Ion Storage Ring of the INR Storage-Accelerating Complex

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Abstract

The Storage - Accelerating Complex (SAC) of heavy ions is intended for the storage of ions up to Neon, their acceleration up to an energy of 300 MeV/n (A/Z=2), and physical experiment on an internal target with the electron cooling used at a high energy. The experiments can be performed both with narrow and wide beams on the targets. The stored current is about $10^9 - 10^{11}$ particles, the luminosity is expected to be $10^{29} - 10^{30} cm^{-2} \cdot sec^{-1}$, the ion beam life-time - several tens of seconds.

I. THE STRUCTURE OF THE COMPLEX AND ITS MAIN PARAMETERS

The Storage-Accelerating Complex of heavy ions at the Institute for Nuclear Research (Kiev, Ukraine) comprises the isochronous cyclotron U-240 used as an injector, fast booster and storage synchrotron. Two stages are anticipated for the SAC development. The storage synchrotron is planned to be constructed in the first stage to store an ion beam up to Ne with the RF-stacking and electron cooling system used to accelerate ions to 300 MeV/n (A/z=2) and to operate on to the inner target at a continuous electron cooling. In the second stage a multiturn recharging injection into the storage synchrotron from U-240 will be implemented, a fast cycling 200 MeV/n (A/z=2) booster with a repetition frequency of 5 Hz will be constructed and repeated single-turn injection from the booster to the storage synchrotron will be realized.

The SAC will make it possible to operate with intensive beams of radioactive nuclei and ions in a wide range of masses (from proton to xenon) with an energy of up to 300 MeV/n (A/z=2) at a high luminosity. The SAC scheme is shown in Fig.1. Its main parameters are given in the table 1.

II. RING ELECTROMAGNET OF THE STORAGE SYNCHROTRON.

It comprises two superperiods with a triplet focusing and includes eight 45 bending magnets, 36 quadrupole lenses and 8 sufficiently long rectangular sections of 3 different types. Two of them with a zero dispersion and $\beta_{x,z} \approx 2-5$m are intended for the installation of the electron cooling system (CЗО) and acceleration stations (УС). Another two of them with a zero dispersion and low $\beta_{x,z} < 0.8$m are designed specially for physical experiments on the target M1. The beam is focused on M1 by two triplets of the quadrupole lenses ЛК 4-6. The arrangement and parameters of the lenses are selected so that their switching-on changes the characteristic functions only in the section, where they are installed. The rest 4 sections with the dispersion different from zero are intended to perfom physical experiments on the target M3 ($\beta < 4$m, $\psi \approx 3$m) and to implement 3 different types of injection into the storage synchrotron, i.e. single and multiturn recharging injection from U-240 with the electron cooling and RF-stacking used and single-turn injection from the booster. Eight sextupole lenses are used for chromaticity correction.

III. INJECTION AND STORAGE.

An average current of ion beams from the cyclotron U-240 varies from 0.2 μA (Ne) to 10 μA (P). With the ECR-source used the ion heavier than Xe can be accelerated in cyclotron. The operating cycle of the storage synchrotron (without the booster) is the following:

1. the single-turn injection of light element nuclei or multiturn recharging injection (of about 40 μA duration) of heavy ions;
2. RF-stacking (of 10–20 ms duration) with an increase in the energy of the injected beam by 2.3% (single-turn injection) or by 1.2% (multiturn recharging injection). The RF-stacking is used to eliminate the cooled beam travel through the input kicker-magnet or the stripping target M2 with, respectively, these two types of injection used;
3. electron cooling of the injected beam during 40–1400 ms;
4. storage resulting from the multiple repetition of the operation according to the above points 1, 2, 3 (duration of up to 10 s and more);

0-7803-1203-1/93$03.00 © 1993 IEEE

Table 1: The SAC parameters

	storage-synchrotron	booster
Perimeter, m	106.275	57.452
Number of betatron oscillations	3.709/3.406	1.8/1.288
Magnet field induction, T	1.5	1.5
Maximum magnet rigidity, T·m	5.4	4.3
Injection energy from U-240, Mev/n		
light ions	25 - 70	25 - 70
C - Ar	5 - 10	5 - 10
Kr - Xe	3	3
Maximum energy, Mev/n		
protons	930	660
ions with A/z=2	300	200
ions with A/z=3	144	94
Vacuum, Torr	lower than 10^{-10}	10^{-9}

5. acceleration with a duration of 1 s;
6. a physical experiment ($\geq$ 10 s) with the electron cooling at high energy;
7. preparation of a new cycle of $\approx$ 1 s.

To store light ions in the storage synchrotron the sngle-turn injection is used. It is used as well to inject the beam into the booster. The injection of not completely stripped ions with $A/z = 3 - 5$ is implemented with the stripping on the foil. The beam is injected onto the closed orbit in the septum-magnet area. After 10–15 turns the disturbance is removed for about a period of revolution and electron cooling system is switched on [1]. The beam is compressed. With a special RF-resonator used, its energy is increased by 1.2% and the closed orbit is displaced outwards by 3.7 cm. Then, RF is rapidly reset, the cooled beam leaves the resonance with the RF-field and moves along the displaced orbit, where $\psi = 0$. The injection cycle is repeated.

The life time of the ions heavier than Ne is 1 s at a pressure in the vacuum chamber of $< 10^{-10}$ Torr and energies achievable on the cyclotron U-240. That is why, their storage is possible only with the booster used. The total storage time in this case amounts to 46 s (Kr), 20 s (Xe). With the operation on the inner target the ion life time is determined mainly by a single scattering on the target and the electron capture by the target atoms, as the multiple processes are suppressed by the electron cooling. The target thickness should not exceed $2.6 \cdot 10^{-16}/z_t$ cm^{-2} so as to compensate energy losses in the target by the electron cooling. A typical life time of heavy ions with a plumbum target is about 20 s. The cooled beam with a maximum energy has an emittance of 2.4π mm·mrad for protons ($N = 10^{11}$) and 0.2π mm·mrad for Ne ions ($N = 10^9$) and a size on the target of 2.8 mm and 0.6 mm for P and Ne ions, respectively.

IV. REFERENCES

[1] N.S. Dikansky et al. "Predelnye vozmozhnosti elektronnogo okhlazhdeniya", Preprint N 88-61, IYaF SO AN SSSR, Novosibirsk, 1988.

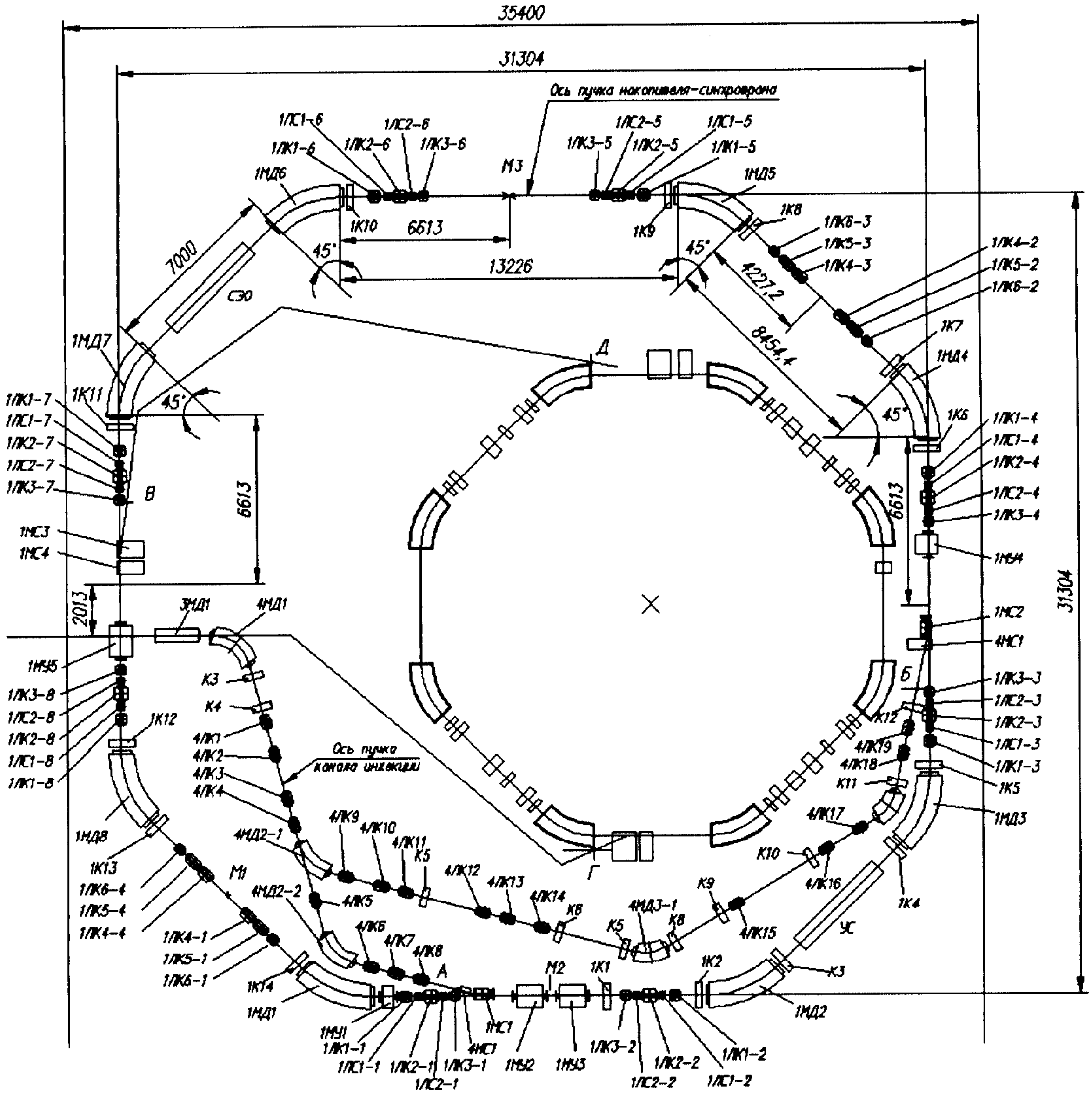

Fig. 1. The INR (Kiev) Storage-Accelerating Complex