DESIGN FEATURES AND OPERATIONAL PARAMETERS OF CHARGE-EXCHANGE HEAVY ION ACCELERATOR UKP-2-1

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Heavy ion accelerator UKP-2-1 is quite precision 1 MV tandem machine allowing to accelerate different ion species, including inactive gas ions, in µA current range. Brief description of UKP-2-1 construction and some preliminary results, obtained during trying out of the machine, installed in Alma-Ata Institute of Nuclear Physics are presented.

Heavy ion tandem UKP-2-1 is intended for investigation in solid-state physics, low-energy nuclear physics and for solution of applied problems in microelectronics and material-engineering.

UKP-2-1 Design parameters:
Beam energy (singly charged ions)..0.4-2.0 MeV
Energy stability.........................0.05%
Beam current.......................up to 50 µA
Mass range..........................1-250 AMU

Two crossed acceleration tracts on the base of one high-voltage source is the main feature of the accelerator. The first tract is used for heavy ion beam acceleration, the second one is for acceleration of hydrogen ions and also inactive gas ions by means of injection of inactive gas atoms. There are four beam transport channels. If necessary, two beams can be directed to same target chamber simultaneously.

Accelerator component layout is shown schematically in Fig.1.

Injector 1 is intended for obtaining of heavy negative ion beams. It include negative ion source, initial beam-forming system, mass-analyzer, einzel lens, electrostatic corrector and Faraday cups with quartz glasses. Cesium sputter ion source [1] allows to obtain beams with current up to 60 µA and emittance less than 0.9 cm·mrad·MeV$^{\frac{1}{2}}$. Immersion lens with a grid on the accelerating electrode is used for initial beam focusing. Mass-analyzer consists of 45° double focusing magnet and remote-controlled iris diaphragm.

Injector 2 is meant for obtaining of H_1^- beam and atomic beams of inactive gases. It includes ion source, initial beam-forming system, separator of electrons accompanying H_1^- beam, gas neutralizer of positive ions of inactive gases with separator of nonneutrolyzed ions and Faraday cup. The same duoplasmatron with displaced emission hole [1] is used for H_1^- and positive inactive gas ion beams production. This ion source allows to obtain H_1^- and $He^+, \ldots Xe^+$ ion beams with current up to 100 µA and emittance less than 0.1 and 0.3 cm·mrad·MeV$^{\frac{1}{2}}$ accordingly. Initial forming of the beams and adjustment with accelerating structure is implemented by immersion and einzel lenses. The separators mentioned above are used also for angular correction of injected ion beam in two planes.

Beam energy at the outputs of both injectors is 30 - 50 KeV.

High-voltage structure of the accelerator is placed in tank under 1.5 MPa pressure of N_2 and CO_2 mixture. Top view of the high-voltage structure is shown in Fig.2. For easy maintenance an accelerating voltage source has been installed on the high-voltage terminal of the accelerator. Isolation column with RC-filter is used as high-voltage terminal support. Accelerating voltage source is symmetric capacitive cascade voltage multiplier for output voltage up to 1.1 MV at 0.5 mA load current.

Four accelerating tubes are located in a horizontal plane. Axes of the tubes and gas charge-exchange targets of each acceleration tract are displaced with respect to each other by 20 mm vertically. Accelerating tubes with ceramic insulators and stainless steel conical removable electrodes have active length of 700 mm. Molybdenum fine grids are installed at the entrance of the tubes. Entrance of the accelerating tube, placed behind the charge-exchange target of 2nd tract is also closed by remote-controlled grid when accelerating inactive gas ions.

Beam transport channels of both tracts are

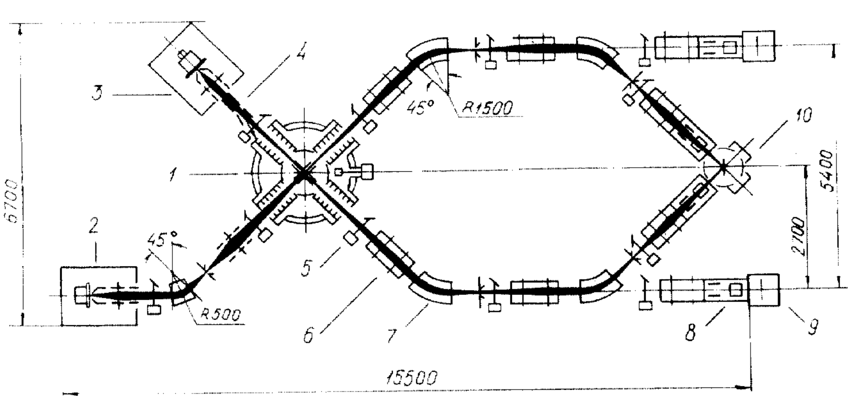

Fig.1 Component layout of UKP-2-1
1. High-voltage structure
2. Injector 1
3. Injector 2
4. Neutralizer
5. Faraday cup with quartz glass
6. Quadrupole doublet
7. Analyzing magnet
8. Electrostatic scanner
9,10 Target chamber

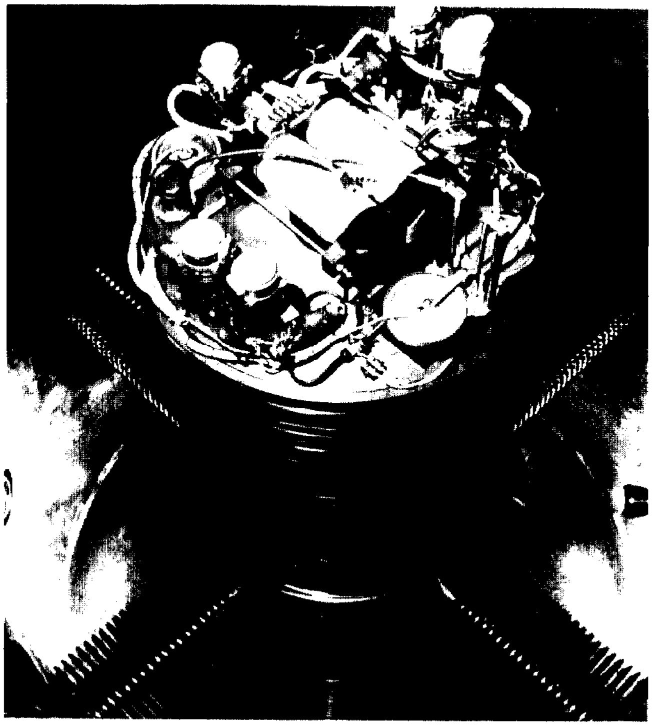

Fig.2. Top view of the high-voltage structure

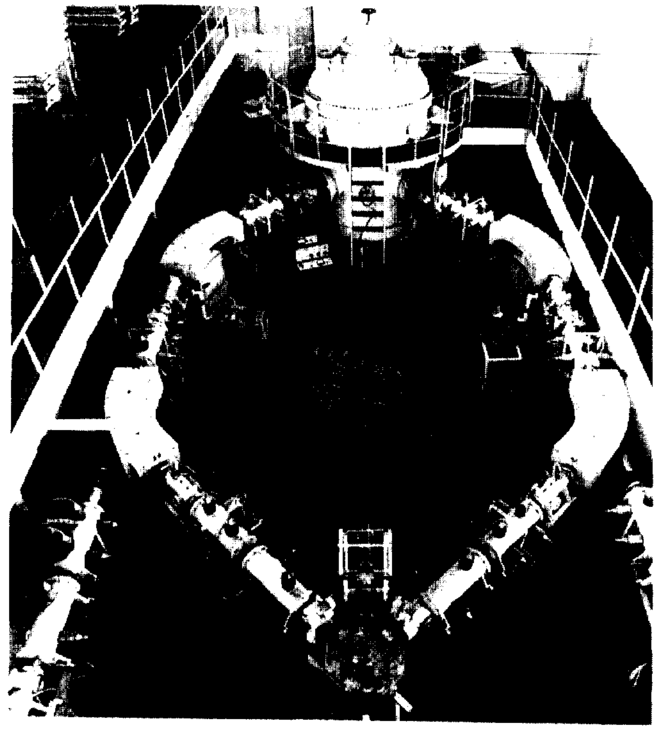

Fig.3. Heavy ion tandem UKP-2-1

identical. They include doublets of electrostatic quadrupole lenses, analyzing and bending magnets, slit assemples, electrostatic scanners and movable Faraday cups with quartz glasses. View of UKP-2-1 accelerator from beam transport channels side is shown in Fig.3. Analyzing and bending magnets are 45° sector ones. Magnetic field homogeneity in the operating region is better than 0.1%. Nuclear magnetic resonance sensors are used for magnetic field measurement and stabilization. Magnetic field instability is not worse than $5 \cdot 10^{-5}$.

Vacuum system of the accelerator has been fulfilled on a base of magnet-discharge pumps. Additionally two diffusion pumps with polyphenyl compounds based fluid are installed in the region of 2nd injector neutralization target.

In 1989 trying out of main units and systems of UKP-2-1 accelerator, installed in the Alma-Ata Institute of Nuclear Physics was carried out. Preliminary investigation of accelerator characteristics in various regimes of operation have been performed. Operating range of beam energy has been expanded up to 0.1 - 2.0 MeV. Beam transmission for different particles in the operating range of energy and current have been investigated. A throughput coefficient for 60 μA hydrogen ion beam in 0.4 - 2.0 MeV energy range about 0.8 and at 0.1 MeV about 0.6 was reached. Dependence of beam transmission on energy for heavy ions is more sharp due to a higher value of emittance. So, for oxygen ions at 1.0 and 0.2 MeV a throughput coefficient was 0.5 and 0.15 correspondingly.

Mass-energetic spectra of accelerated ion beams were studied. Some of the obtained results are given in Table 1. Simultaneous irradiation of a same physical target by H^+ and $^{12}C^+$ beams has been implemented.

Table 1. Ion beam currents for 1 MV terminal voltage

Injected particles	Ion species	Beam current, μA	Energy, MeV
H_1^-	H_1^+	54	2.0
$^4He^0$	$^4He^+$	1.7	1.0
	$^4He^{2+}$	0.04	2.0
$^{12}C^-$	$^{12}C^+$	0.5	2.0
$^{16}O^-$	$^{16}O^+$	3.9	2.0
	$^{16}O^{2+}$	3.1	3.0
	$^{16}O^{3+}$	0.06	4.0
$^{40}Ar^0$	$^{40}Ar^+$	1.8	1.0
	$^{40}Ar^{2+}$	0.1	2.0
	$^{40}Ar^{3+}$	0.02	3.0
$^{63}Cu^- + ^{65}Cu^-$	$^{63}Cu^+/^{65}Cu^+$	2.2/0.5	2.0
	$^{63}Cu^{2+}/^{65}Cu^{2+}$	2.8/0.5	3.0
	$^{63}Cu^{3+}/^{65}Cu^{3+}$	0.4/0.05	4.0
	$^{63}Cu^{4+}/^{65}Cu^{4+}$	0.004/-	5.0
$^{197}TaO^-$	$^{181}Ta^+$	0.09	2.0

From output of γ-quanta in resonance nuclear reaction $^{19}F(p,\alpha\gamma)^{16}O$ and $^{27}Al(p,\gamma)^{28}Si$ magnet analyzers constants, accelerator energy scale and beam energy homogeneity has been investigated. Experimental dependence of γ-quanta output in the reaction $^{27}Al(p,\gamma)^{28}Si$ on energy near 992 KeV resonance is shown in Fig.4. Beam energy spread,

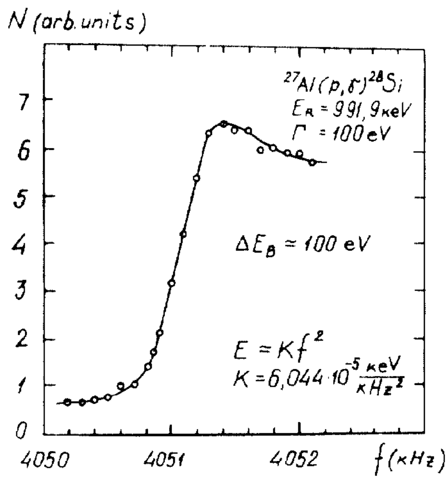

Fig.4. Excitation curve for a thick Al target near 992 KeV resonance

measured in accordance with techniques [2], was about 100 eV. Energy spread value didn't exceed 300 eV in various operating modes of the accelerator.

At present time scheduled cycles of physical investigations are being carried out at UKP-2-1. The plans of works include increase of heavy ion beams current and some additional improvement of the accelerator systems.

References

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