DIAGNOSTIC INSTRUMENTATION FOR THE CELSIUS RING.

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Abstract

The CELSIUS cooler, storage and acceleration ring is equipped with instrumentation for measurement of the following beam properties: Intensity, position, tune, time and frequency structure. There is also instrumentation for measurement of the intensity, time structure and kinetic energy of injected ions. Separate diagnostic equipment is installed for the electron cooler operation. Short descriptions are given of the main systems for these measurements and their performances are illustrated by examples of measurement results.

Introduction

The CELSIUS ring is a cooler, storage accelerating ring. It is intended for nuclear and particle physics with beams of ions (from protons up to about A=100) interacting with internal targets. The ions injected into the ring are coming from the Gustaf Werner synchro-cyclotron [1] through an about 100 m long transport line. A general description of the ring has been given in reference [2], and the present status of the CELSIUS project is presented in another contribution to this conference [3].
This report will describe the diagnostic instrumentation in the transport line and in the ring. The locations of the sensing units of the instrumentation are shown in Fig. 1.

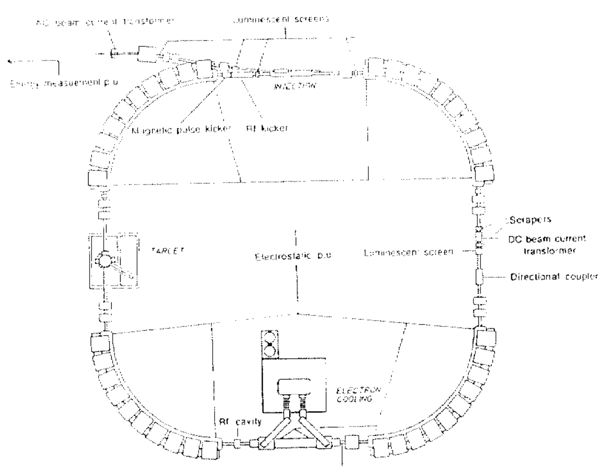

Fig.1. Drawing of the CELSIUS ring, showing the locations of the sensors for the diagnostic instrumentation.

Types of instrumentation

Luminescent screens

The steering of the ion beam in the transport line and also through the first turn of the CELSIUS ring is guided by the use of luminescent screens. The screens are made of chromium doped alumina plates which can be turned into the ion beam. The angle between the screens and the beam is 45 ^{o} and they are viewed through glass windows by means of vidicon cameras having their axes in 90 ^{o} angle to the ion beam. A thick film resistance material is put onto the plates in a rectangular grid with a 1 cm^2 unit cell in order to guide in the positioning and to prevent charge build up.

A special luminescent screen is used during the set up of stripping injection into the ring. This sceen is mounted on the radially moveable holder of the stripping foil so that it can be moved into the intended position of the stripping foil. The light emitted from the backside of the plate can be observed through a 0^o port (the stripping is done in a bending magnet) and thus the beam easily can be positioned on the desired part of the stripping foil.

AC current transformer

For observation of the time structure of the beam from the cyclotron an AC current transformer (ACCT) is installed close to the end of the transport line. The signals from the ACCT are also used for adjustment of the injection timing and for monitoring of the intensity of the injected beam (there are also some Faraday cups for measurement of the mean beam current).
The transformer consists of 20 turns wound on a toroidal core of Ultraperm 10. The output signal is amplified in an amplifier with a bootstrap coupled input stage. The bandwidth of transformer + amplifier is 10 kHz - 10 MHz. Beams can be observed with the number of particles in a beam bunch going down to 10^7. A special intensity reading is obtained with a synchronous detector.

Energy measurement system

For measurement of the kinetic energy of the injected ions a straight section of the transport line is equipped with three electrostatic pick-ups. Two of the pick-ups are mounted rigidly together and form the main measurement unit, the third pick-up is mainly intended for monitoring of variations. The distance between the main pick-ups has been measured to 9.4787 $\pm$ 0.0001 m by means of high precision theodolites.
After amplification (with bandwidth > 400 MHz) the signals from the pick-ups are brought to a network analyzer. The time of flight between the pick-ups can be determined by measuring the phase between the two signals at a suitable harmonic of the bunch repetition frequency (the cyclotron frequency) [4].
The resolution of the time measurement is about 10 ps for a 260 nA beam (see Fig. 2). It decreases to about 100 ps when the beam current decreases to 30 nA. The absolute accuracy of the

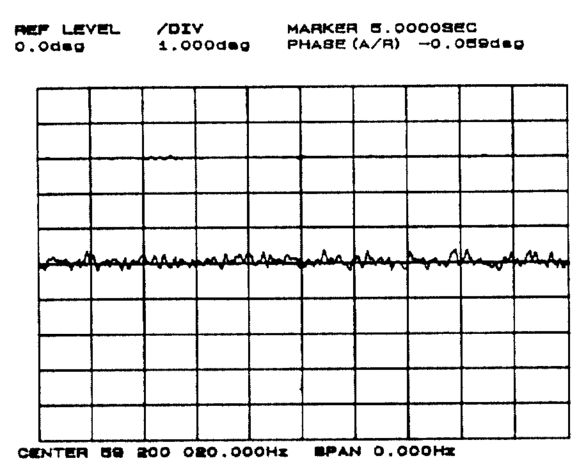

Fig.2. Recording of the phase difference between two pick-up signals from a 260 nA beam with bunch repetition rate 14.8 MHz.

measurement stems mainly from an uncertainty of ± 100 ps in the determination of the difference between the delays in the two signal paths. Thus we have an uncertainty of ± 0.2 MeV in the energy measurement of a 96 MeV H_2^+ beam, while the resolution in the measurement is 0.02 MeV. The obtained energy agrees with the energy determined in tests of the electron cooler (within the estimated uncertainty).

The same measurement technique has also been used to measure the kinetic energy of the ions circulating in the ring. Signals were then taken from the position pick-ups in the beginning and the end of the injection straight section (cf. following section). Fig. 3 shows results of phase measurements on a 500 MeV proton beam indicating a small drift during the "flat top" of the operation cycle.

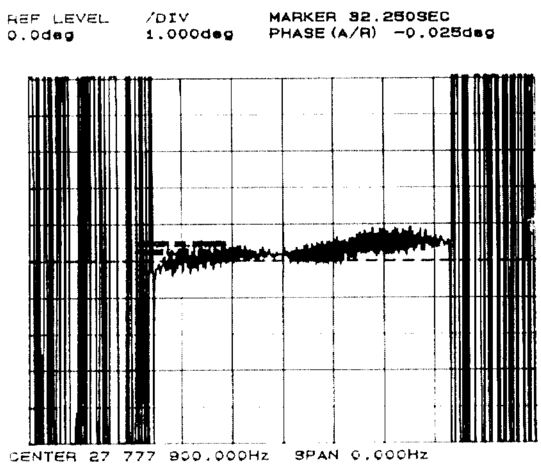

Fig.3. Recording showing a drift in the phase between two pick-up signals in the ring during the "flat top" (constant frequency).

Electrostatic pick-ups

The ring is equipped with 10 pairs of electrostatic pick-ups for observation of ion beam time structure, beam intensity and beam position in horisontal and vertical planes. Two of the pairs are placed in the electron cooler and are especially intended for alignment of the electron and the ion beams. The other pick-ups are placed at the beginning and end of each bending section. They stem from the ICE ring [5]. The amplifiers are of a design made for the LEAR ring [6].

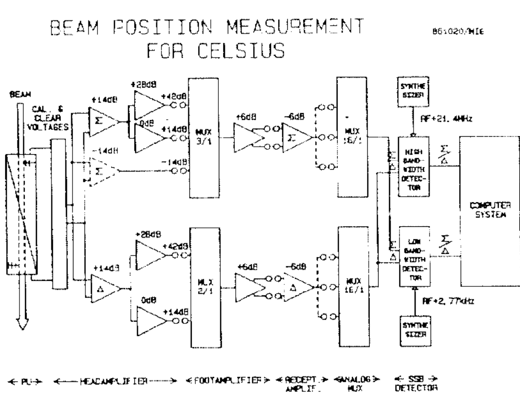

Fig.4. Schematic drawing of the beam position and intensity measurement system for the CELSIUS ring.

A schematic drawing of the electronic signal processing system is shown in Fig. 4. The high and low bandwidth detectors [7] seen in this figure are units with phase detectors which produce pure intensity and position signals which are then digitized in the computer system with a sampling interval of 50 ms. The computer system then provides several ways of displaying and recording of these signals, an example is given in Fig. 5.

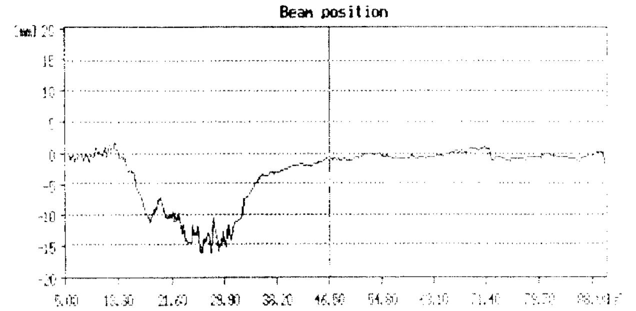

Fig.5. Recording of the radial beam position during an operation cycle accelerating protons from 48 to 500 MeV kinetic energy.

Directional coupler

A wideband directional coupler with characteristic impedance of 50 Ω is installed in the ring for observation of Schottky noise signals. The signals are amplified by low noise amplifiers (NF = 1). The sensitivity can be increased by tuning of the couplers by means of varicaps. The signals are usually brought to a spectrum analyzer in order to determine tune values and spread of the kinetic energy of the ions. An example of the latter type of measurement is given in Fig. 6 which shows the decrease in energy spread during a test of the electron cooler.

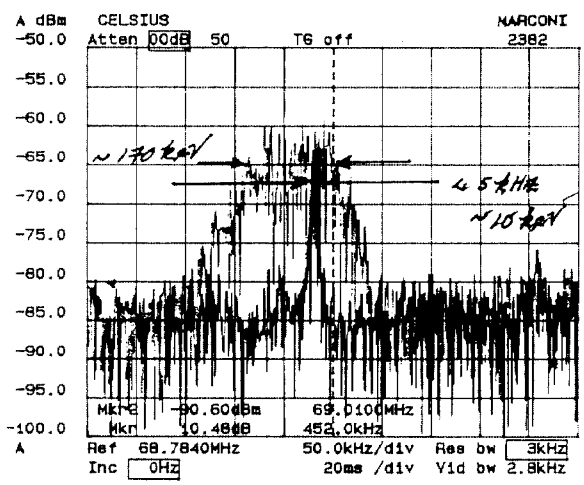

Fig.6. Recording of the decrease in energy spread in the beam during the first test of the electron cooler.

DC current transformer

The circulating beam current can be measured by a DC current transformer designed for the ISR ring [8]. The transformer has been modified in order to increase its sensitivity to 1 μA.

Rf kicker

By means of an Rf kicker in the ring we can heat the beam or make Rf knockout determinations of tune values. The Rf for the knockout can be gated to a short time interval of the operational cycle in order to facilitate tune measurements at an arbitrary time of the cycle.

Systems under development

We are in need of a system for fast tune measurements in order to easily observe tune variations during accelerations and to compensate for these variations. Two such systems are under development. One is based on phaselocking of an Rf kicker signal to betatron sidebands. The other uses a fast magnetic kicker to excite coherent oscillations that can be observed with a transient recorder. The magnetic kicker can operate with 1 kA 800ns long pulses with a repetition rate of up to 20 Hz. The transient recorder can also be used for observations of instabilities of the beams.

References

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