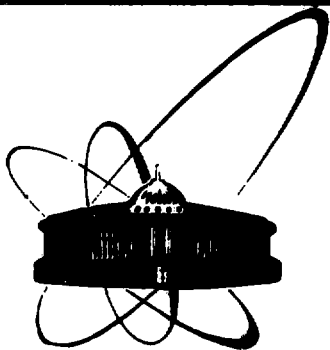


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AUTOMATIC CONTROL SYSTEM OF THE PIG
ION SOURCE FOR THE U-400 CYCLOTRON

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Introduction

The PIG ion sources with an indirectly heated cathode and cathode sputtering of solid working substance are used to produce multiply charged ions (MCI) ^{1,2/} at the U-400 cyclotron of the Laboratory of Nuclear Reactions (LNR) of the Joint Institute for Nuclear Research (JINR).

The discharge regime of the ion source (MCIS) has a significant influence on the MCI beam intensity and determines the efficiency and characteristics of the irradiation of physical targets and technological samples.

The control of the ion source mode causes some difficulties for the cyclotron operator. This is a consequence of that in terms of control the ion source is a nonlinear stochastic system characterized by many variable parameters. Therefore the regular tuning of the source parameters is needed. Sometimes the short-circuit of source electrodes can take place. In this case the rapid out-off of the control influence is necessary to prevent the failure of the ion source. Because of ambiguous parameters of the arc discharge its recovery can be obtained only by using a special algorithm. The non-recurrence of the MCIS parameters after replacement or repair and also the necessity of taking into consideration the kinds of gas and solid working material used make it difficult for the operator to achieve the required mode and stability of ion source operation. An automatic CAMAC-based control system and microprocessor controllers have been designed jointly with Moscow Engineering Physical Institute ^{3-5/} and put into operation for solving this problem in LNR, JINR.

Design and operation of the ion source

The ion source and the block-diagram of its power supply system are shown in Fig. 1. The discharge chamber of ion source (3) is situated in the center of the cyclotron electro-magnet. Cathode (2) is heated by the electrons emitted from filament (1), fed by power supply (9), and accelerated by the potential difference supplied by power supply (10). The arc discharge occurs with gas feeding into the discharge chamber and on the switching-on of power supply (11). The gas consumption is controlled by a remote-controlled needle

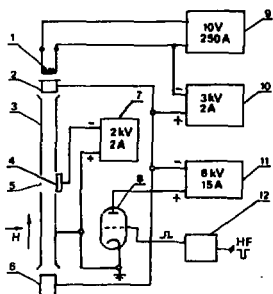


Fig. 1. Block-diagram of the multiply charged ion source with power supply

valve. Anticathode (6) is electrically connected with the cathode. Sputtered electrode (4) with working material is located in the region of the extraction slit. The electrode is sputtered when the power supply (7) is switched on. The sputtered particles are ionized in the discharge. The consumption of working material is regulated by tuning the voltage of power supply (7) and the electrode position. The triggering of the ion source is performed by key (8) and unit (12) synchronously with the triggering of the cyclotron RF generator.

The output parameter of the MCIS (multiply charged ion current) is determined by the source regime. The control of the source regime is fulfilled by variation of the six parameters: the voltages of power supplies, the filament, heated cathode, arc, sputtered electrode, and also of the positions of the gas feed needle valve and of the sputtered electrode.

Functions of the system

An automatic control system (ACS) is intended to fulfil the following functions:

1. Measurement and displaying of the source parameters.
2. Checking and prevention of alarm situations.
3. Automatic program tuning of source to a temporary mode, including the following operations:
 - the control of the indirectly heated cathode parameters;
 - the gas feed control;
 - the automatic switching-on of arc discharge and setting the parameters of discharge preset by operator;
 - the control of the sputtered working substance consumption.
4. The obtaining of preset (maximum) beam current by tuning the ion source mode.
5. The memorization of the current-mode ion source parameters and their stabilization.
6. Memorization and stabilization of the beam current.
7. Automatic switch-off of the technological subsystems of the ion source.

8. Acquisition of data on the ion source mode and their print-out in tabular form.
9. Interactive mode.

The system structure

The ion source microprocessor control system (MCS) is included into the U-400 cyclotron control system (Fig. 2).

The MCS uses two CAMAC crates, namely a resident crate and a MCIS including CAMAC microcomputers KM-001 on the bases of INTEL 8080, 16 KB RAM and 32 KB EPROM /6/. The resident crate is used for interactive mode, for command communication with control and check crates, for listing and also for coupling with a minicomputer TPA 1140 which provides for program debugging and will be used for data base control.

The MCIS control crate of which the block diagram is shown in fig. 3 is used to control function elaboration of the ion source. The crate consists of three subsystems designed for MCIS parameter measurements, for control response delivery and for data representation.

The algorithm of MCIS mode control is based on the measurement of 16 parameters during 80 ms, these parameters being quassiconstant

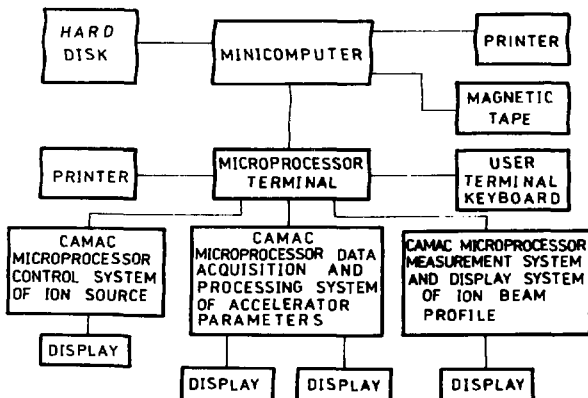


Fig. 2. Structure of the automatic control system for the U-400 cyclotron

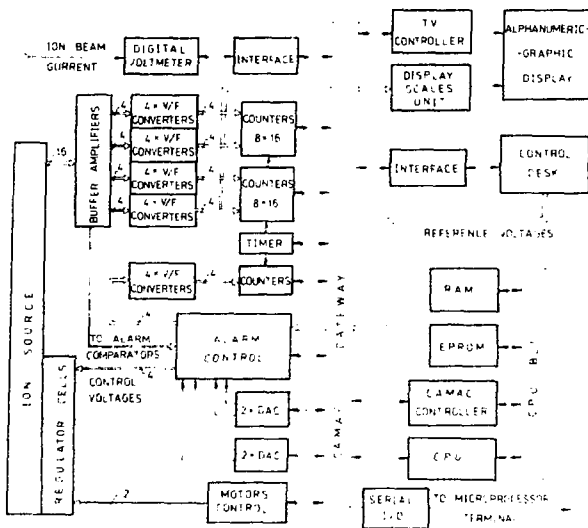


Fig. 3. Schematic of the ion source microprocessor control system

or pulse signals. The measuring channel consists of the unit of buffer amplifiers, 16 voltage-frequency converters providing the necessary measuring precision in electro-magnetic noise conditions, two binary counters 8x16 bits and a timer. Data are brought into RAM using CAMAC dataway. The measuring accuracy is not higher than 0.1 per cent.

The MCIS mode control is performed by tuning the reference voltage thyristor regulators of networks and also by varying the position of the needle valve and of the sputtered electrode.

The reference voltage is generated by the 10-bit DAC and supplied to the regulators through an alarm control guard unit (AC). In the case of an alarm situation (a bad vacuum, short-circuit, etc.) the AC blocks the corresponding reference voltage.

The motor control (MC) of the gas feed valve and of the sputtered electrode is carried out by means of microcomputer instructions with the indication of the direction and working time of the motor.

The operator can give commands for the transition from automatic to manual control through interface of a control desk (CD) and vice versa. In the manual control regime the operator uses helipots

for power supply regulation. The transition from automatic control to manual one is provided without failure of the MCIS mode. The information about the MCIS parameters is shown on a graphic display through a program-controlled controller (TVG). The table of the MCIS parameters and the mnemonic diagram of the MCIS with power supply systems are presented in fig. 4. The basic parameters of the MCIS are displayed as 7 horizontal linear scales with the help of a DSU unit.

The data link between the control and resident crates is realized by means of serial intercrate link units (SIO) providing 1.2 Mbit bit-transfer.

The system software is executed in Assembler and has 12 KB EPROM in the resident crate and 28 KB EPROM in the control crate.

Bunch current control

The problem of the automatic control of the cyclotron beam current is formulated as follows: to get and stabilize the preset or maximum beam current in the limited range of the ion source parameters.

The ion beam current is measured by a digital voltmeter (DV), which is connected to a microcomputer through a CAMAC module. The range of the current measurement is 0.001-100 mA.

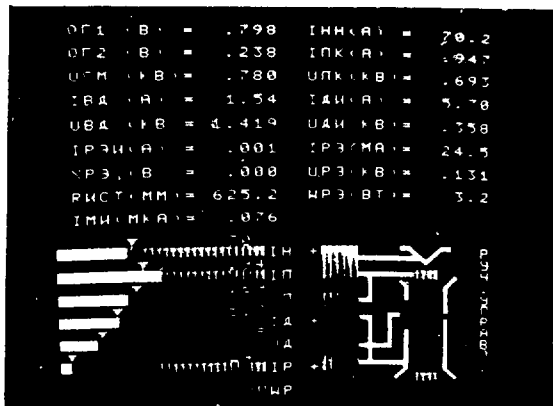


Fig. 4. The display of the MCIS parameters

The algorithm for current beam control with the help of KM-001 was implemented using the extremum coordinate search method with the check of limits execution and with the correction of the permissible range of input variables.

The beam current is considered as the nonlinear function of five independent input parameters of the ion source discharge at fixed cyclotron control parameters.

The procedure of obtaining the preset or maximum beam current is the following one:

1. Interactive setting of the beam current value and its accuracy, initial MCIS parameters, the limitations on the MCIS parameters and the range of input values.
2. The automatic switching-on of the arc discharge and production of the initial values of the discharge and sputtering parameters.
3. Automatic coordinate search of the preset or maximum beam current in the bounded range with the control of the arc failure and short-circuit on the sputtered electrode.

Conclusion

The first experience of operating the system described has given the following results:

- the system allows one to automatically switch on/off the MCIS in the quasioptimal mode during a 10-15 min time interval;
- beam current stabilization can be provided within a 3% error with 5% deviations of the discharge parameters from the preset limits.

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Утнер В.Б. и др.

E9-89-491

Автоматизированная система управления
дуговым источником многозарядных ионов циклотрона У-400

Описана автоматизированная система управления дуговым источником многозарядных ионов циклотрона У-400 на базе аппаратуры КАМАК и микропроцессорных контроллеров. Система позволяет в соответствии с заданием оператора проводить автоматический программный вывод источника на требуемый режим, включая автоматическое зажигание разряда, получение заданных параметров распыления рабочего вещества, автоматический поиск заданного максимального тока пучка при ограничениях на токи и напряжения разряда и распыления. Вывод источника в квазиоптимальный режим осуществляется за время порядка 10-15 минут с нарушением ограничений не более 5%. Система способна автоматически стабилизировать ток пучка посредством коррекции режима источника с погрешностью не более 3%.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1989

Utner V.B. et al.

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Automatic Control System for the Pig Ion Source
for the U-400 Cyclotron

An automatic control system is described for the cyclotron U-400 multiply-charged ion source based on CAMAC apparatus and microprocessor controllers. The system allows the automatic tuning of the ion source to the necessary regime, including the automatic start-up of discharge, the obtaining of the necessary parameters of sputtering, the automatic search for a maximum beam current within the given discharge parameters. The system performs tuning the ion source to the quasioptimal regime for 10-15 minutes with up to 5% deviation from the preset parameters. It is possible to stabilize the beam current within 3% using the automatic correction of the discharge regime.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

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