THE NEW PROJECT OF INR (KIEV'S) STORAGE-ACCELERATING COMPLEX

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Abstract

The new project of Ion Storage Ring (ISR) complex of Institute for Nuclear Research (INR) of Ukrainian Academy of Sciences is presented. The INR ISR complex consists of the U-240 isochronous cyclotron, the ISR with the Electron Cooling (EC) and intermediate Fast Booster (FB). The INR ISR complex will provide ion beams of wide mass range (from protons to xenon) including radioactive ion beams with the energies up to 300 MeV/u at A/Z=2.

1. Introduction

In 1989 the Institute for Nuclear Physics (INP, Novosibirsk, Russia) and INR (Kiev, Ukraine) created the project of the Ion Storage Ring for INR, allowing to provide the experiments with light and middle nuclei up to Neon [1]. In 1991 Efremov's Institute, INR and INP prepared the essentially improved new project of ISR based on the INR U-240 isochronous cyclotron.

The ISR complex of INR is planned to be built in two stages. First, the main ISR with electron cooling will be built for storage of light ions up to neon at injection energies 5-10 MeV/u to have ion beams with energies up to 300 MeV/u. At the second stage the intermediate fast booster (FB) with a multiple charge exchange of ions will be created to have possibility to accelerate ions heavier than neon in order to store them in the main ISR. The storage and cooling of nuclei at physical experiment take place in the main ring (fig.1). The main parameters of the ISR complex are presented in Table 1.

Table 1.

Circumference, m:	
Storage Ring	100
Booster	54
Mass range	1-130
Max.energy, MeV/u:	
protons	900
ions with A/Z=2	300
ions with A/Z=3	200
Magnetic field, T	1.5
Magnetic Rigidity,T·m:	
Booster	4.3
Storage Ring	5.4
Injector	U-240
A/Z	1-3
Injection energy,MeV/u:	
light ions(p,d,a)	25-70
C - Ar	5-10
Kr - Xe	3
Electron cooling energy, kev	2-100
Vacuum, torr	10^{-11}

2. The beam parameters

The average current of U-240 cyclotron ion beams changes from 0.2 μA for the Neon up to 10 μA for protons. When the Electron Cyclotron Resonance (ECR) source will be put into operation then all ions up to Xenon can be accelerated on U-240.

The ISR operation cycle is the following:

1. Injection (duration is 2-40 μsec). Single turn injection for the completely stripped ions is carried out, multiturn charge- exchange injection of heavy ions is prosecuted /2/.

2. RF stecking (duration is 10-20 msec) with increasing of the injected beam energy on 2.1% . RF stecking used for elimination of the cooled beam passing through the stripping foil

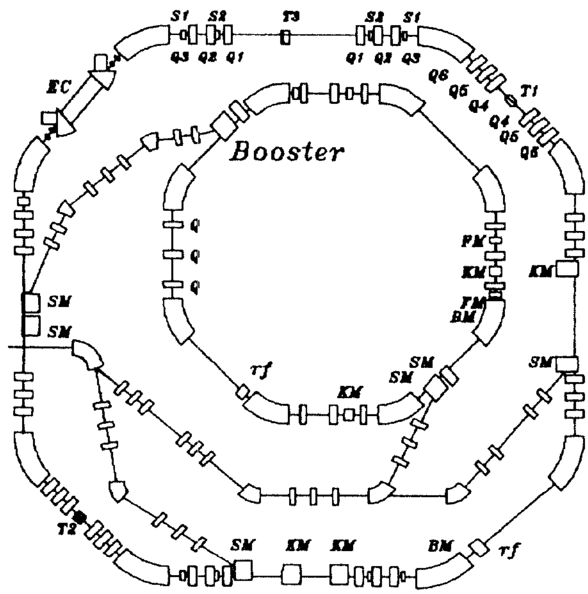

Fig.1. Magnetic structure of Ion Storage Ring and Fast Booster:
BM - bending magnets, Q_i- quadrupoles, T_i- targets, EC - electron cooling, KM - kicker magnets, SM - septum magnets, FM - fast (bump) magnets, rf - RF cavity.

or the injection kicker magnet during following injection cycles.

3. Electron cooling: during the 40-1400 msec the beam is cooled and then another injection cycle follows.

4. Storage:the above mentioned cycles are repeated many times (up to 10 sec or more).

5. Acceleration - during 1 sec the ions are accelerated.

6. Physical experiment (up to 10 sec or more) with electron cooling on high energy.

7. New cycle preparation is 1 sec.

The storage of ions heavier than the Ne ions is impossible at U-240 cyclotron injection energies, because total ion life-times are less than 1 sec. All elements up to Xe can be stored in the main ring if the preliminary acceleration in Fast Booster is used (total storage time can be reached 46 sec for the Kr ions and 20 sec for the Xe ions). The pressure in the ring must be better than 10^{-10}Torr.

When the internal target is switch on, the ion life-time is defined by the single scattering on the target and electron capture by the target atoms since multiply processes are suppressed by electron cooling. The calculations shown that the typical ion life-time is about 20 sec for the heavy ions and the Pb target.

The target thickness should not exceed $2.6\cdot10^{16}/Z_t$ cm^{-2} to compensate the energy losses in the target by means of electron cooling during one ion turn.

The ISR beam parameters estimates are: cooled beam emittance is 2.4 π mm mr for protons ($N=10^{11}$) and 0.2 the Ne ions ($N=10^{9}$), cooled beam cross-section diameter on the target is 2.8 mm for the protons and 0.6 mm for the Ne ions.

3.Magnetic structure of storage ring and fast booster

Designing ISR magnetic structure it was taken into consideration of such requirements:

1) to have the straight sections (with length 7 m) for electron cooling system with zero dispersion (ψ=0) and to obtain the symmetrical beam sizes, i.e. beta-functions with $\beta_X= \beta_Z= 4$ m.

2) to also have the straight sections (with length more than 6 m) in which the dispersions function must be constant (ψ=3 m); these sections will be used for the radial multiturn charge-exchange and single-turn injections;

3) to have straight sections for the internal targets and coordinate triplets which must assure small beam size on the target (i.e. $\psi = 0$, $\beta_X$and β_Z- functions less than 1m).

4) to have straight section for the radial injection from FB to ISR.

5) to provide, for all regimes, the constant position of working point of betatron oscillations to prevent the crossing of resonance lines.

To carry out the aforementioned requirements the octupole magnetic structure with triplets is most convenient (fig.1).

The ion storage ring is the zero gradient synchrophasotron which includes eight 45^0 bending magnets and 36 quadrupole lenses. The

ISR magnetic structure consists of the two superperiods. Beta- functions and dispersion for the ring one-quarter are shown in fig.2.

Two symmetrical triplets $Q_4Q_5Q_6$ provide the beam focusing on the target. When coordinate triplets $Q_4Q_5Q_6$ are switched on the β-functions do not change throughout except in the experimental section where β-function is minimized (dashed lines in fig.2). For the experiments which don't require zero dispersion there is the 6 m section where T_s target can be installed.

Betatron tune values for ISR are: for synchrotron mode ν_x=3.16, ν_z=2.43, for low β-mode ν_x=3.63, ν_z=3.12.

For the chromatic corrections will be used 8 sextupoles installed between main quadrupole lenses.

The booster magnetic structure is more simple (fig.3). Betatron tune values for FB are: ν_x=1.61, ν_z=1.27.

The bending magnets of ISR and FB have frame shape.

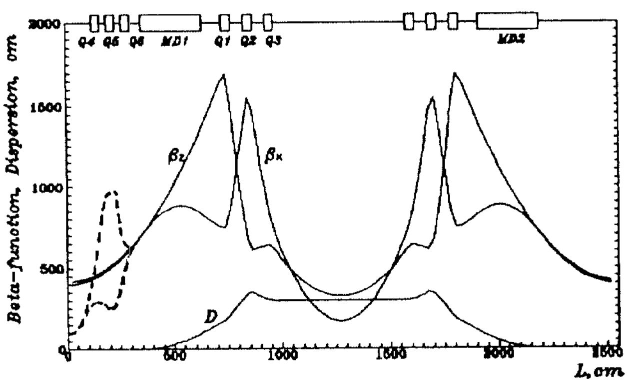

Fig.2.Beta-functions and dispersions on one-quarter of SR:
solid lines - synchrotron mode ($Q_{4,5,6}$-switch off), dashed lines - low β-mode ($Q_{4,5,6}$ - switch on).

4. Electron cooling system

In the electron cooling system the solenoids with the magnetic inhomogeneity $B_\perp/B_\parallel = 3\cdot10^{-5}$ are used. The electron beam is formed by the two-electrodes gun with a smooth optics. The cathode is immersed into the longitudinal magnetic field. The pair of correction magnets with effective length of 20 cm are situated in the entrance and exit of cooler to compensate a negative influence of toroidal magnets on the ion beam. [3,4].

5. Injection system

The single-turn injection into the ISR was designed for the light ions. The such injection system is also used for the ion beams transmitted from U-240 cyclotron into FB and from FB to ISR.

The multi-turn radial injection system with the ion stripping on the foil was designed for the incompletely stripped ions with A/Z = 3-5. During injection the ions with A/Z = 4 and A/Z = 2 fall simultaneously on the stripping foil just where the tangencies come together.

To inject a new beam portion in the ISR the circulating cooled beam must been shifted to the outer orbit on 5-6 cm with increasing of beam energy on 2.1% by auxiliary RF cavity. All injection elements are located in one of the straight sections.

6. Conclusions

The experimental luminosity is expected to be 10^{29}-10^{30} $cm^{-2}\cdot sec^{-1}$ and the ion beam life-time from several tens to hundred seconds. The Storage - Accelerating Complex is planed to use for the studies of nuclear reactions in the wide energy range, nuclear spectroscopy, nuclear structure etc.

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