COMPLEX "ALFA" AFTER 10 YEARS OF OPERATION ON TRACK MEMBRANES PRODUCTION

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Abstract

The film irradiation complex "ALFA" dedicated to expose the polymer films used in the track membranes production was designed and manufactured by JINR (Joint Institute for Nuclear Research) for "TRACKPORE TECHNOLOGY" company [1] and put into operation in 2002 year [2] in Dubna, Russia. "TRACKPORE TECHNOLOGY" holding company was established to solve complex problems of track membranes mass production and a wide range of filtering products based on track membranes.

COMPLEX "ALFA"

The complex "ALFA" includes the following:

- external ECR ion source which was designed and manufactured by Efremov NIIEFA (S.-Petersburg),
- CYTRACK isochronous cyclotron with electrostatic extraction system,
- beam transport of the accelerated ions and film irradiation chamber.

The complex "ALFA" produces polyethylene terephthalate track membranes with less than 25 μm thickness and less than 40 cm width.

TRACKPORE TECHNOLOGY" company produces plasmapheresis apparatus for medical treatment and donor plasma separation.

DESCRIPTION OF CYTRACK CYCLOTRON

Cyclotron CYTRACK (see Fig.1) accelerates argon 8+ ions up to the energy - 2,4 MeV/nucleon, intensity of extracted beam is about 500nA, extraction efficiency totaled ~50%.

CYTRACK is an isochronous cyclotron with axial injection, radio-frequency accelerating system and electrostatic deflectors for extracting ions from the accelerator.

The main characteristics of CYTRACK are given in Table 1.

Magnetic System

The leading and focusing magnetic field is created by electromagnet with four pairs of sector shims located on cylindrical poles. The appropriate average magnetic field increase along radius is provided by rising of the angular extension of the sector shims from 30 to 41,8°. Shims were also used in valleys of the magnet in order to produce an isochronous field with the required accuracy.

Table 1: Parameters of CYTRACK Cyclotron

Accelerated particle	$^{40}Ar^{8+}$
Ion source type	ECR
Type of injection	axial
Injection energy (MeV/nucleon)	0.003
Final energy (MeV/nucleon)	2.4
Injection radius (mm)	53
Extraction radius (mm)	730
Extracted beam intensity (nA)	500
Extraction efficiency	50%

The radial betatron oscillation frequency is close to unity resulting in strict tolerance to first harmonic of the magnetic field. The first harmonic amplitude was found to be less than 3 Gs in the accelerating area.

Table 2: Magnetic System Parameters

Overall dimensions of yoke	(m^3)	3.7*2*1.65
Weight of iron	(t)	83
Diameter of poles	(m)	1.6
Mean magnetic field	(T)	1.48
Current	(ampere-turns)	92750
Power consumption	(kW)	25
Gap between poles	hill (mm)	40
	valley (mm)	100

Axial Injection System

Cyclotron CYTRACK is equipped with the external ECR ion source. Ions energy from ion source is equal 3keV/nucleon. Axial injection line contains bending and analyzing magnet, focusing and adjustment elements, diagnostic devices and sinusoidal buncher.

The spiral inflector for ion bending from axial to median plane is used. The spiral inflector is a rotating cylindrical deflector to take into account the magnetic field of the cyclotron with a=20mm – radius of curvature of the electric field. There is a possibility of inflector rotation by ±8° to assure fitting of ion trajectories from inflector to central region trajectories in radius and azimuth.

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Figure 1: Cyclotron, beam transport of the accelerated ions and films irradiation chamber.

RF Accelerating System

Fixed frequency RF accelerating system is used for ion acceleration in the cyclotron CYTRACK. The RF system consists of two quarter-wave cavities with dee electrodes. The available frequency can varied from 18.25 MHz to 18.6 MHz. The two 45º dees of the acceleration system are located in the opposite valleys of the magnetic system. The aperture of the dees is 24 mm. Antidee frames are placed on both sides of the dees. The RF cavities are exited from individual generators. The power of each generator is 15 kW.

Table 3: RF System Parameters

Number of dees		2
Azimuthal extension	(°)	45
Voltage amplitude	(kV)	40÷50
Frequency	(MHz)	18.258
Harmonic number		4
Quality factor		3500

Extraction System

Extraction system contains two sections of the electrostatic deflector with angular extents 21° and 28°, three beam-current measuring probes (entrance, intermediate, exit) and a passive magnetic channel with azimuthal extension 17° for radial focusing in the extraction region. Radial aperture of the deflector is 7.5 mm. Deflector voltage can be regulated from 0 to 53 kV.

After being extracted from the cyclotron, the beam is transported along a vacuum channel provided with bending magnet, two quadrupole lenses which focus the beam in the horizontal and vertical directions, vertical correcting magnet and scanning magnet distributing the accelerated ions along the width of the film under irradiation.

The irradiation system consists of vacuum chamber with a special ribbon-pulling mechanism, which pulls the film at a constant velocity 2−80 cm/c in the vertical direction.

General view of the cyclotron and extracted beam transport is given in Fig. 1.

FACILITY UPGRADE

In 2010-2013 upgrade of full facility was done without breaking production process.

Vacuum system was substantially renovated. Old pumps in ECR ion source, transport lines, irradiation chamber were replaced by new ones. As a result there is no need in using liquid nitrogen trap any more. This saves company more then 5000 $ per month.

Control system was upgraded either. Now we have two operators consoles in which all data concerning magnet system, RF system, vacuum system operation are indicated.

Diagnostic system was enriched by additional multiwire profilometer situated before irradiation chamber. Old sector profilometers in transport line were

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either replaced by multiwire profilometers. In order to stabilize intensity of the extracted beam (to have uniform pore density) the signal from profilometer commands parameters of buncher fixing extracted beam intensity.

Sinusoidal power supply of scanning magnet was replaced by sawtooth-like one with adjustable amplitude and frequency in order to improve the uniformity of film irradiation.

These activities leaded to more stable and reliable operation of the complex.

COMPUTER SIMULATIONS

For future improvement of the "ALFA" complex operation there are number of perspective possibilities.

The possibility of accelerating krypton ions of lower charge has been studied by computer simulations [4]. The motion of Kr_{84}^{+11} ions in the electro-magnetic field of the cyclotron from injection to extraction was simulated using the same software as in the paper [3]. Cyclotron center model and simulation results are presented in Figs. 2, 3.

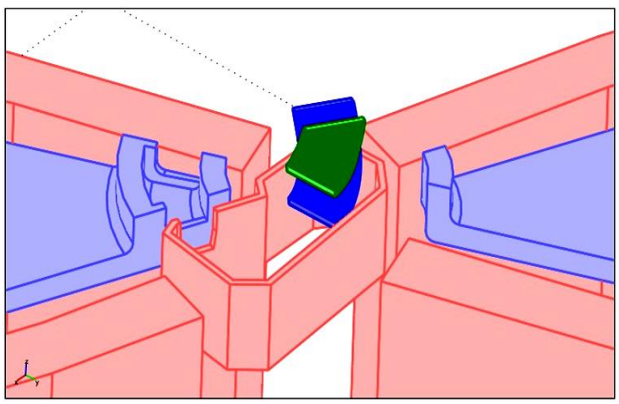

Figure 2: The CYTRACK cyclotron center model.

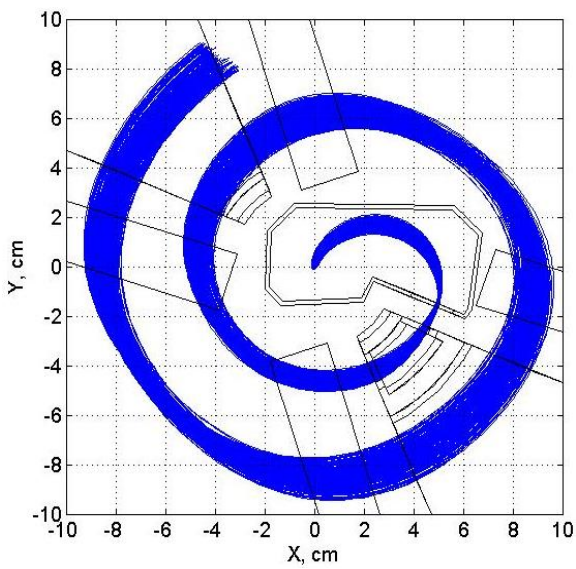

Figure 3: Beam trajectories in the center of the CYTRACK cyclotron.

Computer modelling confirms the possibility of Kr_{84}^{+11} ion acceleration in the formed magnetic field with increase of the magnetic field level by 1.6 % on the 6 harmonic of the accelerating system with no change of frequency. Beam energy will be 1.04 MeV/nucleon (see Fig.5, on the right).It is sufficient for exposure of the film with thickness 10 μm.

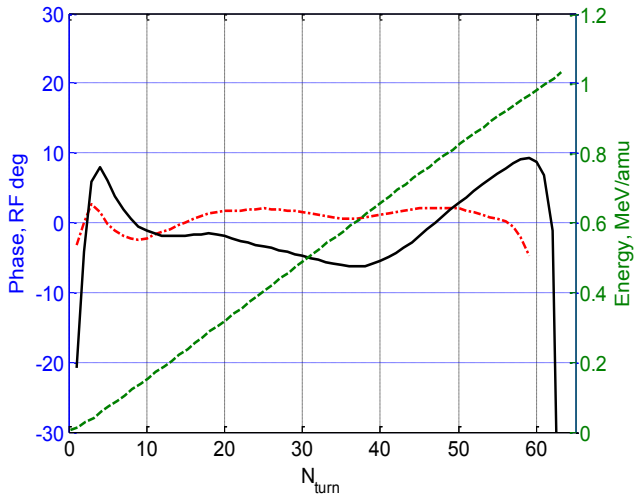

Figure 4: On the left, the phase motion of the equilibrium ion is shown as a solid line; is a dashed–dotted line. The dependence of the equilibrium ion energy on the number of turn (dashed line) is shown on the right.

If ECR ion source of the CYTRACK cyclotron would be replaced by more powerful one produced by Pantechnik it will provide possibility of acceleration of Kr and Xe ions with A/Z≈5 up to energy - 2,4 MeV/nucleon.

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