STATUS OF CYCLOTRON FACILITY IN ALMA-ATA

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Abstract

This paper reviews the innovations which have recently been made on the isochronous cyclotron. These include: spatial and time beam diagnostic system, a NMR system for magnetic field stabilizing in 2-20 kG range, the system of automatic tuning control of the cyclotron resonator frequency in the 6-20 MHz range, putting into operation of a compact research cyclotron specially designed and built for detailed central region orbit dynamics investigation.

Introduction

The variable energy isochronous cyclotron of the Institute of Nuclear Physics of Kazakhstan Academy of Sciences was put into operation in 1972 in Alma-Ata. Design and construction of the cyclotron have already been described in former publications[1,2]. This is a 150-cm low spiral three sector machine. For more than six years the cyclotron continues to successfully serve low energy nuclear and radiation physics with 6-30 MeV proton, 12-25 MeV deuteron, 25-50 MeV alpha-particles and 18-62 MeV helium-3 ion beams.

In recent years several modifications have been performed leading to the increasing of beam quality and cyclotron reliability and performance: elaboration of the system designed for spatial beam density measuring, elaboration of the system for ion pulses time characteristics measuring, designing of the system for magnetic field stabilization, putting into operation of the automatic frequency control system for stabilizing accelerating voltage frequency, and putting into operation of a compact large pole gap cyclotron mainly designed for optimizing the large cyclotron central region.

The system of the beam spatial and time diagnostics

In addition to the traditional visual observation methods for external beam observation while tuning the cyclotron, there was designed and now in use electrical method of external beam spatial density distribution measuring. Electrical readout is obtained from two wires moving in horizontal and vertical planes. The wires are tungsten of 1 mm diameter. Their moving speed is sufficiently constant and can be varied from 0.5 cm/sec to 5 cm/sec and they trace a 11 cm diameter circle. For measuring weak pulse signals broad band amplifiers are used (0-20 MHz) with maximum sensitivity of 2 μV and that permits to measure the ion beam current in the range from 5×10^{-12} to 2×10^{-7} A. The photograph of the probe is shown in Fig. 1

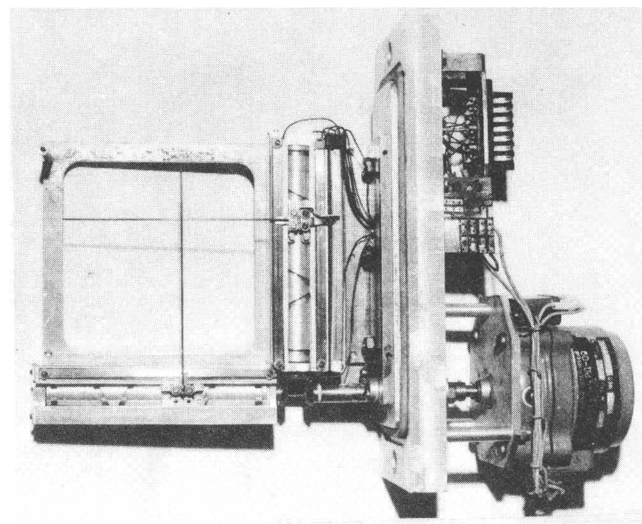

Fig. 1. Wire beam scanner used to measure external beam density distribution in horizontal and vertical planes. Wire is 1 mm tungsten.

The cyclotron is equipped with ion beam phase measuring instrumentation to display ion beam signals. These signals are presenting a good survey of time width and time distribution alongside radius, that is very helpful in fine tuning of the cyclotron, eliminating phase loss of the beam during acceleration. This measurement is made with nonintercepting double electrostatic pickup probes. An electronic switch and the sampling technique are also used.

The six probes are mounted in the dee and placed concentrically at the appropriate radii in such a way that every group covers the same number of ion orbits. The pickup electrode is of a rectangular form, its square being 11 cm^2, and azimuthal duration is 9.4°. The signal generated by the double pickup electrodes is delivered to an amplifier using a two-junction field-effect transistor. The amplifier is mounted in the vacuum chamber. As was mentioned above a sampling technique is used for the ion bunch phase length determination[3]. Fig. 2 represents a typical beam phase signal on a cathode ray tube of a sampling oscilloscope. This signal was obtained after some optimizing work which concerned the position of the ion source, the value of beam current, the amplitude of accelerating voltage and the currents of the trim coils. The sensitivity of the system lies in the range of 5-9 mV/μA when using a rejection filter at the basic operating frequency. By this technique the error of the absolute

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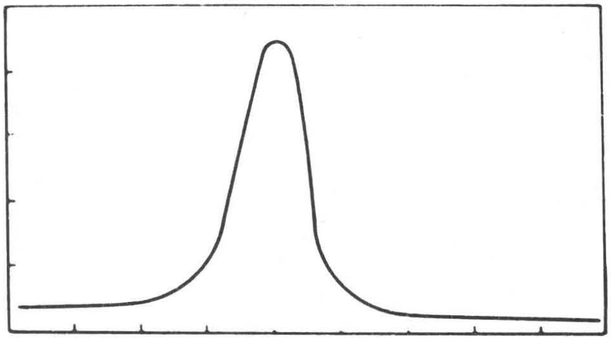

Fig. 2. Typical internal beam pulse measured with a sampling oscilloscope. Horizontal scale is 5 nsec per division.

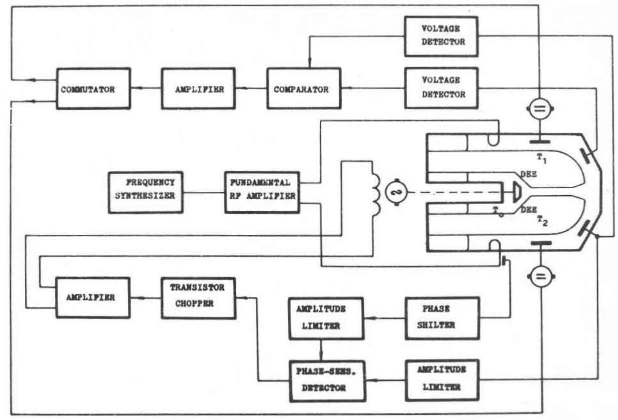

Fig. 3. Block diagram of the automatic frequency control system.

time measurements is less than 0.5×10^{-9} sec.

The system of the magnetic field measurement and stabilization

The system based on the NMR method with flow sample was designed for the measurement and stabilization of the magnetic field of the cyclotron main and bending magnets. Distillate water was used as a performance fluid. The separation of the NMR signal is performed by bridge scheme with an additional field modulation. The modulation frequency is chosen in such a way as to have a digital frequency meter readout in the units of magnetic field induction.

The system operates in the side band of the NMR frequency spectrum. The NMR signal delivered by a phase detector is used for tuning the reference oscillator frequency in the measurement mode, and for tuning the magnetic field in the stabilization mode. A frequency synthesizer with a digital control and 4.527 kHz adjustment step is used as a reference oscillator.

An error of the magnetic field measuring is determined by the amplitude of the NMR signal, its line width, the resonance frequency shift in the sensing device and by the NMR signal to noise ratio. The measured line width of the NMR signal is 30 Hz and at the signal to noise ratio being equal to 3 the measuring error does not exceed $\pm\,3\times10^{-6}$ at the magnetic field induction of 2 kG. The accuracy of the magnetic field stabilization in the range from 2 kG to 20 kG is 1×10^{-5} to 1.5×10^{-6}.

The automatic frequency control system of the resonant circuit

The AFC system was designed for accelerating voltage frequency stabilization. Its simplified block diagram is shown in Fig. 3. The performance of the system is based on the comparison of the phase of the dee voltage and high frequency voltage of the final stage of amplifier. A broad band phase detector is used as a comparison device, its signal through a converter and a low frequency amplifier is delivered to the control winding of quick-response motor to adjust the trimming capacitor T_0.

The AFC system performs in the 6-20 MHz frequency range. The retention band of the system is ± 40 kHz.

The servo system maintains an accelerating voltage symmetry at the dees at the accuracy of 5×10^{-3} by means of the trimming capacitors T_1 and T_2. With the automatic frequency servo the system is operating without any attention for long periods of time, and the ease of operation is improved markedly.

Compact research cyclotron

For detailed orbit dynamics study in cyclotron central region and for improvement and increasing reliability of other systems of isochronous cyclotron a compact research cyclotron was designed and constructed. The cyclotron was put into operation in 1977. The pole diameter is 50 cm, and magnet gap is equal to 20 cm. The C-shaped magnet yoke leaves more of the vacuum tank free for diagnostic equipment. The solid state rectifiers provide the magnetic induction at the cyclotron centre of 11 kG.

The radiofrequency system of the compact research cyclotron consists essentially of a quarter wave coaxial line resonator integral with a single 180° dee, and a high power RF source which includes a crystal-controlled master oscillator, and two intermediate and power stages. The power is transmitted from the final 25 kW amplifier stage by means of a 50 Ω coaxial line and is inductively coupled to the dee stem. Two coupling loops are used. The Q-value of the system is equal to 3000. The fine tuning of the cyclotron is achieved by regulating the position of two trimming capacitors, and the frequency can be adjusted over a 1 MHz range.

The RF resonator produces high accelerating voltage at 11 MHz, which is the first or second harmonic of the particle revolution frequency. The single dee is operating at 60 kV with a minimum breakdown gap of 3 cm and it is spaced 3 cm from a dummy dee which restricts the axial aperture for the ion beam to 5 cm.

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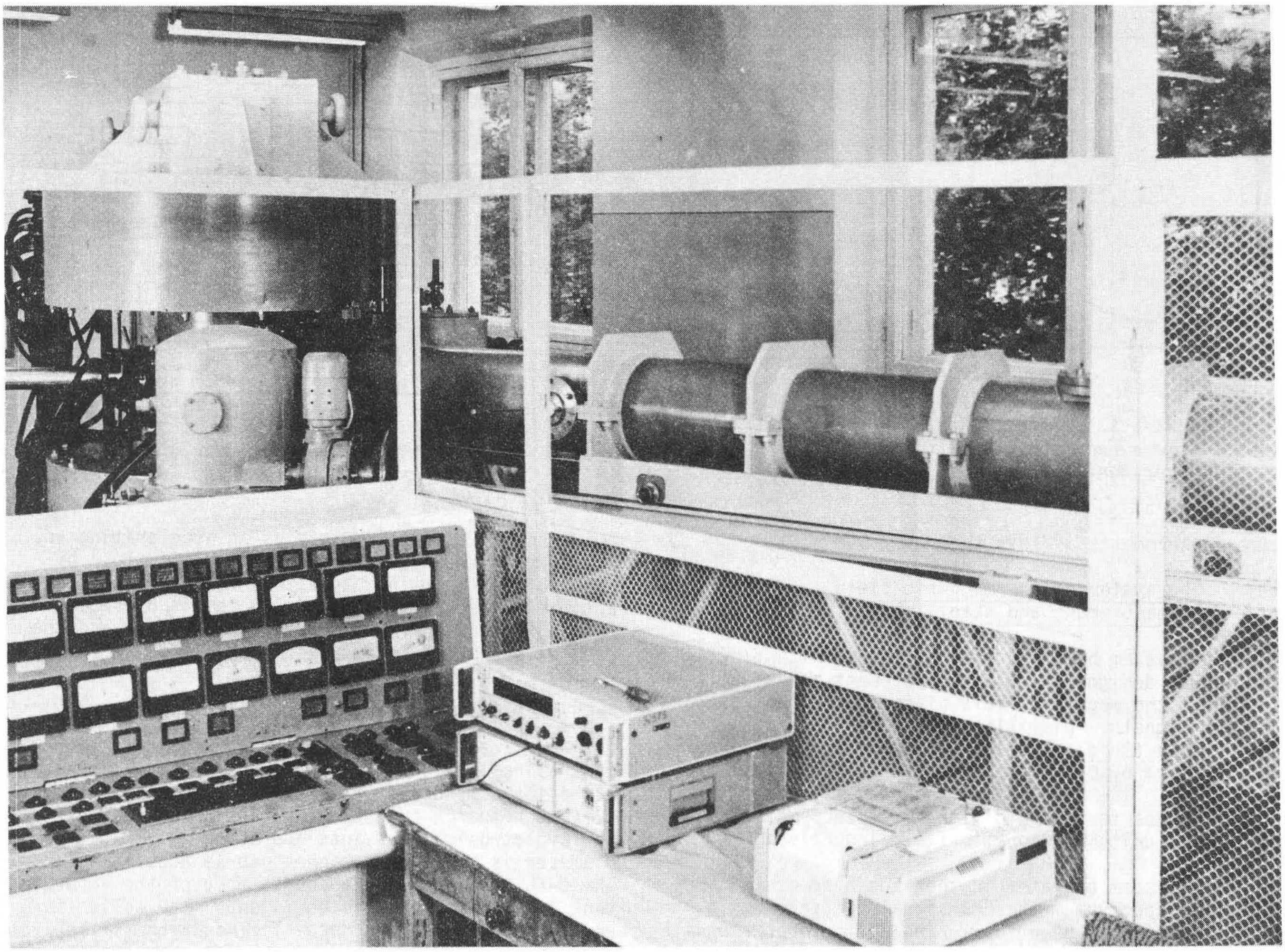

Fig. 4. Photograph of the compact research cyclotron.

A hot filament hooded-arc ion source of the conventional type can be brought in radially and the filament can be replaced easily. The filament is made of 3 mm tungsten and requires about 300 A.

The vacuum system consists of a stainless steel vacuum chamber pumped by two oil diffusion pumps. Each pump has a pumping speed of 2000 litres per second. The operating pressure is about 1.5×10^{-5} torr. The pumping system reduces the pressure to the operating value in 3 hours.

The diagnosis technique at the compact research cyclotron allows to measure in digital form spatial (total ion beam current and its density distribution) and time beam characteristics. The protons were accelerated approximately to the 1 MeV energy. Measurements of current vs. radius gave evidence of clear separation of the orbits and no appreciable loss of beam. The total beam current was 200 μA. The horizontal width of the beam was 5 mm and the vertical height was 11 mm.

The general view of the compact cyclotron is shown in Fig. 4.

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