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HEAVY ION ACCELERATOR FACILITY

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The study of relativistic nuclear physics and of anomalous states of nuclear matter in the multi-hundred MeV range defines to a large extent the approach and the main parameters of a heavy ion accelerator facility (HIAF)[1] developed using the Dubna synchrophasotron.

The HIAF will consist of two steps in cascade (Fig. 1). The first step is a heavy-ion synchrotron (HIS). It must provide for a physics program utilizing beams of heavy ions in the medium energy range and also injection into the synchrophasotron. In the future it will provide injection into the nuclotron.[2]

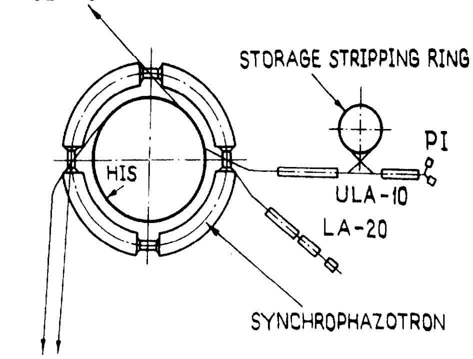

Fig. 1. Schematic layout of the heavy-ion accelerator facility.

A special linear accelerator, ULA-10, and a 20 MeV proton linear accelerator, LA-20, will be used as the HIS injector. The peak energies of some characteristic beams are given in Table 1.

TABLE 1.

Accelerated nucleus	Energy, GeV/nucleon HIS		SFT
^{40}Ar	0.47	0.60[a]	4.1
^{132}Xe	0.35	0.49[a]	3.6
^{238}U	0.25	0.34[a]	3.4

[a]At fast injection.

As a source of ions for the ULA-10, it is planned to utilize a Penning type source.

An electron-beam source[3] will be used when accelerating nuclei up to argon or calcium in the LA-20.

It is planned to construct the linear accelerator, ULA-10, in two parts. In the first part, phase-variable focusing[4,5] will be used up to energies of 1 MeV/nucleon. Focusing by magnetic quadrupoles will be used in the second part from 1 MeV/nucleon up to 10 MeV/nucleon. A stripping section with a solid target, focusing devices and bending magnets is placed between these parts. The accelerating system consists of four resonators. The first two resonators are excited at a frequency of 25 MHz, and the others at a frequency of 150 MHz. Each resonator is excited from a separate HF generator. The basic parameters of the ULA-10 are presented in Table 2.

TABLE 2.

First part:	
Energy of injected ions	15 KeV/nucleon
Energy of accelerated ions	1.0 MeV/nucleon
Accelerated ions	Ar - U
Momentum spread, $\Delta p/p$	±0.006
Beam emittance	10π cm·mrad
Space charge limitation	3 mA
Repetition rate	1 - 3 Hz
Second part:	
Energy of injected ions	1 MeV/nucleon
Energy of accelerated ions	10 MeV/nucleon
Accelerated ions	Ar - U
q/A of injected ions	39/238 for U
Number of accelerated charges	9 for U
Acceptance	13π cm·mrad
Accelerated beam emittance	
for one charge	3.5π cm·mrad
for nine charges	8.3π cm·mrad
Momentum spread	
for one charge	±0.001
for nine charges	±0.002
Space charge limitation	80 mA
Repetition rate	1 - 3 Hz

Magnetic elements developed for the IHEP booster[6] will be used for the HIS. To a large extent, this defines the structure of the synchrotron.

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As described in Ref. 7, some charges can be accelerated simultaneously in a strong-focusing synchrotron with a momentum compaction of $\alpha \ll 1$. In this case the momentum spread $\Delta p_s/p_s$ of synchronous ions with charge spread $\Delta q/q$ is determined by the ratio

$$\Delta p_s/p_s = -\alpha\gamma^2\Delta q/q \quad .$$

In the HIS, three uranium charges $q = 70 \pm 1$ can be simultaneously accelerated for which $p_s/p_s = \pm 0.001$. This momentum spread is about five times smaller than for adiabatic capture.

The accelerator will have a circumference of 150 m and consist of eight superperiods. Each superperiod will include three periods with FODO structure (Fig. 2, Table 3).

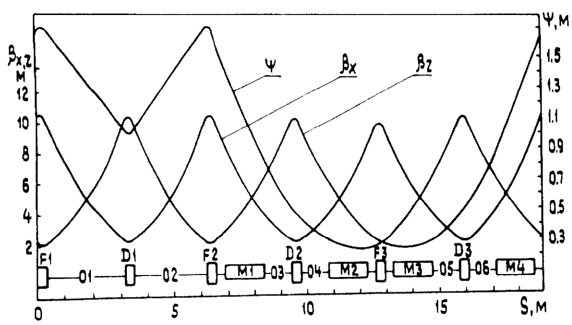

Fig. 2. HIS superperiod.

TABLE 3. Main parameters of the HIS magnetic system.

	$^{238}U^{70+}$	Nuclei q/A = 0.5
Kinetic energy, MeV/nucleon		
peak	250	616.3
injection	10	10
critical	3390	3390
Magnetic rigidity, TM		
peak	8.262	8.262
injection	1.556	0.916

Radius of the orbit curvature in the dipole magnets	7.538 m
Number of dipole magnets	32
Number of quadrupole lenses	48
Length of a dipole magnet	1.48 m
Length of a quadrupole lens	0.465 m
Aperture of a dipole magnet	170×74 mm^2
Aperture of a quadrupole lens	ϕ 150 mm
Aperture of the vacuum chamber	150×54 mm^2

The betatron oscillation frequency is chosen to be $Q_x = 5.80$, $Q_z = 5.85$. The horizontal and vertical acceptances determined by the dipole magnet aperture are equal to $A_x = 46\pi$ cm·mrad, $A_z = 9.6\pi$ cm·mrad.

The HIS electromagnet will be excited by trapezoidal pulses with a dwell period for injection and a smooth transition to the flattop.

TABLE 4. Basic parameters of the HIS accelerating system.

Number of harmonics	-3
Frequency range	(0.87 - 5.06) MHz
Number of accelerating stations	4-6
Peak accelerating voltage	40 kV
Acceleration time	0.07 s
Peak power consumed by a station	75 kW

A vacuum pressure no less than 2×10^{-9} Torr will be held in the HIS vacuum chamber.

The beam intensity will be increased by means of a storage-stripping ring (SSR). Multiply charged injection into the SSR is provided by multiple passage of ions through a special target placed in the vacuum chamber. A special type of magnetic channel[8] is needed to implement this method. The dispersion function, ψ, and its derivative should be equal to zero at the azimuthal position of the target.

The intensities of particles at the extraction points of the HIS and the synchrophasotron are shown in Table 5.

TABLE 5.

Type of accelerated particles	Intensity (particle/cycle) HIS	Synchrophasotron
U	3×10^8	10^8
U (with storage)	3×10^9	10^9
Xe	3×10^9	10^9
Xe (with storage)	3×10^{10}	10^{10}
Ar	1.6×10^{11}	10^{11}

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