MEASURING SYSTEM OF PHASE CHARACTERISTICS AND BEAM PHASE STABILIZATION OF CYCLOTRONS

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Abstract

Block-diagrams of measurement systems for phase duration of the cyclotron internal beam and its phase relative to RF accelerating field are described. In the measurements, a stroboscopic method of converting nanosecond periodic signals is used. Compensation of RF-induced noise results in a marked increase of the signal-noise ratio at the system output. The block diagram of the beam phase stabilization system is given. Measurement results of the cyclotron beam phase duration are presented.

Introduction

For the choice of optimal acceleration regime and for a number of experiments on a cyclotron, particularly, in formation of a "white" neutron beam, information on the time duration of the charged bunches and their time position relative to the accelerating high voltage is required. This information can be used to realize automatic trimming of the beam phase with respect to the accelerating voltage by changing the current in special concentric windings, located either on a finite acceleration radius or on several radii, where "transparent" beam pickups are placed.

Measuring Diagram of Bunch Phase Duration

The measuring unit for beam phase duration, whose block diagram is given in Fig. 1, is of particular interest. Similar to [1) 2)], beam capacitive pickups are used for measurements. The measuring diagram employs the principle of linear transformation of periodic signal time scale by a stroboscopic method.

RF accelerating voltage is sent through the matching device to the input of the synchronizer, which fixes the RF voltage phase and provides stable operation of the measuring system in the frequency range from 7 MHz to 20 MHz. At the

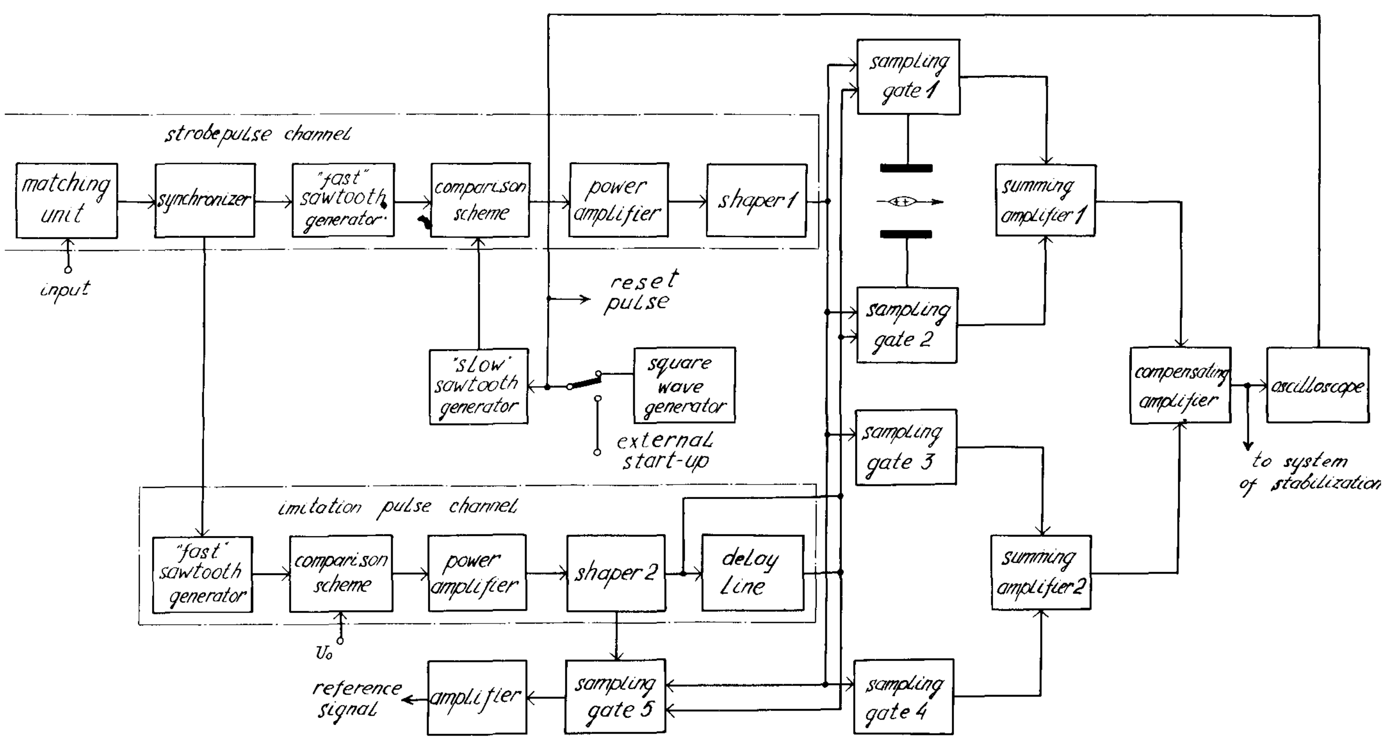

Fig. 1 Block-diagram of the beam phase duration measuring system

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synchronizer output, pulses are developed which control the operation of the automatic shift system, consisting of a "fast" sawtooth generator, "slow" sawtooth generator and comparison circuit 1, to which the voltages from the two generators are sent. When these voltages become equal, pulses are developed which form ∿ 0.5 ns, ∿ 1 V strobe pulses after the power amplifier and shaper.

The pickup, mounted immediately in the cyclotron chamber, is a sampling gate, having a pickup plate, gate diode and low-frequency amplifier. Sampling gates are made as two identical circuits, located symmetrically in the screen case relative to the cyclotron median plane. This eliminates the influence of the beam vertical displacement on measurement results and enhances the sampling gate sensitivity. From the sampling gate outputs, low frequency signals are fed to the summing amplifier 1. The schematic diagram of one half of the sampling gate is given in Fig. 2.

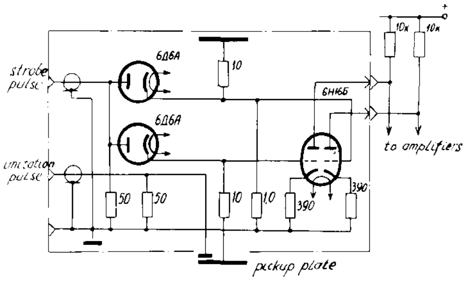

Fig. 2

Schematic diagram of one half of the sampling gate 1 and 3.

Calibration of the time scale of the measuring system and its tuning is accomplished by an imitation signal, fed to the pickup plate through a capacitive coupling formed by the imitation plate and pickup plate.

The imitation signal is developed by a circuit similar to a strobe-pulse forming circuit. The delay line (some length of coaxial cable) makes it possible to obtain double imitation signals, delayed with respect to each other by a time exactly defined by the cable electric length. This calibrated time interval is a scale timing mark on a low-frequency oscilloscope screen.

For compensating RF noise induced by the accelerating field and spurious amplitude modulation of strobe pulses, each half of the pickup employs a "darkened"sampling gate, whose circuit is the same as described above. The distinguishing feature is "darkening" of the pickup electrode, i. e. its screening from the beam. Output signals from these sampling gates are fed through the summing amplifier 2 to the compensating amplifier 3, to which the output signal from the summing amplifier 1 is also fed.

The schematic diagram of the compensating amplifier is given in Fig. 3. The use of compensation results in a marked decrease of requirements on screening of all communications in the

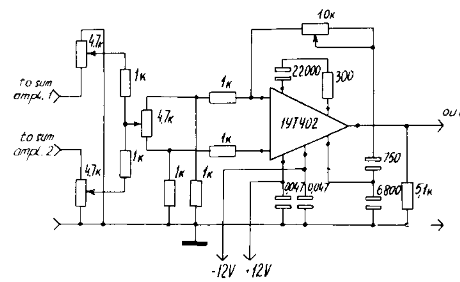

Fig. 3

Schematic diagram of the compensating amplifier

measuring system. From the compensating amplifier output, a "cleaned" low-frequency signal characterizing the bunch pulse shape is sent to the oscilloscope input. The start-up of the oscilloscope scanning is effected by the starting pulse of the "slow" sawtooth generator.

The imitation signal channel is also used for measuring the beam phase relative to the RF voltage. For this purpose, signal from the shaper 2 is fed to the sampling gate 5 and is gated by the same strobe-pulses which are sent to the pickup. From the sampling gate output, the pulse is amplified and formed by means of the forming amplifier. This pulse is regarded as a reference pulse.

Beam Phase Measurement

For precise measurements, the circuit (Fig. 4) is provided, in which the main pulse and reference pulse are fed through the OR-circuit to the trigger. The trigger output pulse is fed to the AND-circuit, in which the pulse is filled with reference frequency signal from the frequency generator. This information then enters the scaler,

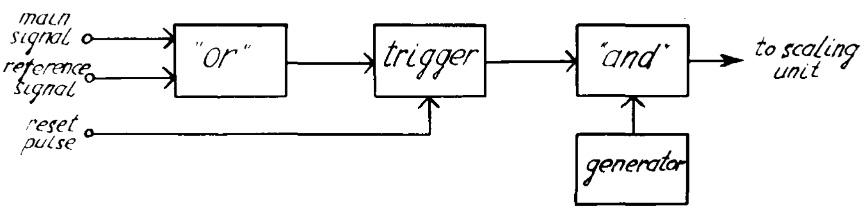

Fig. 4

Block-diagram of the beam phase measuring unit

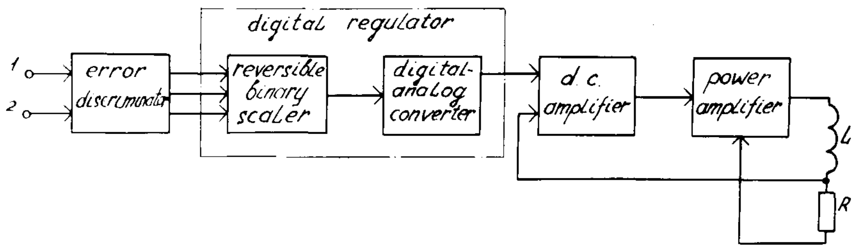

Fig. 5

Block-diagram of the phase stabilization system

which yields a digital value of the beam phase relative to RF voltage either in units of time or in angular values. The circuit is calibrated by the imitation signal, fed to one of the inputs with a known delay relative to the reference.

Beam Phase Stabilization

The block-diagram of the beam phase stabilization system is given in Fig. 5. It consists of a current stabilizer, whose reference voltage is provided by a digital regulator, and an error discriminator. The compensating amplifier pulse is fed to one input of the discriminator and the reference pulse, time-delayed by a value corresponding to the beam optimal phase, is fed to another input. Time mismatch between these pulses because of the beam phase drift is an error signal which emerges on the discriminator output. The discriminator also develops two more signals characterizing the error sign.

These signals enter the digital regulator consisting of a reversible binary scaler and a digital-analog converter. Depending on the error value and sign, the regulator output voltage and, hence, the concentric winding current changes so that time mismatch of the stabilization system input pulses should decrease and the beam optimal phase should be kept.

Experimental Results

The described measuring system for the bunch phase duration was tested on the cyclotron Y-150. The measurements were conducted at accelerating frequencies of 9 MHz and 18 MHz.

Fig. 6a presents a voltage diagram taken at the summing amplifier 1. Low-frequency signal, corresponding to the beam bunch shape, is seen against the background of gated RF noise (time scale of scanning is 10 ns/div).

Fig. 6b and Fig. 6c give voltage diagrams at the compensating amplifier output (scanning time scale is 5 ns/div). Scanning time scale was calibrated with the help of a coaxial cable 1 m long, which corresponded to time interval of 5 ns.

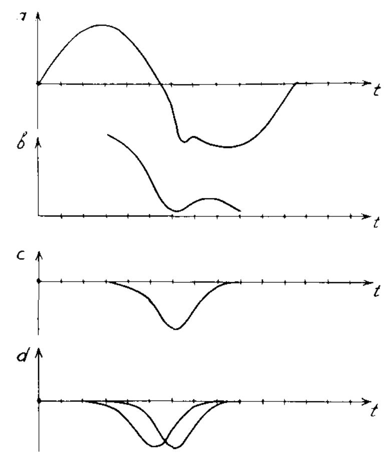

Fig. 6

Output voltage diagrams of
a) summing amplifier
b) compensating amplifier before compensation
c) compensating amplifier after compensation
d) time calibration of the oscilloscope scanning

Calibration diagram is given in Fig. 6d. It is seen that bunch duration (at accelerating voltage frequency of 9 MHz) is ∿ 10 ns or ∿ 35°. The measurements were conducted at the beam average current of 10 μA. In this case, the output voltage at the sampling gate 1 and 2 was 0.5 V.

It is expected that a similar measuring system with an increased number of beam phase pickups at several radii will be used in the Kiev cyclotron.

References

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2) H. Feldman IEEE Trans., 1966, NS-13, No. 4, 30