SUPPLYING AND ACCELERATION OF MULTICHARGED IONS ON THE KIEV ISOCHRONOUS CYCLOTRON U-240.

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ABSTRACT

The Kiev Isochronous Cyclotron U-240 is working from 1976 year as accelerator of Protons and Light Ions. Few years ago facility was modernized to accelerate heavy ions. The test band was built to study charge state distribution and yield of multicharged ions. The Ion Source was modernized and tested. New technology to supply solid matter ions by sputtering of composite material from anticathode was realized. The Central Region of Cyclotron was reconsidered in order to accommodate different RF harmonics of acceleration. Ions of Carbon, Nitrogen, Oxygen etc. have been successfully accelerated.

INTRODUCTION

Kiev Isochronous Cyclotron U-240 was constructed as accelerator of light ions with possibility to accelerate species until Argon up to the energy $E=140\ Z^2/A$. During magnetic field measurements discrepancy between designed and real field configurations was found especially for high level fields. It was necessary to investigate central region in case of acceleration of heavy ions. Constant orbit regime when central geometry is fixed can't provide acceleration of different ions. The heavy ion beam was partly lost during first experiments. To study ion source it was necessary to construct stand where Charge State Ions Distribution (CSID) could be measured and optimized. Also some interest presents investigations of new perspective cathode and anticathode materials. For the first time backed tungsten cathodes and anticathodes were tested for Penning-ARC Ion Sources.

ARC IONS SOURCE TESTING

Existing ion source on cyclotron U-240 was constructed for supplying of light ions. Source was installed vertically through the axial hole in the U-240 yoke and was fixed with respect to the cyclotron center. Some attempts to use old construction for heavy ions acceleration were proved to be unsuccesful. New design of PIG-Arc Ion Source was made on. Construction allows to supply light ions with directly heated filament cathode made from 3 mm diameter tungsten wire. To produce heavy ions it were used indirectly heated cathodes and anticathodes made by method of powder metallurgy. The test band on the base of M-20 magnet with increased up to the 1000mm diameter of magnet poles was build (fig.1). Registration system presents 180O magnetic spectrometer. Ion current is measured in the focal plane of Dee by Faraday cup. Particles extracted from Source by DC voltage up to the *-30 kV* while magnetic field varies from 0 to *7 kGs*

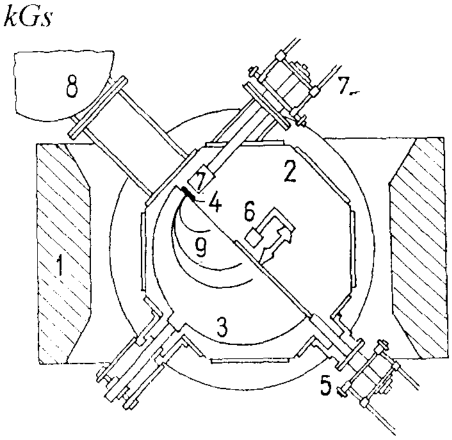

Fig.1. Test band. 1-magnet, 2-vacuum chamber, 3-Dee, 4-puller, 5-moving probe, 6-Faraday cap, 7-source, 8-vacuum pump, 9-ion orbits.

At the first time tungsten cathode assembly (cathode, screen, support and anticathode- fig.2) made by powder metallurgy method were tested. Backed cathode of low ***W*** density was melted under the electron bombardment from filament while cathode surface on discharge side was swelling. Stable arc during 15-20 hours of job was reached for samples with powder *W* density more than 18.5 g/sm^3 which is closed to wrought tungsten. It was experimentally observed that ion spectrum was transformed into higher charges side for more dense cathodes. Results have been correlating with cathode consumption rate and arc regime. We have supposed that additional tungsten ions sputtered into discharge may be the reason of plasma temperature drop. The same results were observed for cathodes with different *W* grain size (fig.3). And again it was supposed that for cathodes made from big size grains tungsten gradually comes into discharge from monocrystal planes of these grains while for little grain structure material drops into discharge as whole colonies from grain borders.

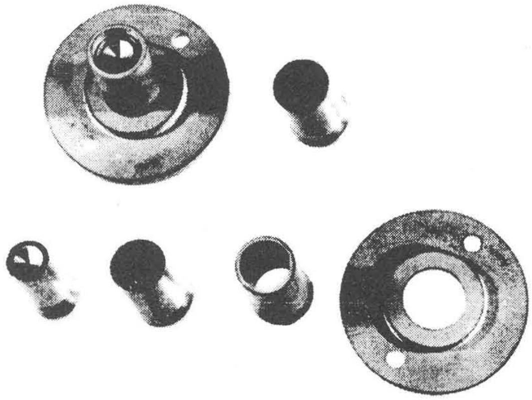

Fig.2.Cathode and anticathode assembly

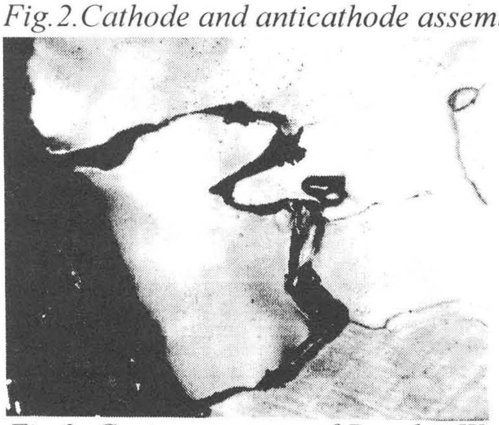

Fig.3. Grain structure of Powder W cathode under electron microscope.

Source discharge parameters and beam current for specified charged states are presented in tabl.1. Arc voltage is supplied each *T=20 msec* in impulses of duration T_i=*1-10msec*. Beam current was recalculated to impulse values where quality factor $Q=T/T_i$ was varied from 3 to 10. Method of powder metallurgy allows us to produce also composite cathodes and anticathodes by pressing and following backing of disperse mixtures of tungsten and compositions like *Al2O3,, **BN** **(admixture from 2 to 10%)*** with high temperature of melting. Current of the Aluminum and Boron ions was comparable with current of gaseous ions when composite anticathode installed close to the extraction slit. We do not observe termodiffusion footprints of admixture atoms in the cathode or anticathode.

U-240 CENTRAL REGION

Computer simulations of full equations of motion have been done to study beam dynamics. Constant orbit regime, which has been used for acceleration of protons, was substituted by mixed geometry. Position of ion source was optimized for each set of ions. First harmonic of magnetic field was used to correct coherent radial oscillations caused by Gap-Crossing Resonance in the center. Increasing of the first gap between source and puller from 8 to 12 mm is unacceptable because will cause growth in radial oscillations amplitude from 2 to 7 mm. Circulating emittance and energy spread in this case will grow up in few times, RF phase acceptance will dropped from 30^0 to 10-20^0. Such a large radial dispersion of beam is caused by gap-crossing effect when particles accelerating on the third harmonic of RF frequency. Displacement of Ion source along as well as across Dee-gap axis with respect to optimum value will increase centering error in few times. Based on these calculations U-240 central region was reconstructed.

EXTRACTION OF HEAVY IONS

Precession mechanism of extraction when particles crossing radial resonance ν_r=*1* is used on U-240 cyclotron. Unlikely tune diagram for heavy ion is crossing parametric vertical resonance ν_z=0.5 and Walkinshaw coupling resonance $\nu_r=2\nu_z$ in the extraction region while for light ions such conditions were absent. Due to presence of uncontrolled first harmonic (10-15Gs) from trims coils and extraction elements beam was crossing extraction region with amplitude of radial oscillations more than 10mm. During first attempts to extract particles beam was blow up vertically. Also phase slippery of heavy ions in the extraction region was to big and beam has been lost. Different maps of magnetic field have been calculated and tested. With careful tuning of cyclotron beams of Carbon, Nitrogen, Oxygen, Neon etc. have been successfully extracted and physical experiments were carry out. Energy of beams is varied from *4 to 10 MeV/nucleon* while beam current is changed from *0.01* to 1 $p\mu A$..

CONCLUSION

Experiments on U-240 cyclotron have proved possibility to accelerate heavy ion beams. For the first powder technology was introduced for PIG ion sources. Multinuclear transfer reactions of elastic scattering for *O,N,C* nuclei have been studied during physical experiments on U-240.

REFERENCES

1.A.Papash.*Suplying and Acceleration of heavy ions at the U-240 isochronous cyclotron.* Ph.D. thesis, 1987, 240 p.

Tabl.1.Source parameters and beam current for different ions. Krypton was used as support gas for Al and B ions.

Ions	Arc voltage	Arc current	Beam current for different charge states, *mA*/impulse						
	V	A	+1	+2	+3	+4	+5	+6	+7
C	*600*	9	15	13	2.8	0.02	---		
O	600	9	14	15	12	1.6	0.04	--	
N	500	8	12	16	10	1.3	0.01	--	
Ar	800	9	14	27	29	13	4	0.7	0.07
Kr	850	10	11	19	22	16	10	5	1.6(+8= 0.2)
Al	820	12	--	1	0.6	0.15	--	--	--
B	800	8	1.2	0.4	0.04				