BNL-101421-2014-TECH
RHIC/RF- 1;BNL-101421-2013-IR

The possibilty to correct the longitudinal injection error by adjusting the RF phase

J. Xu

March 1993

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy
USDOE Office of Science (SC)

Notice: This technical note has been authored by employees of Brookhaven Science Associates, LLC under Contract No.DE-AC02-76CH00016 with the U.S. Department of Energy. The publisher by accepting the technical note for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this technical note, or allow others to do so, for United States Government purposes.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RHIC/RF-1

RHIC Project
BROOKHAVEN NATIONAL LABORATORY

RHIC/RF Technical Note No. 1

The Possibility to Correct the Longitudinal Injection Error by Adjusting the RF Phase

J. Xu

March 1993

The Possibility to Correct the Longitudinal Injection Error by Adjusting the RF Phase

Jianming Xu
Brookhaven National Laboratory
March 1993

The longitudinal injection error is generally damped by using the wideband damping cavity to apply a voltage which is in phase with the main cavity to reduce the momentum error. Because the absolute energy error is quite large, one can only reduce it to zero in thousands of turns. For example, in RHIC, if $\frac{\Delta E}{E} = 10^{-4}$, for gold ion $\Delta E = 1.1 \times 10^6$ eV/N, for proton, $\Delta E = 2.9 \times 10^6$ eV. If the damping voltage is 1000 volts, the damping process lasts more than 2000 turns or about 40 msec. In this period, the bunch smears and the bunch area becomes larger and larger. In this case the damping system can only reduce the bunch area blow up, it can not eliminate the area increase. When the accelerating voltage is small, a relatively small damper voltage which is $\pi/2$ out of phase to the main accelerating cavity can effectively change the bunch center phase relative to the combined RF System – the main cavity plus the wideband damping cavity.

Suppose the voltage of the main cavity and damping cavity are as follows:

$$V_{\text{main}} = V_m \sin(\omega t + \phi_0) \tag{1}$$

$$V_{\text{damp}} = V_D \cos(\omega t + \phi_0) \tag{2}$$

The voltage of the combined RF System V_{com} can be expressed as follows

$$\begin{aligned} V_{\text{com}} &= V_m \sin(\omega t + \phi_0) + V_D \cos(\omega t + \phi_0) \\ &= V_c \sin(\omega t + \phi_0 + \Delta\phi) \end{aligned} \tag{3}$$

where

$$V_c^2 = V_m^2 + V_D^2, \tag{4}$$

and

$$\Delta\phi = \tan^{-1}\frac{V_D}{V_m}. \tag{5}$$

If the amplitude of the phase error relative to the main cavity is $\Delta\phi_0$, we select the V_D so that

$$\Delta\phi = \Delta\phi_0 \tag{6}$$

and

$$V_D = V_m \tan \Delta\phi_0 \tag{7}$$

In this case, the phase of the combined RF voltage relative to the main accelerating voltage is $+\Delta\phi_0$, the bunch center phase error relative to the main accelerating voltage remains the same but the bunch center phase error relative to the combined RF voltage is zero. This means that the injection error is eliminated instantaneously by shifting the phase of the RF system. There will not be smear process and will not be bunch area increase also, because there is no coherent oscillation of the bunch center in the combined RF System.

In order to realize this damping method, we should measure the bunch center phase error relative to the main accelerating voltage. When this error reaches it maximum value $\Delta\phi_0$ (in this time $\frac{\Delta p}{p} = 0$) turn on the damping voltage whose amplitude is expressed in equation (7). This damping voltage should be turned on when that bunch begins to pass the damping cavity, keeping this amplitude when that bunch passes through and then a voltage corresponding to the phase error amplitude of the next bunch should be built up before it approaches, so that the bunches can be damped individually. This V_D is reduced adiabatically. In this course, the phase of the combined RF voltage relative to the main RF voltage which is the same as the bunch center phase relative to the main accelerating voltage decreases adiabatically also. Finally, V_D is reduced to zero and the bunch center approaches to φ_s (generally at injection $\varphi_s = 0$) of the main accelerating voltage adiabatically and the injection error is eliminated.

In RHIC, for protons, $V_m = 12$ kV. If $\Delta\phi = 5^o$ the required V_D is 1050 volts, which is an acceptable value. If we use two wideband cavities, the impedance is 100Ω, the total power will be about 5 kW. For gold ions, the RF voltage is much higher, about 215 kV. The required voltage to shift the RF phase of 5^o is too high, about 18.8 kV. In this case, we can only use the damping cavity to reduce the energy error and swallow the bunch area increase. This means that, when gold ions are injected, the damping cavity voltage is in phase with the main accelerating voltage and controlled by the $\frac{d\phi}{dt}$, where ϕ is the phase of the bunch center relative to the main cavity, when protons are injected, the damping cavity voltage is $\pi/2$ out of phase and its amplitude is determined by the bunch center phase error amplitude and then reduced to zero adiabatically.