METHODS AND INSTRUMENTATION FOR MEASUREMENT OF LOW ION BEAM CURRENTS AT CRYRING

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Abstract

In many CRYRING experiments an accurate measurement of the circulating ion beam current is essential for determination of, for example, absolute cross sections. However, the current produced from the ion source can be very low, below 1 nA. Various detector systems have been developed for the storage ring, CRYRING, to measure both bunched and coasting beams by using the overlapping ranges of these systems.

BUNCHED-BEAM CURRENT MEASUREMENTS

Bunched beam parameters:
duty cycle: 10-60%,
frequency range: 40 kHz-1.5 MHz

For bunched beam measurements a Bergoz Beam Charge Monitor with Continuous Averaging (BCM-CA) and an Integrating Current Transformer (ICT) were installed in 1997 giving 200 μA full scale range and 20 nA RMS resolution.
Newer electronics (a low noise, high gain preamplifier, moved closer to the ICT, and a 10 Hz low pass filter) has improved the measurements made with the Bergoz transformer. The full-scale range has been lowered from 200 μA to 5 μA, with 1 nA RMS resolution. An example of the increased sensitivity of the modified system can be seen in Fig. 1.

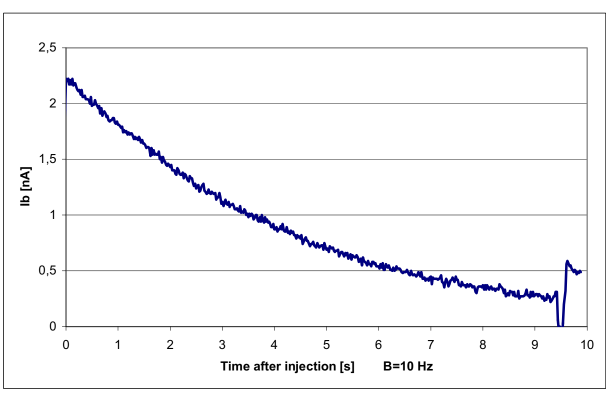

Figure 1: Current measurement with the Bergoz BCM. H_2S^+ ion beam current during 10 s with 66 averages.

The sensitivity of the current measurements made with the AC transformer is limited by the preamplifier noise and the RF background. To minimise the background the sum signal of the capacitive pick-up which is located furthest from the RF system is used. The measured RMS resolution is about 100 pA, as it is shown in Fig. 2.

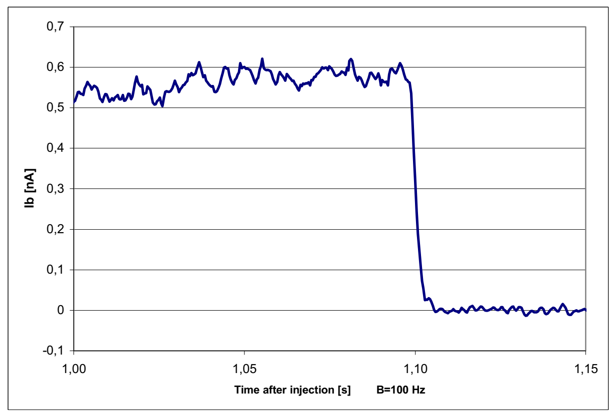

Figure 2: Current measurement made with capacitive pick-up. $D^{13}CO^+$ ion beam current with 4 averages. RF off after 1.1 s.

COASTING BEAM CURRENT MEASUREMENTS

To measure the coasting beam intensity different relative current measuring devices has been built, using micro-channel plate (MCP) detectors in ion counting mode. The residual-gas beam profile monitor (RGBPM) and the neutral particle detector can handle 1 Mcps count rate with maximum 1 cps dark count rate. On the magnetic flat-top, 20 ms is available to calibrate the relative current measuring devices with the output signal of the Bergoz AC transformer. As the duty cycle of the bunched beam can vary from 10% to 60% their measuring range has to be very high to avoid saturation. Presently a 50 Mcps secondary electron multiplier, with a conversion dynode, is under construction with a maximum dark count rate of 0.05 cps.

BEAM PROFILE MONITORS

To measure the transverse density distribution of a stored ion beam, different MCP-based monitoring devices have been developed for use in CRYRING [1,2,3].

Residual gas ionisation beam profile monitors detect the ionisation products arising from the interaction of the ion beam with the residual gas. With two monitor units installed in the ring, the horizontal and vertical profiles of the stored ion beam can be measured with a spatial resolution of about 0.5 mm FWHM [4]. The beam profiles of both an electron-cooled and ordered $^{58}Ni^{17+}$ ion beam can be seen in Fig. 3 and 4, respectively.

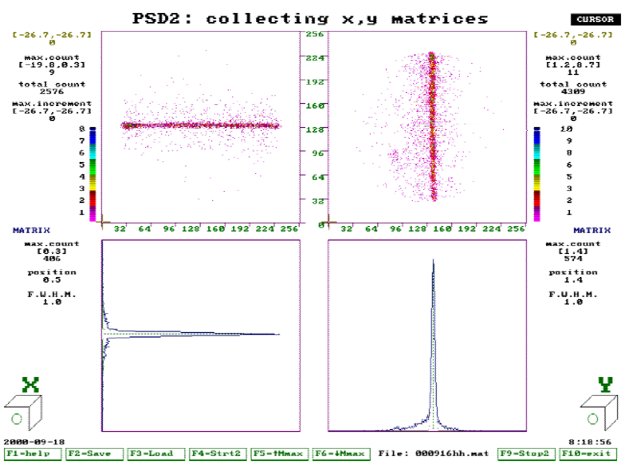

Fig.3. Vertical and horizontal profiles of the cooled $^{58}Ni^{17+}$ beam

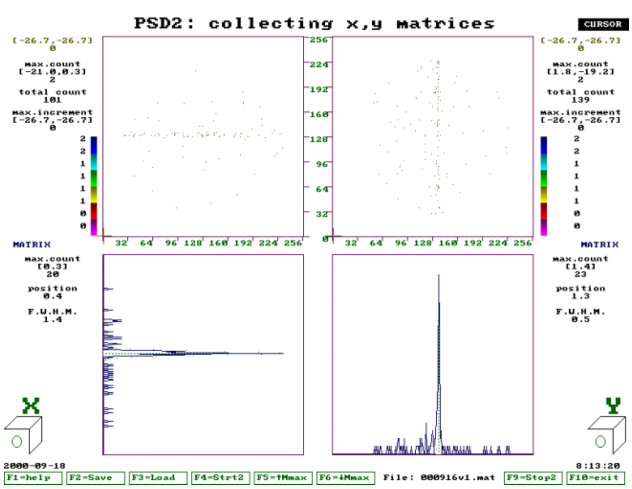

Fig.4. Vertical and horizontal profiles of the ordered $^{58}Ni^{17+}$ beam

The neutral particle detectors measure the density distribution of neutralised singly charged ions and molecular fragments arising from interactions of the stored ion beam with residual gas particles.

The imaging components for both types of detectors are MCPs mounted in a Chevron (set of two 40 mm MCPs) configuration matched to a resistive anode encoder (RAE). The position signals from the resistive anode are derived by the charge-division method. Charge pulses at each end of the resistive anode are integrated in charge sensitive preamplifiers (PA), and these output pulses are then shaped by a spectroscopy main amplifier (MA) with a 0.5 µs shaping time constant.

Using a resistive anode encoder, with 30 kOhm total resistance over the resistive plate between two readout electrodes, the spatial resolution is limited by thermal noise to 0.3 mm FWHM. The absolute x,y location of the event is computed by two analogue dividers coupled to the stretched bipolar signals from the main amplifiers (MA). The timing signal, generated by a fast transimpedance amplifier connected to the backside of the second MCP plate, has a 2 ns rise time and 6 ns pulse width. For real-time visualisation, a PC based dual-port incrementing matrix memory card has been developed with an 8 bit, 3 µs type ADC. The total system dead time is 5 µs using a 0.5 µs shaping time constant in the main amplifiers [3].

The buffered timing output signal can be also used for precise lifetime measurements, with a linear counting capability up to 1 Mcps with a few cps dark count rate.

SOFTWARE

The current measurements are managed with a LabVIEW program with emphasis on data safety and management. Presently we use an oscilloscope and a GPIB card but we will soon switch to an ADC card which, among other things, will increase flexibility and reduce the time required for data transfer. The current readings will also be accessible from the new ConSys control system.

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