KEK POLARIZED PROTON PREACCELERATOR

S. Fukumoto, Z. Igarashi, K. Ito, T. Kato, C. Kubota, Y. Mori
A. Takagi, E. Takasaki and T. Takenaka
National Laboratory for High Energy Physics
Oho, Tsukuba, Ibaraki, 305, Japan

Abstract

A 750 kV Cockcroft preaccelerator is being built for acceleration of polarized H$^-$ ions and for injection into the 20 MeV linear accelerator. To stack more particles in the booster synchrotron, H$^-$ ions are preferred instead of protons. A new polarized H$^-$ ion source is being developed, and a beam intensity of 5 μA was achieved. The accelerating column is similar to the operating column for ordinary protons. At the beginning of a 40 m long beam line, which transfers the 750 keV H$^-$ ions from the column to the old LEBT, the proton spin of the H$^-$ ions is rotated from parallel to the beam to vertical. An ordinary H$^-$ ion source is also being developed for dual mode operation of the polarized and unpolarized beams.

Introduction

In a design of the KEK proton synchrotron, acceleration of polarized protons was studied. However, a strong intrinsic resonance was supposed to occur in the 500 MeV booster synchrotron and no polarization was considered to be kept after the resonance. Recently, it was pointed out that the resonance is so strong that the polarization is substantially kept by spin flip[1]. There are many resonances in the 12 GeV main ring too. Some are strong enough to keep polarization by spin flip, but others are not so strong that depolarization should be avoided by fast passage.

The booster synchrotron was designed for five-turn injection of the 20 MeV protons. It is estimated that an effective 100-turn injection is possible for charge-exchange injection of 20 MeV H$^-$ ions[2]. It means that the equal circulating current is obtained by a 200 μA proton beam or a 10 μA H$^-$ beam in the booster. A pulsed high current Lamb-shift ion source had been developed at KEK and a beam current of more than 1 μA was achieved. However, it seemed very difficult to increase its beam current drastically by the system, so a new ion source has been studied and it seems promising. Thus the polarized preaccelerator adopts the H$^-$ system. When it is completed, the operating proton preaccelerator should be changed to a H$^-$ preaccelerator for dual mode operation of the polarized and unpolarized

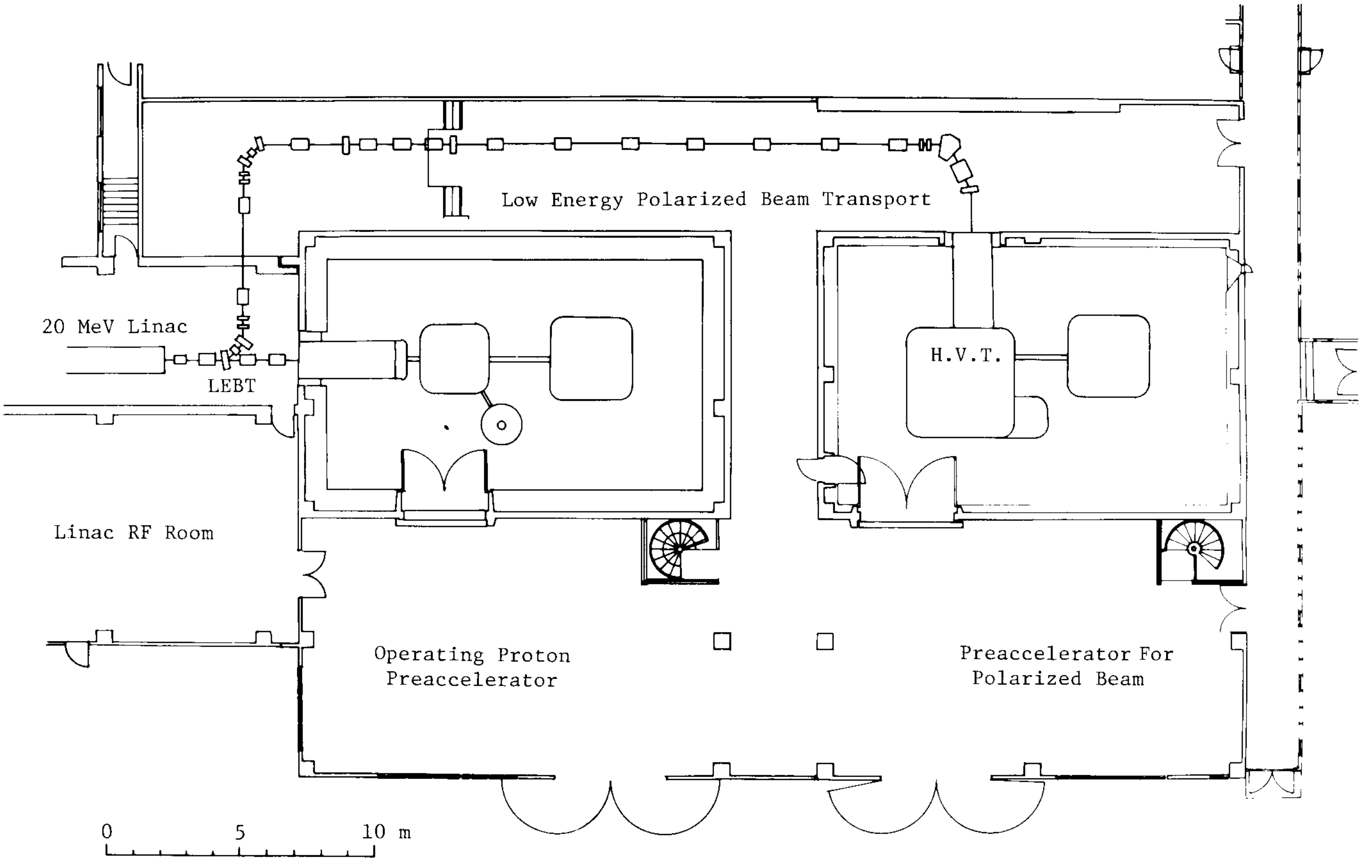

Fig. 1 Layout of 750 kV Cockcroft-Walton preaccelerators.

beams.

Although an RFQ linac seems very attractive for acceleration up to 750 keV, the beam will debunch unless it is injected directly from the RFQ linac into the DT linac. Therefore, it was decided to make an open Cockcroft-Walton preaccelerator[3].

Layout of Preaccelerators

As there is no sufficient area to build a Cockcroft preaccelerator for the polarized H^- ions beside the operating preaccelerator, a new building was built behind the operating preaccelerator building and they are connected each other. The ions will be accelerated and transported to the operating LEBT by a 40 m long beam line as shown in Fig. 1. The floor of the new room is 1.4 m higher than that of the old room because the new beam line must avoid the power line cable tunnel which was already installed between two rooms. This will affect little on polarization of the beam.

Ion Sources

A key of the project is a high current polarized ion source and a 5 μA beam was already achieved. It has following features[4]: the 3-S electron of the sodium atom is polarized by a dye laser which is optically pumped by an argon laser, the polarized electron is transferred to a 5 keV proton, polarization of the electron is transferred to the proton by conventional zero-crossing magnetic fields and the nuclear-polarized hydrogen atom is changed to a H^- ion by charge-exchange reaction with the sodium vapor. When the polarized electron is transferred to the L shell of the hydrogen atom in a weak magnetic field, the electron of the p-state may be depolarized by the LS coupling. To prevent the depolarization, the electron should be transferred in a strong magnetic field of about 1 T. If a proton beam delivered from a duoplasmatron is guided into such a high magnetic field, then the protons have azimuthal velocities and an emittance of the electron-polariz-

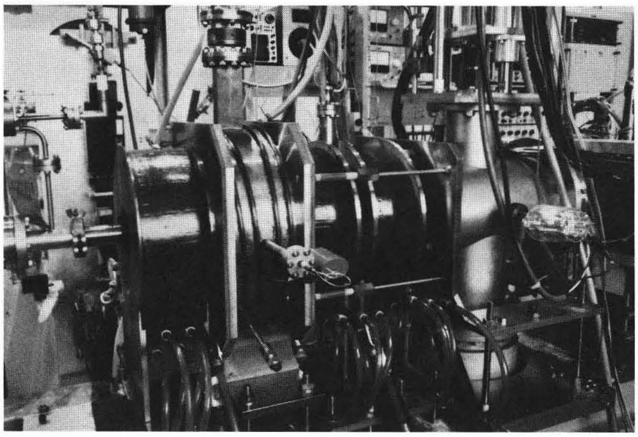

Fig. 3 ECR ion source test stand.

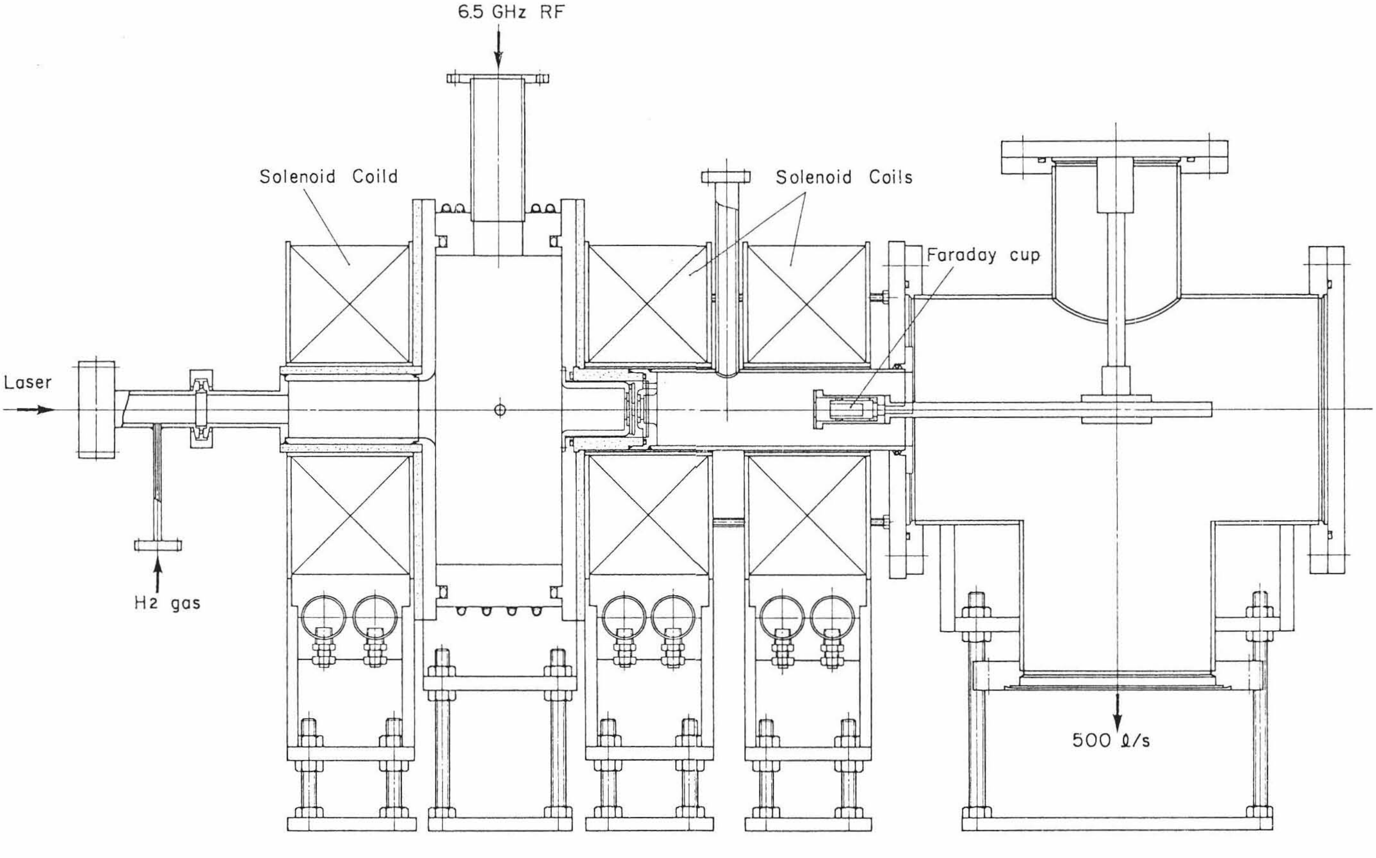

Fig. 2 6.5 GHz ECR ion source.

ed atomic beam deteriorates. Thus an ECR ion source is being developed. Preliminary results are as follows: the achieved beam current is 30 mA with a current density of 25 mA/cm^2, its proton ratio is 80 % and it is consistent with the measured electron temperature of 14 eV. A 6.5 GHz RF power is supplied by a klystron, and the corresponding magnetic field for electron cyclotron resonance is 0.25 T. Protons are extracted at the region of 0.45 T. A high power argon laser and ring dye laser will be on the ground in the future, and a light beam of 5895.92 Å will be emitted to the ion source in the 750 kV high voltage terminal.

As the injection system is different for protons and for H$^-$ ions in the booster synchrotron, it takes too much time to switch from one to the other. For dual mode operation of high-current ordinary protons and polarized protons in the booster, the present proton preaccelerator should be converted to a H$^-$ system. A magnetron type surface-plasma source[5] is being tested for high current H$^-$ beams. A current of 40 mA was achieved in the cesium mode. It was attained by a higher extracting voltage using a pulse source instead of a DC source. However the pulse source has insufficient capability, and it is partly responsible for change in beam current during a pulse.

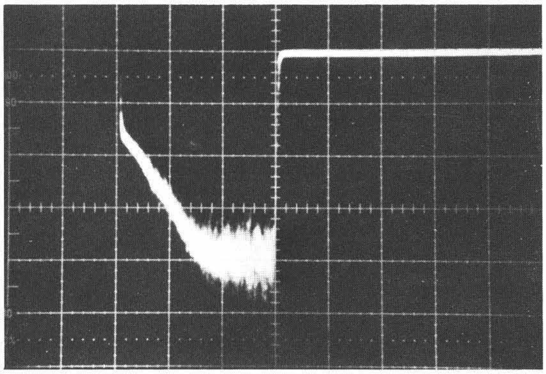

Fig. 4 H$^-$ ion beam of surface-plasma ion source. X: 50 μS/div, Y: 10 mA/div.

High Voltage Apparatus

The accelerating voltage is supplied by an open symmetric Cockcroft-Walton generator. Its voltage will be stabilized within ± 0.1 %. The voltage drop and ripple due to charging and discharging the capacitors are approximately

$$\Delta V_c = \frac{I}{fC}\,\frac{N}{3}\left(\frac{N^2}{2}+1\right) ,$$

$$\delta V_c = \frac{I}{fC}\,\frac{N}{2} \qquad (p - p) ,$$

where N is a number of the stages, I is an output current, C is a capacitance of each capacitor and f is a frequency of the driving AC. Here, N = 4, C = 0.01 μF, f = 350 Hz and the maximum value of I is 5 mA. The voltage drop due to the output current is in some cases much larger than the ΔV_c, however, it is cancelled by a feedback system. δV_c is also reduced by a stray capacitance of the high voltage terminal and a dumping resistor.

The high voltage terminal must be large enough to contain the polarized source and its auxiliary equipments. Moreover, the ordinary H$^-$ source will be tested in it until the operating preaccelerator is changed to the H$^-$ system. So its dome is 4 m long, 4 m wide and 3 m high. An electric power of 80 kVA is supplied in it by a generator driven with a FRP shaft.

The accelerating column consists of two big porcelain tubes similar to the operating column[6], which has run since 1974 and was not disassembled since 1976. There is no indication of deterioration in high voltage characteristics. Its inside diameter is about 1 m, thus it ensures a large conductance for the ion source gas load.

Low Energy Polarized Beam Transporting System

The beam line must transport properly not only the H$^-$ ion but also its proton spin. When the H$^-$ ions are extracted from the polarized ion source and accelerated up to 750 keV, their spins are parallel to the beam direction. Immediately after the accelerating column, they are rotated by a 23.7° bending magnet and become perpendicular to the beam in the horizontal plane. Then, the ions pass through a 0.0704 T-m solenoid and their spins are rotated around the beam axis by 90°. After the solenoid, the ions are focused and bent by quadrupoles and dipoles and injected into the linac through the old LEBT as shown in Fig. 1. The spins are vertical except in a region where the ions go down by 1.4 m from the new preaccelerator level to the old one. Beam envelopes were calculated by the computor program MAGIC and TRANSPORT assuming emittances of $\varepsilon_x = \varepsilon_y = 100\,\pi$ mm•mrad. All quadrupole magnets were made in a company and delivered to the laboratory with their DC power supplies. They have hyperbolic poles and deviation of dB/dr is expected to be less than 0.2 % within 80 % of the bore radius of 4.6 cm. The maximum design field gradient is 4.34 T/m.

The project started in 1980 and is expected to be completed by the end of 1982 fiscal year.

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