DEVELOPMENT OF PICKUP SYSTEM FOR STOCHASTIC COOLING IN ACR

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Abstract

Stochastic cooling is one of useful methods for rapid cooling of beam with very large emittance and wide momentum spread as in ACR, where secondary RI beams are accumulated. Pickup with large gain and wide band is one of the important devices for the rapid cooling. We made a test pickup system and measured time and frequency domain spectra using HIMAC beam. A flexible coaxial cable used for connection between an electrode and a feed-through was good enough for vacuum of the HIMAC. The obtained spectra reproduced features of the beam well. Pickup sensitivity obtained from the frequency domain measurement is strongest around 1.5 MHz, which is consistent with the designed value. However we didn't determine useful frequency region of the pickup because unexpected peak around 750 MHz appeared.

1 INTRODUCTION

In accumulator cooler ring (ACR [1]) at MUSES project [2] beam cooling is required for a secondary radio-isotope (RI) beam with very large emittance (ε_x=125 π mm*mrad) and wide momentum spread ($\Delta p/p = \pm 0.15$ %) to perform colliding experiment with high luminosity in double storage ring [3]. Moreover the cooling should be rapidly done because RI has an intrinsic life time.

Stochastic cooling [4] is one of useful methods for cooling of the ion beam. Since principle of the stochastic cooling is feedback from a pickup to a kicker via an amplifier, a rapid cooling time is obtained by the stochastic cooling in a region of large ε_x and $\Delta p/p$ where feedback is large. From this feature stochastic cooling is used for pre-cooling in ACR.

In order to realize rapid cooling, it is important to make a stochastic cooling system that has a large feedback gain for wide frequency region since the RI beam in ACR has several kinds of velocity. From the requirement the system must have a high sensitive pickup and a high power (several kW) amplifier with wide band.

As the first step to make the system, we made a test pickup system and measured its characteristic property using a beam in HIMAC [5]

2 PICKUP SYSTEM

Figure 1 shows a pickup system. The pickup system composed of 16 pairs of electrodes, a ground box, and a vacuum chamber. Each electrode is a loop typed coupler and length of it (50 mm) is determined so as to be most sensitive around 1.5 GHz. Width (81 mm) and gap (60 mm) of an electrode are determined so as not to disturb HIMAC beam. Signal picked up by the electrode is sent to two terminals located at both edges of it through a stripe-line of 50 Ω composed by the electrode and the ground box. Each terminal is connected by a coaxial

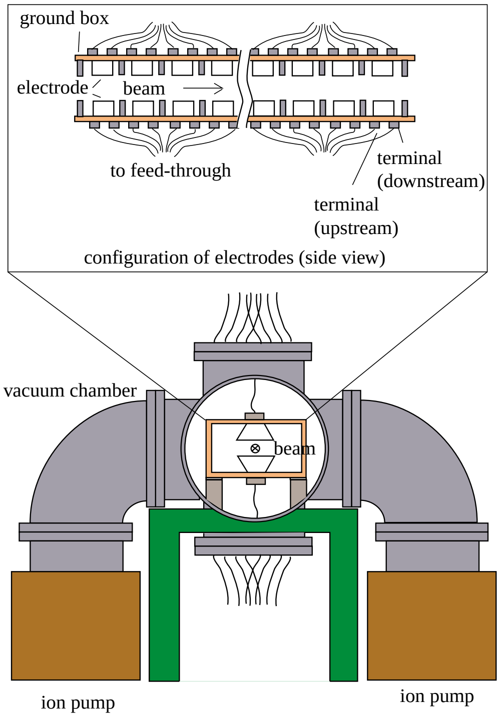

Fig. 1 Schematic drawing of the pickup system

cable (Dipsol co. LTD. ; Cu-s5DDs-08) with a character of wide band and low outgas and the signal is sent outside of the vacuum chamber through an original feed-through connector. Since voltage of output signal from the terminal depends on beam velocity we prepare two terminals so that we can choose the larger signal of two terminals. On using the system the terminal with smaller signal is terminated by 50 Ω terminator.

In order to satisfy good vacuum pressure ($\sim 10^{-10}$ torr) in the synchrotron the vacuum chamber has two ion pumps (each 400 l/s). Before the pickup system was install into the synchrotron we baked it. Temperature of baking was raised up to 180 °C for two days and kept the temperature for two days. After one week from end of baking vacuum pressure became 2×10^{-9} torr. In actual, after a month from install the pressure was 5×10^{-10} torr.

3 BEAM TEST

Beam test for the pickup system was performed using carbon beam of 290 MeV/u from HIMAC synchrotron. Intensity of the beam was 1.9×10^{9} particles per second and it was very stable. In the test we measured signals picked up by electrodes for a bunched beam and a coasting beam after acceleration. The signal from the bunched beam was mainly measured with time domain and it from the coasting beam was done with frequency domain. For the coasting beam measurement was started from 500 ms after an RF voltage of a cavity in the synchrotron was turned off. From calculation of longitudinal distribution, 500 ms is long enough to make the coasting beam.

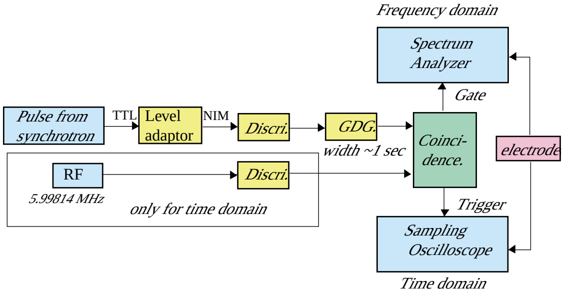

Fig. 2 Electrical circuit for measurement of the pickup signal

Figure 2 shows an electrical circuit for the measurement. A pulse from the synchrotron produced at finishing time of acceleration was used as a gate signal for the measurement. For the measurement by the bunched beam an RF signal was used as a signal to make time origin. The signal from the electrode was sent to a preamplifier (0.1~2.0 GHz, 40 dB, NF 1.1, MITEQ co. Ltd.) located near the vacuum chamber and then to a room of data acquisition using about 30 m length of BNC cable. The preamplifier was used for only frequency domain measurement.

Data were taken by sampling oscilloscope for the time domain measurement and a spectrum analyzer for frequency domain. In measurement, when the signal from one terminal is measured the other terminal was terminated.

Figure 3 shows time domain signal for the bunched beam of ^{12}C 290 MeV/u. Interval between peaks in Fig. 3 shows interval time between bunches. The measured value of 166 ns was consistent with RF frequency set for the synchrotron (5.998MHz).

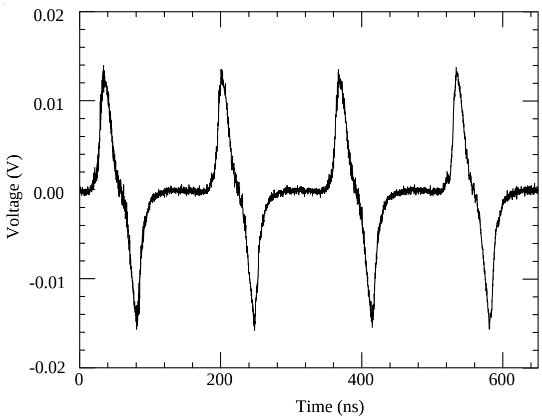

Fig. 3 A signal by time domain measurement from an electrode of the pickup system

We tried to reproduce the time domain signal on basis of theoretical calculation [6]. In the calculation distribution of the bunched beam was supposed to be Gaussian plus flat part and frequency up to 100 MHz. Widths of Gaussian and the flat part and sensitivity of the pickup were parameters for the reproduction. Here, sensitivity is a quantity defined by V_{out}/I_{beam}, where V_{out} is output voltage measured in the sampling oscilloscope and I_{beam} is average beam current. In Fig. 4 reproduced spectra for two terminals of one electrode are shown with measured signals. In the figure widths of Gaussian and the flat part are common for two curves. The obtained half width of Gaussian is 2.0 m and that of the flat part is 0.85 m. Obtained sensitivity of pickup around 100 MHz is 1 Ω for an upstream terminal and 0.3 Ω for a downstream terminal. These values are rather high compared to ones from theoretical calculation.

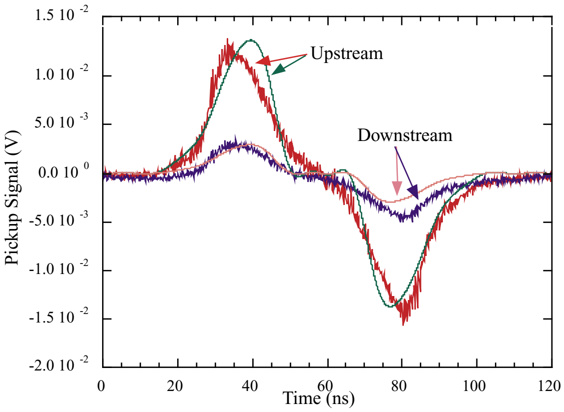

Fig. 4 Calculated and measured time spectra for both terminals of one electrode

Figures 5a~5d are shown frequency domain signals of ^{12}C 290 MeV/u from both edges of one electrode in several regions. In this figures we didn't make any

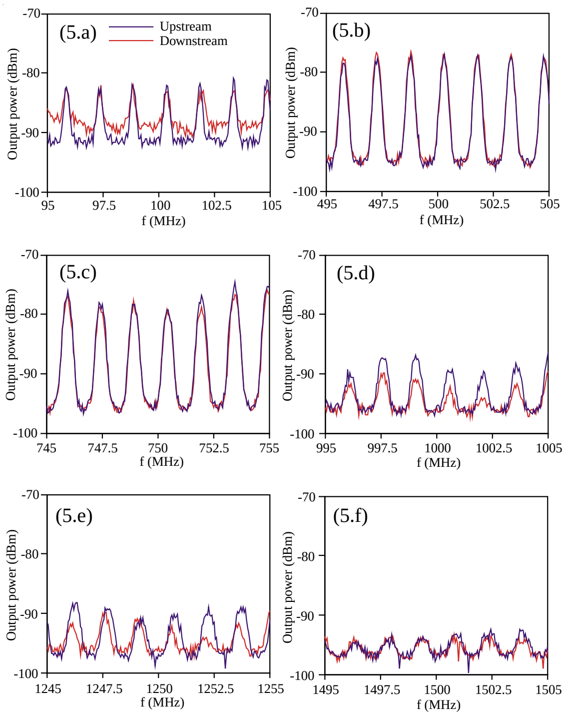

Fig. 5a~f. Frequency spectra for signals from both edges of an electrode in 6 frequency regions

corrections. More than 1750 MHz we could not see any peak. Interval between peaks is 5.998 MHz and consistent with revolution frequency of this beam. Momentum spread obtained from widths of these spectra is 0.05 % and almost same as designed value of the synchrotron.

To obtain the pickup sensitivity defined above we make correction power loss of the BNC cable and gain of the amplifier. In the correction we took account of reduction of peak in Schottky signal by increasing of frequency. Obtained pickup sensitivity of upstream is shown in Fig. 6. In the figure sensitivity is represented with normalised value by that of 1500 MHz to compare with others easily. Absolute sensitivity of 1500 MHz is about 25 Ω. Sensitivity of downstream is almost similar.

As shown in Fig.6, the most sensitive frequency exists around 1500 MHz, which is almost same as the designed value. Useful frequency (more than 0.75) is about 1100 MHz but it is not so clear because unexpected peak around 750 MHz appeared. The reason for appearance of the additional peak is not understood.

4 SUMMARY

We made the test pickup system of stochastic cooling for ACR and installed in HIMAC. Vacuum is good enough for an accumulator ring using the Dipsol flexible coaxial cable. Beam test was performed using HIMAC beam and measured the time and the frequency spectra. These spectra reproduce the features of HIMAC beam well. The sensitivity of the pickup obtained from the frequency domain measurement is strongest around 1.5 MHz. However, for unexpected peak around 750 MHz we didn't determine useful frequency region clearly.

We will study how to combine signals from several electrodes and measure useful frequency region for the pickup system. Another important device for stochastic cooling is an amplifier. We will start to study it from this year.

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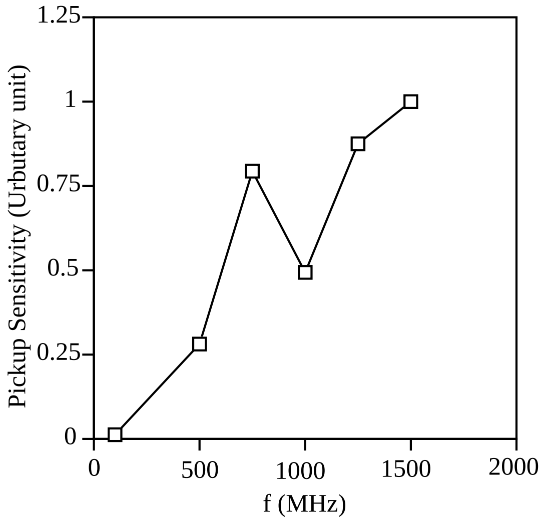

Fig. 6 Frequency dependence of pickup sensitivity