MAINTENANCE OF ITEP-TWAC FACILITY OPERATION AND MACHINE CAPABILITIES DEVELOPMENT

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Abstract

The ITEP-TWAC facility operation with proton and heavy ion beams for ~4000 hours per year in several modes of beam acceleration and accumulation is determined by present-day demands of different beam users in the frame of current machine resources. Displacement of state interests from fundamental research to strictly-practical tasks as the spirit of the time stimulates multimode operation of accelerators with tendency of beam using for applications on the basis of modern beam technologies development. Mastering of Ag^{19+} ions acceleration in the UK ring up to the energy of 100 MeV/u and Fe^{26+} beam stacking in the U-10 ring at the energy of >200 MeV/u in addition to routine operation with C^{6+} beam at energy of 200-400 MeV/u with fast and slow extraction of circulating beam clear the way to beam using for a lot of applications requiring extension of the facility experimental area. Development of laser ion source (LIS) technology takes aim at high current and high charge state ions generation to get ratio of Z/A up to 0.4 for elements with A ~ 60 to be effectively stacked in the U-10 ring with multiple charge exchange injection technique at the beam energy of ~700 MeV/u. The machine maintenance efforts and current results of activities aiming at both subsequent improvement of beam parameters and extending of beam applications are presented.

INTRODUCTION

The ITEP-TWAC Facility consisting of main synchrotron-accumulator U-10 with 25 MeV proton injector I-2 and linked to U-10 ring booster synchrotron UK with 4 MV ion injector I-3 runs now in several operation modes accelerating protons in the energy range of 0.1-9.3 GeV, accelerating ions in the energy range of 0.1-4 GeV/u and accumulating nuclei at the energy of 200-300 MeV/u. Accelerated beams are used in several modes: secondary beams generated in internal targets of U-10 ring are transferred for experiments to Big experimental hall (BEH); beams extracted from U-10 ring in one turn are transferred to Target hall (TH); and proton beam bunch extracted from U-10 ring is transferred to Biological research hall (BRH). Some of secondary beam transfer lines are used now for transferring of slow extracted beams from U-10 ring.

MACHINE OPERATION

Next year will be 50-th anniversary of ITEP Ring Accelerator was started for operation that continues up today in parallels with machine modernization.

Statistic of ITEP-TWAC operation time is shown on Fig.1. The total machine run time of near 4000 hours per year is divided between three operation modes: acceleration of protons (~50%), acceleration of ions to relativistic energy (~10%) and nuclei stacking (~40%). Statistic of beam using for different research fields shows the tendancy of machine operation time increase for applications as proton and ion beams using in biology, medicine and radiation treatment of electronics for cosmic apparatus. The required beam time for users exceeds the possible one by factor of two. This discrepancy has to be cardinally reduced in a result of machine infrastructure development and extension of its experimental area.

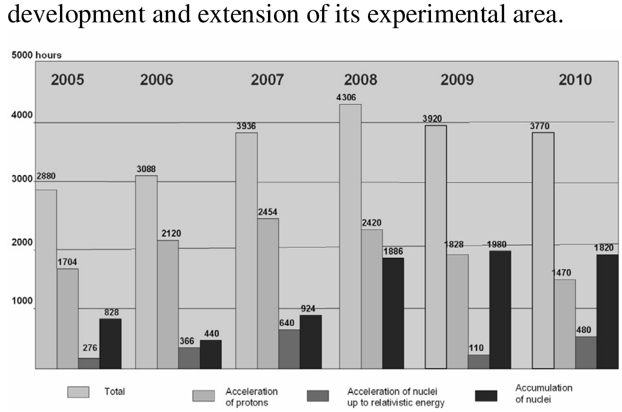


Fig.1. Statistic of ITEP-TWAC operation time

New modes of Fe-nuclei acceleration up to the energy of 3.6 GeV/u and of Ag^{19+}-ions acceleration up to the energy of 100 MeV/u realized in 2008-2009 are illustrated by oscillograms in Fig.2 and Fig.3. In the mode of Ag^{19+}-ions acceleration from very low level of injection energy as 0.7 MeV/u at vacuum in the beampipe as $1x10^{-9}$ Torr, particle losses at acceleration exceeds 90%.

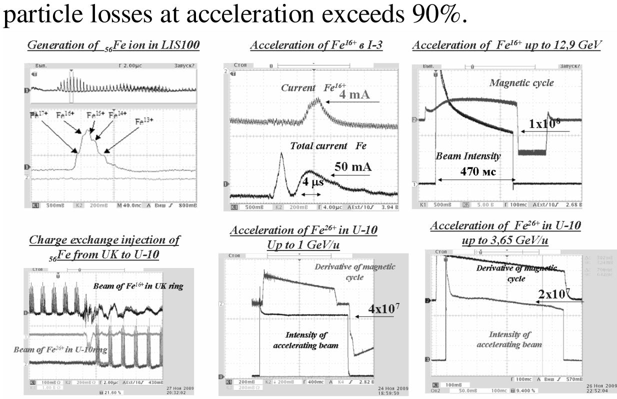


Fig.2. Acceleration of Fe-nuclei up to relativistic energy

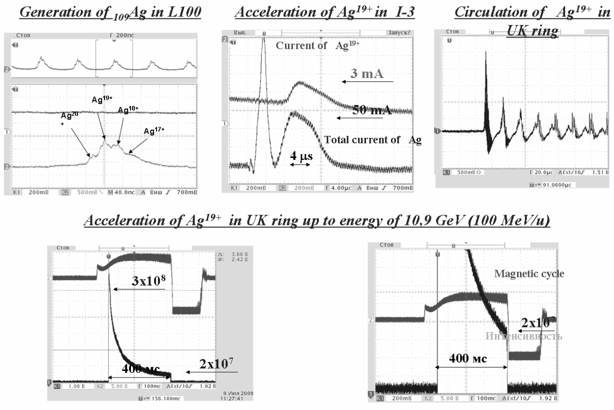
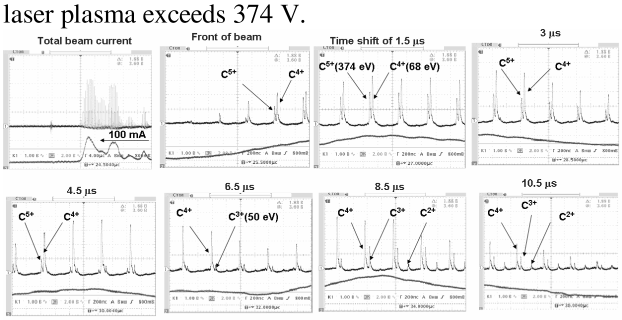


Figure 3: Acceleration of Ag^{19+} ions in UK Ring.

EXPERIENCE WITH LIS OPERATION

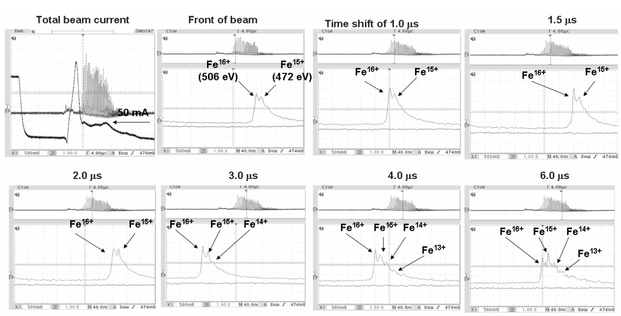
First compact configuration of LIS with 5J CO_2 laser L5 [1] has been in operation at injector I-3 until 2006 when it was reconstructed under using in the frame of a new universal optical scheme the 100J CO_2 laser L100 which was assembled and prepared for operation [2]. Old LIS was used for generation of C-ions only (Fig.4) and maximal charge state specie C^{5+} had been observed in this beam which shows that ionization potential (IP) in the laser plasma exceeds 374 V.



Beam parameters

	C^{5+}	C^{4+}
Pulse width, µs	3.5	10
Number of particles	$3x10^{10}$	$5x10^{11}$

Figure 4: C-ions generation in old LIS with L5 (2006).

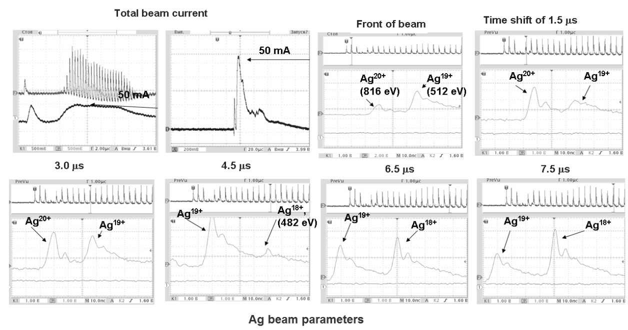


Beam parameters

	Fe^{16+}	Fe^{15+}
Pulse width, µs	4.5	5
Number of particles	$1x10^{10}$	$8x10^{9}$

Figure 5: Fe-ions generation in new LIS with laser L100.

The new LIS with laser L100 is in operation from 2008 and it's used with target materials of Al, Fe and Ag. Generation of Fe-ions (Fig.5) shows maximal charge state specie Fe^{16+} with IP= 506 V. The higher level of charge state specie Fe^{17+} with IP=1168 V has been also observed in some measurements but in very few quantity. Generation of Ag-ions (Fig.6) shows maximal charge state specie Ag^{20+} with IP= 816 V and very few specie Ag^{21+} with IP= 960 V has been also observed in some measurements. Summarizing results of ion generation in old and new configurations of LIS at injector I-3 is shown on Fig.7 with another data obtained from different publications [3-6].



Ag beam parameters

	Ag^{20+}	Ag^{19+}
Pulse width, ms	2.5	6
Number of particles	$2x10^{9}$	$1x10^{10}$

Figure 6: Ag-ions generation in new LIS with laser L100

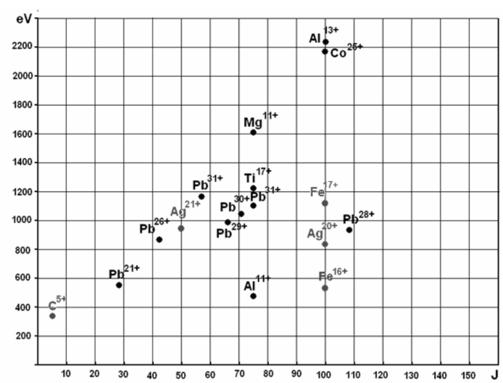


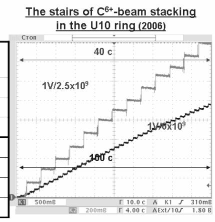
Figure 7: Ionization potentials reached in LIS stand tests from different publications (black points) and in LIS at injector I-3 (red points) from laser used radiation energy.

DEVELOPMENT OF HEAVY NUCLEI STACKING TECHNIQUE

The charge exchange injection technique is used now with stacking factor of 70 for C-nuclei stacking at the beam energy of 300 MeV/u [7]. The efficiency of Fe-nuclei stacking at the energy of 230 MeV/u is limited on the level of stacking factor 10 due to disturbing effects of beam interaction with stripping foil. Efficiency of beam stacking for nuclei of mass number A~60 will be increased many times with increasing of injected beam energy up to 600-700 MeV/u. For nuclei with A<30, disturbing effects of beam interaction with stripping foil are small enough and efficiency of beam stacking is a function of injection scheme parameters and of storage ring dynamic aperture. We are planning to start experiments on the beam stacking process optimization at the end of this year with stacking of Si^{12+}=>Si^{14+} ions at the energy of >500 MeV/u. Expected results of stacking process improvement are shown on Fig.8.

Parameters of beam stacking with laser L5 (L100 for Si) and 4MV injector I-3

Parameters	Reached for C^{4+}=>C^{6+}	Expected for C^{4+} =>C^{6+}	Expected for Si^{12+} =>Si^{14+}
Energy	300 MeV/u	400 MeV/u	650 MeV/u
Injected beam intensity	$6x10^8$	$\sim5x10^9$	$\sim5x10^9$
Cycle time , s	3	2	2
Acceptance, A_x, π mm mrad	10	30-50	30-50
Vacuum, Torr	$\sim1x10^8$	$\sim1x10^9$	$\sim1x10^9$
Stacking factor	~70	~200	~200
Stacked beam intensity	$4x10^{10}$	$\sim10^{12}$	$\sim10^{12}$



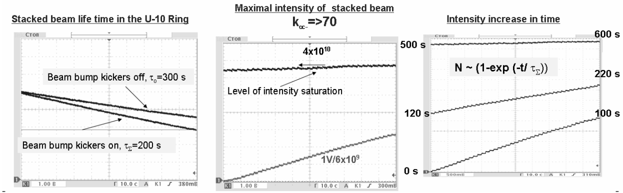


Figure 8: Optimization of beam stacking at A<30.

DEVELOPMENT OF ITEP-TWAC INFRASTRUCTURE

Elaborated strategy of ITEP-TWAC infrastructure development is aimed to redouble beam time for physical experiments and applications extending of functionality of UK synchrotron for protons acceleration too and for generation of slow extracted beams to the area of beam using for applications. Layout of expanded Injection Complex with additional beam lines from injectors both I-2 and I-4 to UK Ring is shown on Fig.9.

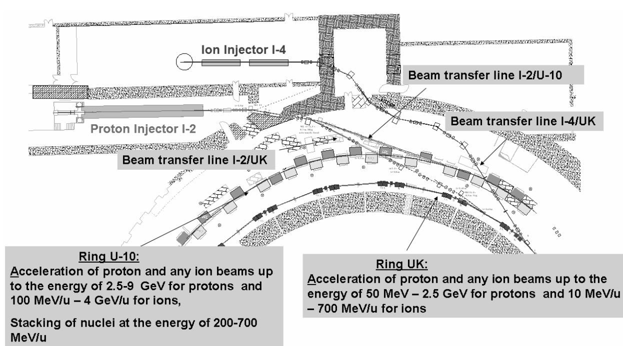


Figure 9: Expanding of ITEP-TWAC Injection Complex

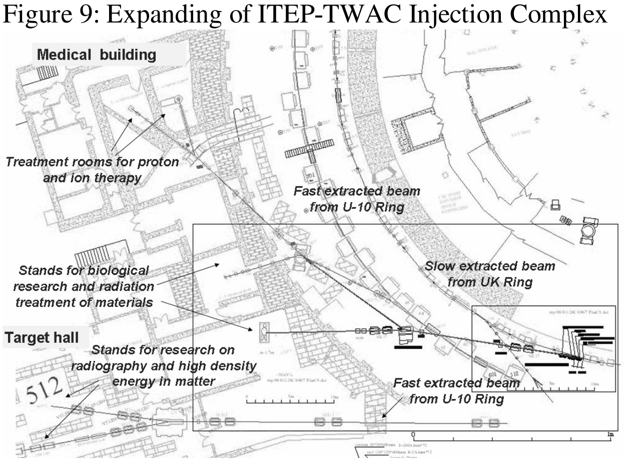


Figure 10: Expanding of beam area for applications.

Layout of beam using area for applications is shown on Fig.10. New projected beam line for slow extracted beam from UK Ring is directed to free space of Target hall (where stand will be installed for biological research) and linked with beam line from U10 Ring used now for proton therapy.

We consider also possibility of construction the second slow extraction system for U-10 Ring to BEH [8] for the beam of maximal beam momentum of 10Z GeV/c. Area of this beam using in the corner of BEH has to be rounded by radiation shielding.

CONCLUSION

The ITEP Accelerator Facility is in operation by ~4000 hours yearly accelerating proton and ion beams and stacking nuclei for physics experiments, methodical research and radiation technologies.

The progress has been achieved in acceleration of heavy ion: specie of Ag^{19+} have been generated in LIS and accelerated in synchrotron UK up to the energy 100 MeV/u with intensity of $2x10^7$; nuclei of Fe^{26+} have been accelerated using three stage scheme I-3/UK/U-10 up to record energy of 3.6 GeV/u or 200 GeV per particle with intensity of $5x10^7$.

Experiments on the ion beam generation in LIS with 100J CO_2 laser L100 give evidence of optic used imperfection reducing the laser radiation power density on the target surface by factor of more than ten. New focusing scheme for target station is elaborated on a base of parabolic short focusing mirror to increase the power density by factor of three. Next factor of power density increase will be achieved replacing windows by them of better quality.

Construction of the new heavy ion injector I-4 is in progress: the RFQ section for the energy of 1.5 MeV/u of Z/A=0.3 ions is constructed and successfully tested for resonator parameters measuring and RF power loading [9]. Preparations of RFQ section for the beam test is now started to be carried out in the first quarter of next year.

The progress in intensity of heavy ion beam stacked in U-10 Ring using multiple charge exchange injection technique is expected in the experiments planned for the end of this year with ions Si^{12+}=> Si^{14+} stacking at the energy of 500 MeV/u.

Development of ITEP-TWAC facility Infrastructure is aimed to redouble beam time for physical experiments and applications making operation of both U-10 and UK synchrotrons in parallels .

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