only small changes occurred. The noise modulation is less than 15 %. The measured output intensities listed in Table 2 fit the design values.

The low energy beam transport is designed for a beam with 200 π mm· mrad at 2.5 keV/u. A spectrometer has been assembled which allows charge state and mass separation. Even lead isotopes can be separated. The dipole magnet is splitted into two 67.5° magnets in order to minimize second order effects by curvatures of the inner pole faces. A triplet and a solenoid serve to transport and match the beam to the entrance of the RFQ accelerator.

RFQ Accelerator

The design and construction of the RFQ linac have been carried out at the Institut für Angewandte Physik, University of Frankfurt.[5] Acceleration from 2.5 keV/u to 300 keV/u is being done with a Four-Rod RFQ. A scheme of the structure is shown in Fig. 5.

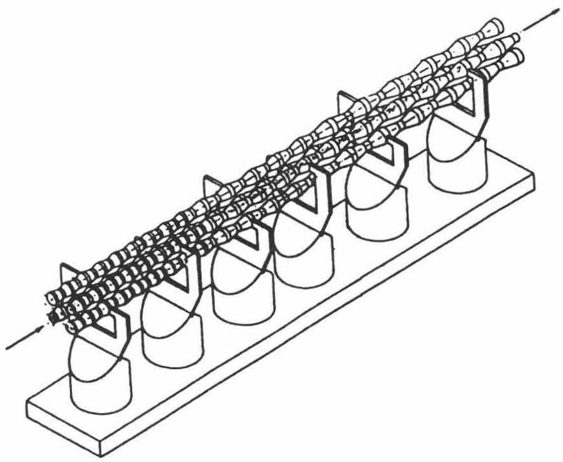

Fig. 5: Scheme of the Four-Rod RFQ

Circular rod electrodes are supported by a linear array of straight radial stems. The particle dynamics design was optimized for a minimum longitudinal and transverse emittance growth and good transmission. An RFQ was designed with a length of 2.9 m, electrode voltage 90 kV, a minimum aperture of 3.0 mm and a maximum modulation of 2.1.

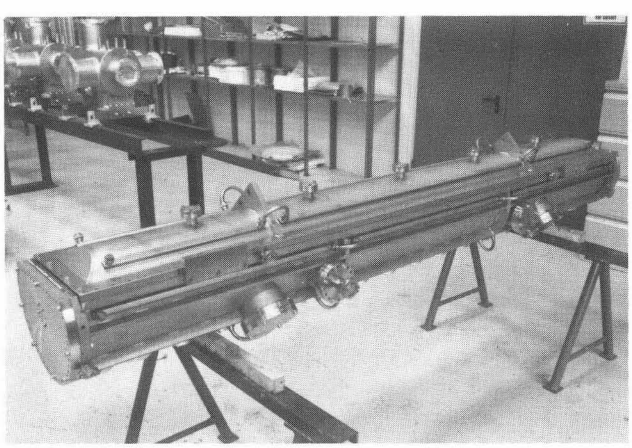

Fig. 6: Photograph of the RFQ tank. Length is 3 m.

The mechanical design had to take into account the high duty cycle of 50 %, e.g. direct cooling of the rod electrodes. The tank itself consists of two halves to facilitate installation and alignment. A photograph of the 3 m tank is shown in Fig. 6. The tank is made of stainless steel and is being prepared for copper plating at GSI.

IH-Accelerator

Details of the IH accelerator section are given at the Linac 88 and in a contribution to this conference.[1,6,7] Characteristic parameters are listed in Table 1. The efficient acceleration from 0.3 to 1.4 MeV/u is demonstrated by these parameters. All parts for the IH-structure were ordered. The 3.5 m long tank made of mild steel was delivered. The copper plating has been started.

Beam Transport at 1.4 MeV/u

A 180° beam transport system was designed for the injection of the 1.4 MeV/u beam into the UNILAC poststripper accelerator (see Fig. 2). An 11° fast kicker magnet behind the IH-tank will serve local experiments. For switching the beams from the new and "old" injector, a 30° kicker magnet will be installed. Five quadrupole lenses for pulsed operation in front of the Alvarez linac will form the two beams to match the transverse acceptance of the first Alvarez tank.

Status and Schedule

All components were ordered. But the delivery for some components has been delayed. Together with man power problems at GSI - the synchrotron and storage ring have been installed with high priority - the new injector project is behind the schedule. Cooling water, electrical supplies and cabling and other utilities are now being installed. The unforeseen repairs on the tanks in our copper plating workshop and the exchange of the electrolytic bath caused a late beginning of copper plating of the IH- and RFQ-structure - it will be finished in October this year. In the revised time schedule, the first beam is planned for the spring 1991.

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