EVALUATION OF RIPPLE OF THE POWER SUPPLY TO A BEAM SPILL DURING A THIRD ORDER RESONANT EXTRACTION IN HIMAC

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Abstract

Ripples in the HIMAC synchrotron power supply are below ppm level both for the Focussing magnet power supply and the Bending magnet power supply. With this low ripple content, one is able to identify a qualitative relation between the ripple content of the power supply of the Quadrupole magnet and the Bending magnet power supply. This article describes their relation by using a Ripple Basher, which is a device of adding external sinusoidal pseudo-ripple harmonics phase-locked to AC three phase voltage into the power supply.

1 INTRODUCTION

Current ripple or current spike of a power supply of a synchrotron is inevitable. This was considered to be due to a finite number of thyristor power supply and also due to imbalances of input voltages of a rectifier. Ripple causes fluctuations in extracted spill of a resonant extracted beam. A requirement of the current ripple to the power supply, however, has been too severe and an uniform beam spill has not been realized by main power supplies alone. Although auxiliary devices of Quadrupole magnet with a servo-feedback system is employed, a physics and a mechanism of the feedback system including slow extracted beam was not completely understood and an effort for more uniform beam spill has been continued.

Present available theory of the resonant extraction seems to be rather crude. A computer simulation lacks in intuitive insight of grasping physics behind an observation of slow extraction. A large amount of memory and cpu time and a very fast computer is necessary. It will be instructive to get valuable information from actual beam to understand beam physics.

There was an attempt to measure a relation between an extracted beam and a ripple of a power supply at GSI. Due to a extremely distinguishing a sensitive level of the ripple, where it is said beam spill is the most sensitive device of detecting a small level of ripple,they introduced an artificial ripple in the power supply output of slightly different frequency to distinguish it from intrinsic ripple[1].

A power supply of HIMAC twin heavy ion synchrotron is boasting of its small current ripple content[2, 3] as well as its reproducibility. It is around a tenth of ppm level at a rated current in rms. This synchrotron therefore is suited to study the mechanism of slow beam extraction. At this small level of ripple, one can also add an external ripple of a specified frequency which may be the frequency of illogical and logical ripple. This article presents the measured results of the relation between the fluctuation of the spill and the current ripple in HIMAC Focussing Quadrupole of one of the synchrotrons.

2 METHOD

We have made a two set of five channel device which can generate a sinusoidal output voltage called “ripple basher”. This device is expected of bashing and exterminating hated harmonic voltages inherently existing in the output of every existing power supplies. The sinusoidal harmonic waves are all locked to an AC input voltage by Phase Locked Loop and a magnitude and a phase can be independently adjustable. The frequencies of choices are multiples of 50 Hz, from 50 Hz to 1200 Hz. A single mode of 75 Hz is also made as a special case. The triggering timing of the Main power supply of the HIMAC is also controlled by a system of APPS with a Phase Locked Loop. This PLL system easily facilitate a canceling between the intrinsic ripple and the signal of the ripple basher. The output signal of the ripple basher can be fed into the input of the active filter or the terminal point of minor-AVR system. The phase and the amplitude are independently adjusted by observing the voltage ripple of a breeder resistor in the power supply circuit so that the resultant magnitude of the target ripple is set.

3 EFFECT OF QUADRUPOLE AND BENDING MAGNET

The effect of the ripple of the magnets differs depending upon whether it is Focusing Quadrupole(QF), Bending magnet or Defocusing Quadrupole(QD). The sensitive magnet is a Focusing Quadrupole or Bending magnet(B). The least sensitive is Defocusing Quadrupole. The effect of the Bending magnet’s ripple depends on a magnitude of a chromaticity and possibly depend on a momentum spread of the ion beam. Until we found the ripple tolerance of the Bending magnet is more than we had anticipated, our effort of reducing the ripple in view of the uniform spill is concentrated only to that of the QF. We will not go into detail of the mechanism of the effect of the Bending magnet’s ripple but only present the data and call an attention to the reader its importance. Figure 1 illustrates a typical example of the beam spill of the one of the two rings. The ripple performance between the two ring slightly differs; the performance of the upper ring is better. As a drastic example we show the beam spill by turning off each Active Filter of three power supplies in Figures 2, 3 and 4 for QF,B and QD. The relative rms magnitude of the voltage ripple is shown in the figure captions in dBV and the current ripple in ppm. Note in other literature of the authors[2, 3], the relative ripple is given for maximum rating energy of 800MeV/u. This data are taken when the maximum beam energy is 290 MeV/u carbon ion and roughly factor of two differs. The relation between the voltage ripple V and the relative current ripple ϵ is given by the following relation;

$$\epsilon = \frac{F\ 10^{\frac{-V}{20}}}{\omega LI}$$

where L is an inductance of a magnet string an I is a current of the magnet. L , rated I , F are 0.1 H and 1260 A and 50 for Q and 0.6 H , 2280 A and 300 for B.

4 RIPPLE VS. SPILL FLUCTUATION

In order to quantify uniformity of the beam spill, we define the spill fluctuation as as shown in Figure 5. This quantity is evaluated as a function of the magnitude of a voltage ripple by adjusting the ripple basher and is plotted in Figures 6, 7, 8, 9 and 10 for typical frequency of interest. The spill fluctuation due to 100 Hz ripple shows non-linear dependence to a magnitude of the ripple. Above 10 ppm(rms) the spill fluctuation seems to be roughly saturated although it is weakly dependent on the ripple magnitude. Between 10 ppm and a few ppm it is sensitive. Below a few ppm it is again weakly dependent. A simple linear analysis indicates a rate of a change of a separatrix is proportional to a spill fluctuation . The spill fluctuation δ is thus proportional to a current ripple frequency for a given amount of δ. The amount of current ripple is shown in Figure 11 for δ=50%. In contrast an expectation, it is observed a deviation from a linear dependence for the frequency below 300 Hz. We are expecting to add more data points for further investigation.

5 REFERENCES

[1] H. Eickhoff,GSI, private communication

[2] M.Kumada et al.,proceeding in this conference.

[3] M.Kumada et al., to be published in particle accelerator.

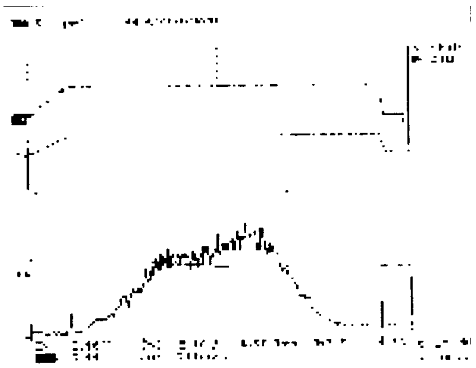

Figure 1: Typical spill

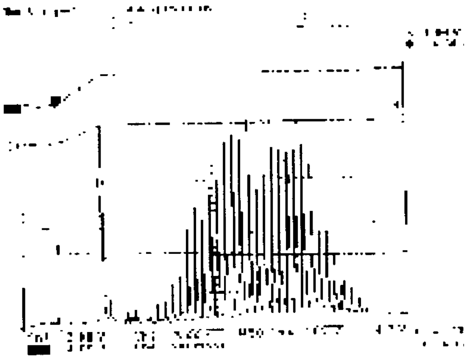

Figure 2: Spill without Active filter of QF.(dB, ppm)

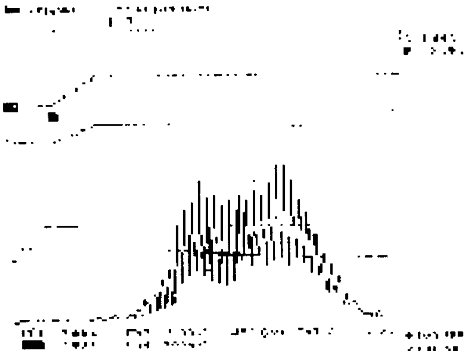

Figure 3: Spill without Active filter of B.(dB, ppm)

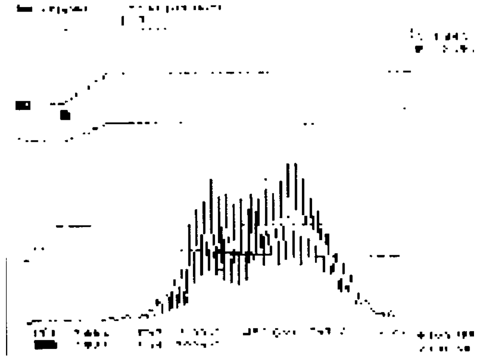

Figure 4: Spill without Active filter of QD.(dB, ppm)

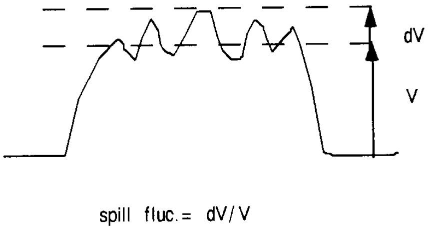

Figure 5: Definition of the spill fluctuation

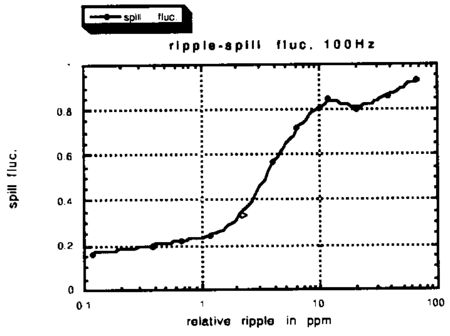

Figure 6: Spill fluctuation vs. 100Hz ripple

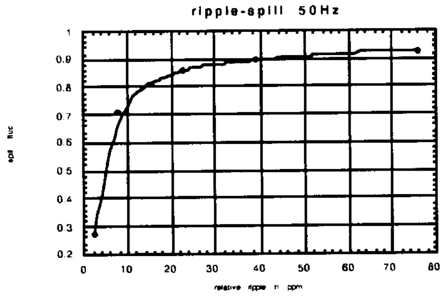

Figure 7: Spill fluctuation vs. 50Hz ripple

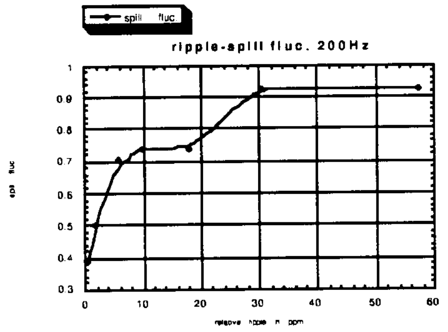

Figure 8: Spill fluctuation vs. 200Hz ripple

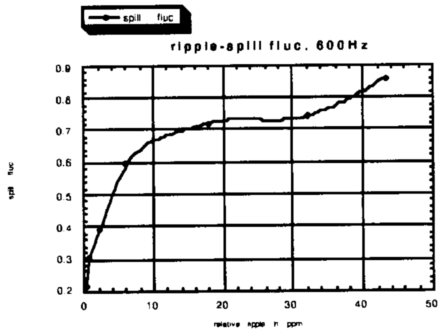

Figure 9: Spill fluctuation vs. 600Hz ripple

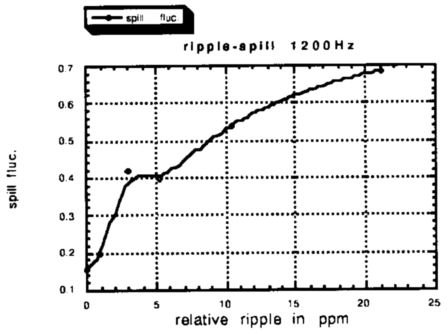

Figure 10: Spill fluctuation vs. 1200Hz ripple

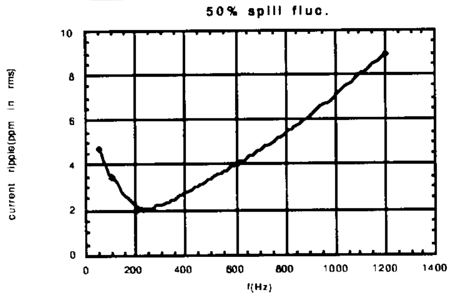

Figure 11: 50% spill fluctuation vs.ripple freq.