DEVELOPMENT OF THE PHASE PROBE IN THE INR CYCLOTRON

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ABSTRACT

The phase of the internal beam with respect to the RF accelerating voltage of the INR Cyclotron is measured using several capacitive phase probes. The measuring system is based on the heterodyne principle. Several double-balanced mixers are used in mixing and filtering techniques. For example, the precision of the beam phase of 15 MeV protons reaches 0.5 degree. The work will be continued in order to establish an automatic control system of trim coils with measured beam phase.

1. Introduction

At the Cyclotron Laboratory of the Shanghai Institute of Nuclear Research, automatic control of the SFC is being developed. For this purpose a number of beam properties are measured continuously and without interception of the beam. Among these is the phase angle of the internal beam with respect to the accelerating voltage. A rather simple phase measuring system has been built, based on the heterodyne principle. The measuring system is described in Section 2 and results are analyzed in Section 3.

2. Measuring System

2.1 Phase Probes

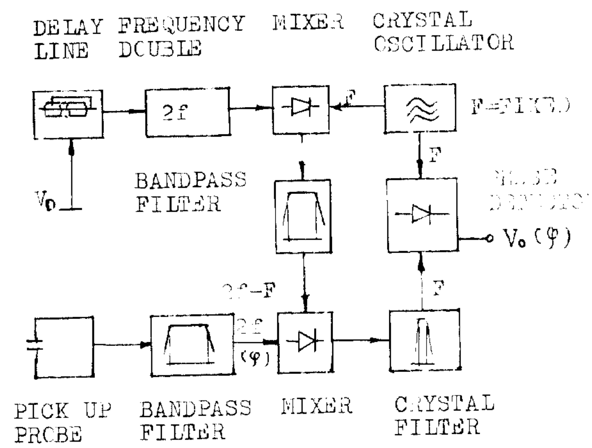
The beam signals are decoupled by electrostatic induction pick-up probes mounted as usual above and below the median plane of the cyclotron. The probes are located along the centerline. They are radially positioned in such a way that the distance between subsequent probes covers the same number of turns. Nine pairs of probes are mounted in one support. The upper and lower signals transported by coaxial lines are added to each other outside the vacuum chamber, and then the signals are sent without amplification to the control room. The area of the probe is 20 x 7 mm^2.

2.2 Measuring Principle

We worked on the second harmonic because the beam signal to HF-noise ratio is better for high harmonics. In signal handling we make use of the heterodyne principle to achieve a fixed frequency in the information channel as well as in the reference channel. The frequency of the processing signal is 10.7 Mc. The HF-signal at the INR cyclotron is tuned between 10 and 20 Mc, corresponding to energy variation between 10 and 30 MeV/nucleon. Several double-balanced mixers have been used to produce the desired frequencies. Filtering in the intermediate frequency stages is performed by a narrow-band crystal filter which removes all unwanted mixing products from the signal. The signals from the reference channel and the information channel are fed to a phase detecting circuit containing only one double-balanced mixer. This circuit produces a DC-signal which is the component of a vector concerning phase angle. We can use a variable delay line to determine this vector. The block diagram is shown in the accompanying figure.

3. Analysis of Results

The measuring process can be divided into two steps. First, the relationship between outputs of the phase detector and delay time (or phase) is measured by using a variable delay line. Second, the relationship between outputs of the phase detector and beam delay time is measured. Then the actual relative beam phase angle can be obtained by comparing the two delay times. Using the calibration method of Garren-Smith, we can determine the beam angles. The measuring precision of beam phase angles of 15 MeV protons and 11 MeV protons is less than 1° if the errors of non-circular orbits of the particles are omitted, which can be corrected by calculating beam orbits. If the accelerating voltage frequency is higher than 16 Mc, the noise of the second harmonic of the accelerating voltage from the pick-up probes is very strong. We should make further efforts to solve these problems.



Block Diagram of Measuring System

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