Particle Accelerators, 1990, Vol. 26, pp. 229–234
Reprints available directly from the publisher
Photocopying permitted by license only

ITEP PROTON SYNCHROTRON RECONSTRUCTION

N.N.ALEXEEV, A.E.BOLSHAKOV, L.L.GOLDIN, V.I.NIKOLAEV,
K.K.ONOSOVSKY, A.S.RJABTSEV, M.A.VESELOV, V.P.ZAVODOV
Institute for Theoretical and Experimental Physics,
Moscow

Abstract The current status of the ITEP proton and ion accelerator complex which is being created now on the base of the ITEP 10 GeV Proton Synchrotron is described. The paper includes also a brief overview of the ITEP accelerator complex future development plans which are under intensive discussion now. One of the proposals under discussion is the construction of an accelerator with superconducting magnets for 30–40 GeV energy (protons) and $5\cdot10^{12}$ p/s intensity, and an $\bar{p}$-generator for $>10^{7}$ $\bar{p}$/s with $< 10^{-4}$ momentum spread.

INTRODUCTION

The ITEP Proton Synchrotron is now being reconstructed into a proton and ion accelerator complex facility which will be able to accelerate ions of all atoms with various Z/A values [1,2]. The first stage of the reconstruction which, when finished, will make it possible to accelerate partially stripped heavy ions up to 1 GeV/A is in full swing. A new injector for ion acceleration has been constructed and tested. The ion guide from the new injector to the synchrotron has been assembled and put to work. A new synchrotron vacuum chamber and its pumping system which can sequre vacuum better than 10^{-10} Torr have been constructed and assembled [5]. Some parts of high power RF system have been modernized. A new, computer controlled low power RF system has been developed and put to work [3].The slow extraction system has been constructed and is now beam-tested.

First ions of He^{2+} have been injected into the synchrotron and accelerated to 4.3 GeV/A energy in the middle of 1988. First physical experiment with He^{2+} ions accelerated in the ITEP synchrotron had been performed in the 1989 May–June session. The intensity of the beam was approximately 10^{9} particles/pulse. Circulation of about $1.5\cdot10^{9}$ N^{+} ions in the synchrotron ring at constant magnetic field had been achieved in June of this year. Ions were generated in a new injector with a duoplasmotron source. We will be able to accelerate partly stripped ions as soon as we change for new the old internal targets' gears which do not permit us to achieve vacuum better than 10^-8 Torr.

So we can accelerate now in the synchrotron light ions with Z/A = 0.5 up to 4 GeV/A and will be able to deal with unfully stripped heavy ions in near future (up to 1 GeV/A).

The next stage of the reconstruction includes installation of an additional ring in the tunnel of the synchrotron. With this ring finished the acceleration scheme will change. Heavy ions initially accelerated in the synchrotron with small Z / A value will be ejected from the synchrotron, stripped by foil and saved in the additional magnetic ring as long as the synchrotron is reajusted for a new charge value. Afterwards the ions will be reinjected from the saving ring into the synchrotron and accelerated up to the maximum energy (3-3.5 GeV/A).

ACCELERATION OF PARTIALLY STRIPPED IONS

The two step scheme of acceleration of heavy ions that includes as the first step the acceleration of partially stripped ions in the synchrotron gives us the possibility to use a low energy injector and low Z / A values of ions. The disadvantage of the scheme is the necessity of very high vacuum (of the order of 10^-10 Torr) in the synchrotron ring. These requirements, though, are not too severe for modern vacuum technology, and we succeeded in construction of the vacuum chamber and the pumping system meeting all our needs.

Heavy Ion Injector

A simple resonator structure with few accelerating gaps can be effectively used for acceleration of ions with various Z / A values. We use now a structure that contain 4 accelerating gaps. The frequency of the accelerating field is about 3 MHz and the amplitude voltage reached nowadays is about 2 MV. We hope to reach 2.5-3 MV in nearest future. Calculations confirm that 0.5% momentum spread can be sequred for Z / A values from 0.05 to 0.15 with injector phase acceptance of about 180°.

We are going to use several ion sources. Light ions (up to Ne or Ar) can be generated in ordinary duoplasmotron sources which produce rather high ion fluxes in low charge states (up to 3+). Some versions of CO_2 laser sources and a MEVVA ion source are being developed to produce heavy ions from solid substances.We have developed a CO_2 laser source with 5 J pulse energy and are working on the 200 J laser.

Beam Transport Line

The ion guide from the new injector to the synchrotron has been assembled and tested. It is placed in the part of the synchrotron tunnel which is very densely occupied by bulky equipment of secondary beam transfer lines. The trajectory of the injected beam goes around it and has five bends. The parameters of the transported beam are: energy - up to $24(Z/A)^{2}$ MeV/A,transverse emittance - 100π mm·mrad in every plane,momentum spread - up to 0.5%. The ion beam transfer line has been put to work. As was said before circulation of a beam of N^{+} ions in the synchrotron ring had been achieved in June 1989.

RF Low Power System

The new RF-manipulation system for ion acceleration had been developed [3]. As was already mentioned, the synchrotron has to accelerate ions with different Z / A values. The RF-manipulation system is to be easily reajusted from one ion type to another. Intensity of ion beams, especially of heavy ones, may be low. Accordingly, beam position observation and radial feedback seem to be embarrasing. Therefore the system has to reproduce the dependence of the accelerating frequency on the magnetic field induction without radial feedback as accurately as possible. The new system must permit also to change the harmonic number in the course of acceleration because the frequency range of the accelerating stations is unsufficient for heavy ion acceleration.

The new system and the algorithm of its tuning as well as harmonic number change procedure have been tested with protons and He^{2+} ions. Relative deviations of frequency values (wihtout feedback) did not exceed 10^{-4} from those given by calculations. This accuracy is sufficient for ion acceleration.

Vacuum System

We have changed the synchrotron vacuum chamber and its pumping system. The new vacuum system can be heated up to 400° C. For pumping, we use ion pumps and getter elements which are stretched in the vacuum volume along the vacuum chamber walls. To produce these elements we cover stainless steel tubes by porous titanium. The titanium is activated when the tubes are vacuum heated by electrical current. The absorption capability of the getter can be increased essentially if the stainless tubes are cooled by liquid nitrogen. We have reached 1·10^-10 Torr in several sections of the synchrotron vacuum chamber. To the end of this year we will replace the internal targets' gears by new ones and hope to reach 1·10^-10 Torr in the whole volume of the synchrotron chamber.

Slow Extraction

For slow extraction we excite transverse oscillations of the particles in the vertical plane by a third order resonance. The particles with big enough oscillation amplitudes jump over the iron septum of a Lambertson magnet. The vertical magnetic field of the magnet deflects then the particles in horizontal plane and directs them into the beam transfer line. Such a scheme of extraction made it possible to get 40% ejection efficiency. The development of the system to get better ejection efficiency is continued.

We must add here that the traditional schemes of slow extraction are hardly possible in our synchrotron because of large nonlinearity of the magnetic field in the horizontal plane.

Saving Ring

As had already been said it is impossible to get fully stripped heavy ions at injection because of low injection energy. Therefore the ions will not reach maximum energy. It will be possible to do it after saving magnetic ring installation. Accelerated in the synchrotron heavy ions with low Z / A value will be stripped in the foil placed in the transfer line linking the synchrotron with the saving ring. The ions will circulate in the ring as long as the synchrotron systems are ready to accelerate ions with new charge value. Then the ions will be reinjected into the synchrotron and accelerated there up to the maximum energy (3-3.5 GeV/A).

The saving ring has FODO structure and consists of 21 cells formed by 42 bending magnets and 42 quadrupole lenses. The magnetic field in the ring is constant and there are no acceleration stations (small RF-voltage can be used for beam bunching only). By now all the magnets and lenses are installed on their supports with the presizion better than 0.1 mm. The power supply system and cooling system are being assembled. The vacuum chamber production and installation are in full swing. The equipment for the beam transfer lines from the synchrotron to the saving ring and back as well as the equipment of the injection and ejection systems are being manufactured.

Control System

The control system of the heavy ion accelerator complex is based on the existing proton synchrotron control system and is rather its further development. Several mini-computers are linked at the same hierarchical level by a single communication line. Mini-computers are equipped with powerful storage devices and execute the functions of the central processing and the data basing. The distributed equipment of the accelerator complex is linked with the central processors by multidrop buses. The length of the buses is up to 400 m, bit-rate is 5 Mb/s. Interface crates connected to the multidrop buses play the role of knote stations which may be used for modules incorporation and multidrop bus branching. We are going to use several types of knot stations. Some of them are simple data translators between the multidrop bus and branch buses, and the others can be driven by a microprocessor or contain multi-processor assemblies. Some of the micro-processor controlled knots are connected with each other by additional serial data links to reduce the informational load of the multidrop bus. Local control of various types of accelerator equipment will be fulfilled by microprocessor modules of several types.

OUTLOOK IN THE FUTURE

In last years the ITEP proton synchrotron has been working for physical experiments 3,500 - 4,000 houres/year with average intensity 3·10^11 p/s. Secondary particle beams are generated in internal targets by protons of up to 9.3 GeV. In addition, protons with 70-200

MeV energies are used for applied purposes (mostly for medicine). After reconstruction we will be able to accelerate various types of ions up to 3-4 GeV/A. We will direct slow extracted ions and protons into the channels that are used now for secondary particle beams transportation. That is our perspective for the neariest 5-7 years.

The plans of future development of the ITEP accelerator complex are now under discussion and not yet finally determined. We consider ways to increase proton energy up to 15 - 40 GeV and beam intensity to 5•10^12 - 1•10^14 p/s.

The construction of an atiproton facility to generate more than 1•10^7 $\bar{p}$/s of 30 - 40 GeV with 10^-4 monochromatisity is discussed. (To have such an intensity of antiprotons one needs at least 2• 10^12 p/s of 30 GeV energy).An interesting program of experiments with such antiproton beams has been suggested resently [4].

The problems that must be solved are not in the accelerator technology field only. Severely limited territory of ITEP that is situated among the densely populated blocks of the sity limits the size of installations.The ecological problems which arise because of the aboveground position of the now existing proton synchrotron must be very carefully considered in future development plans.

We are working now at the project of the 40 GeV synchrotron (protons) that will be situated in an underground tunnel with about 700 m circumference. Such an accelerator will permit to construct the above mentioned antiproton facility. All variants under consideration include the possibility of ion acceleration.

REFERENCES

1. N.N.Alexeev, M.A.Veselov, L.L.Goldin et all, ITEP Complex for Proton and Heavy Ion Acceleration.IEEE Trans. on nucl.sc.,1985, Vol.32, N 5, p.p. 1693-94.
2. N.N.Alexeev, A.E.Bolshakov, L.L.Goldin et all, Accelerator for Protons and Heavy Ions. Proc. of XIII Inter. Conf. on High Energy Acc.,1987, Vol. 1, p.p. 234-36.
3. N.N.Alexeev, V.P.Piskunov, A.S.Rjabtsev et all, Computer Controlled System for RF-manipulation in the ITEP Proton Synchrotron U-10. Proc.of Europ. Part. Acc. Conf., Rome. 1988.
4. B.L.Ioffe, Preprint ITEP, N 143, 1987.
5. L.L.Goldin, Ju.B.Zudinov, N.E.Ivanov et all, Vacuum Chamber for Proton-Heavy Ion Synchrotron. Proc.of the 1987 IEEE Part.Acc.Conf., Vol. 2,p.p.876-77.