OPTIMISATION OF THE CYCLOTRONG HIGH-FREQUENCY ACCELERATING VOLTAGE AMPLITUDE TO A BEAM CURRENT

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Abstract

An automated system for controlling the parameters of the KI cyclotron high-frequency (HF) complex is described. The system ensures the automatic choice of the accelerating HF voltage amplitude and its adjustment to a maximum beam current, the operative trimming of the resonant circuit, as well as the collection and indication of data about the operating conditions of the unit controlled. Introduction of an accelerating HF voltage amplitude optimization regime allows one to increase considerably the stability and the efficiency of cyclotron operation and to free the operator from a major part of routine work. The characteristics of the system are given; hardware and software for automation of the control over the system are described shortly. The system was developed on the basis of CAMAC modules controlled by an IBM PC/AT computer. Fibre-optics information exchange systems are used to couple the units of the system. The system considered is usable in other electrophysical facilities.

1. INTRODUCTION

A multi-purpose isochronous Kurchatov Institute (KI) cyclotron [1] is extensively used for a wide range of research and applied works. Some nuclear physical investigations require many-hour exposures, during which uncontrolled heating and deformation of the dees occur. The deformation of the dees and the beam leading of the resonant system cause, in turn, a detuning of the resonant system and some change in the gap between the dees and the measurement electrodes of capacitance-type dee-voltage detectors. As a result of such a detuning of the resonant system elements the accelerator output current decreases. For this reason, consideration was given to the problem of automatic adjustment of the cyclotron accelerating voltage with respect to a maximum current of the accelerated beam onto a target.

2. KI CYCLOTRON HF SYSTEM

The simplified structure of the KI cyclotron HF system is shown in Fig.1. The resonant system [2] includes two resonant circuits in the form of coaxial lines connected with 180 - dees. The strong coupling of the circuits is realized through a capacitance between the dees. The frequency of the circuits in the range of 8-21 MHz is tuned by shorting plates. The frequency of the circuits can be shifted into the range of 5-10 MHz with the replacement of the dees by higher-capacitance ones. Trimmers at the dees ensure the fine frequency tuning within 50 kHz. the Q-factor of the resonant system varies from 3000 to 2000 over the frequency range.

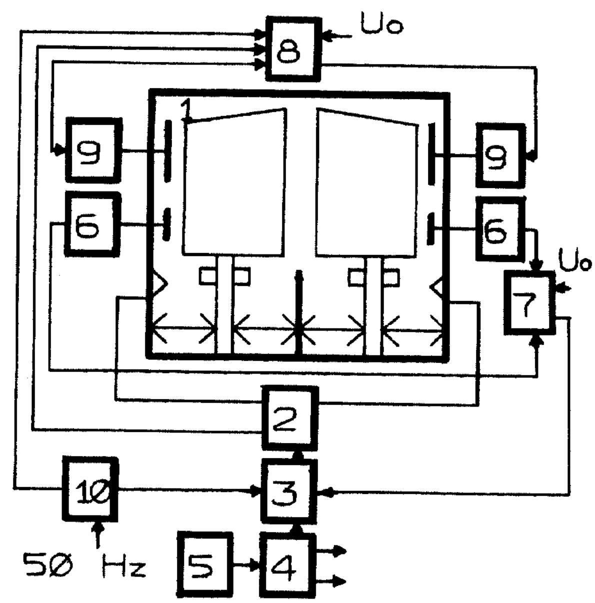

Fig.1. The block diagram of the KI cyclotron HF system: 1 - resonant system of cyclotron; 2 - HF oscillator PKV 250; 3 - HF controller; 4 - HF wide-band amplifier; 5 - master HF oscillator; 6 - capacitance-type HF dividers; 7 - error amplifiers with reference supply; 8 - regulator of the natural frequency of resonant circuits and the difference of the voltage at the dees; 9 - servoamplifiers; 10 - pulse oscillator.

The resonant system is excited by HF oscillator (2) of a PKV-250 broadcast transmitter. Its mean power in the range of 4-25 MHz is 250 kW. The HF oscillator is driven by quartz master oscillator (5) via wide-band amplifier (4) and HF controller (3) of the accelerating voltage amplitude stabilization system. The controller has three control inputs. the first input is used to feed the voltage from the master oscillator. The signal from an error amplifier in the accelerating voltage stabilization circuit is fed to the second input and the control signals from an pulse modulation and protection unit to the third input (10). The master oscillator operates in both the continuous and the pulsed mode with pulse repetition rate of 12.5-300 Hz at a pulse ratio of 3-100.

The voltage across the dees is measured by capacitance-type dividers (6). The loop of stabilization of the total voltage across the dees is completed through the HF oscillator, voltage sensors and detectors on the dees, the error amplifier with reference supply (7), and the HF controller of the amplitude stabilization system. The system ensures the stability of the accelerating voltage better than 10^{-3}. The frequency of the resonant circuits and the difference of the dee voltages are stabilized by automatic control unit (8). The unit operates in both the pulsed and the continuous modes. A wide-band phase detector of this unit uses the HF voltage signals from the capacitance-type voltage detectors on the dees and from the output stage of the HF oscillator. The system ensures the fine phase tuning to an accuracy of $2-3^{\circ}$ [2] by moving the trimmers through servoamplifiers (9).

3. THE SYSTEM OF ACCELERATING VOLTAGE ADJUSTMENT TO A BEAM CURRENT

The block diagram of an IBM PC/AT (1) computer based system of accelerating voltage adjustment to an accelerated beam current is shown in Fig.2. The system comprises elements controlling the HF voltage amplitude and monitoring the current. As a reference supply for the control of the HF voltage amplitude use is made of an fibber-optics system which represents an 11-bit

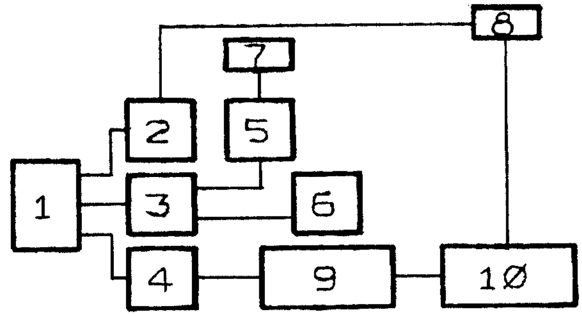

Fig.2. The block diagram of the system for monitoring the current and controlling the HF voltage across the dees: 1 - computer; 2 - ADC; 3 - counter; 4 - DAC; 5 - current integrator; 6 - synchronizer; 7 - beam current detector; 8 - amplitude detector; 9 - HF - generator, 10 - resonant system.

digital-to-analog converter (4).

Measurement of the current is ensured by a beam current integrator (5) generating at the output pulses with a frequency proportional to the current. For example, at a mean beam current of 10^{-7} A the integrator generates 100 pulses per second. A pulse counter fixes the number of pulses per one or several HF macropulses. This is dictated by the necessity of measuring the current to a relative accuracy of about 1%.

The counter is started and stopped by a sync pulse modulating the HF voltage. The amplitude can be adjusted by manually by an operator from the keyboard of the master computer or automatically in accordance with conditions specified in the program. Such a configuration of the HF voltage amplitude control channel allows the operative optimization of the amplitude to the maximum beam current. The current is measured by feeding the pulses from the beam current integrator (5) output to the input of the binary counter (3).

An algorithm for searching for a value of the HF voltage amplitude corresponding to the maximum value of the beam current consists in the following. At the beginning of the procedure the total value of the amplitude of the accelerating voltage at both dees and the current corresponding to this value are stored. Then the reference voltage of the DAC is set in the lower limit of the control range within which the amplitude is varied, for example, 20-30% lower than the beam current value fixed before. In passing through the control range all the values of the amplitude at which the current exceeds its initial value are fixed. After completing the control the voltage established at the DAC output corresponds to the maximum current value.

4. RESULTS

The tests of the system on the KI cyclotron show that at currents of about 10^{-6} A the time required for the search for the optimal value of the HF voltage amplitude is less than 1s. At such an adjustment rate the loss of current in the process of optimization does not exceed 1% and at the same time the operator of the cyclotron gets free of a considerable part of routine work.

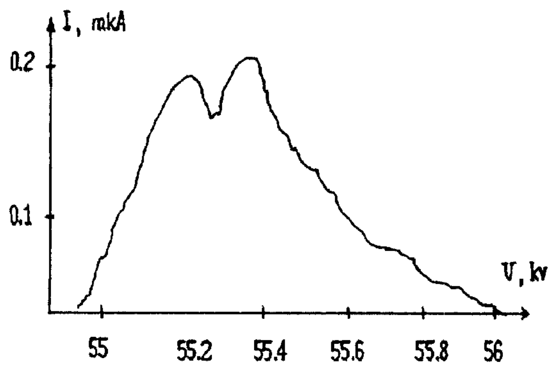

Fig.3. The graphical presentation of the process of searching for and maintaining the chosen extremum of the beam current.

Fig. 3 shows the beam current as a function of the HF voltage amplitude. This dependence was obtained in the process of optimization of the voltage amplitude with respect to the current. it is seen from the shape of the curve that in passing through the amplitude control range there occur several local extrema of the current. The existence of these extrema is explained by the possibility of both the one-turn and the multiturn ejection of the cyclotron beam microbunches.

First of all, this results from the fact that the gap of an electrostatic deflector ensuring the beam extraction from the Ki cyclotron is somewhat wider than the pitch of the beam in the final turns. The presence of slit diaphragms on the dees at the center of the cyclotron influences to the number of turns in the ejection radius. The reason is that the initial phase of the microbunches can change when the accelerating voltage changes. The optimization algorithm allows for the operation at any one of the extrema of the operator's choice. Thus, for works on materials technology it is expediently to have a maximum beam at the taget. But for time-of-flight experiments the minimum duration of microbunch is required. It can be ensured, in particular,by the one-turn extraction of microbunches [3]. For example illustrations of a strong relation of the microbunch form and duration from accelerating voltage amplitude are presented in [4].

Thus, the system developed ensures the optimization of the operating conditions, allows one to maintain the special operating conditions with the one-turn extraction of beam microbunches, visualizes the process of automatic control, and reduces the work load on the operator.

5. REFERENCES

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