The phase loop status of the RF system in CSNS/RCS

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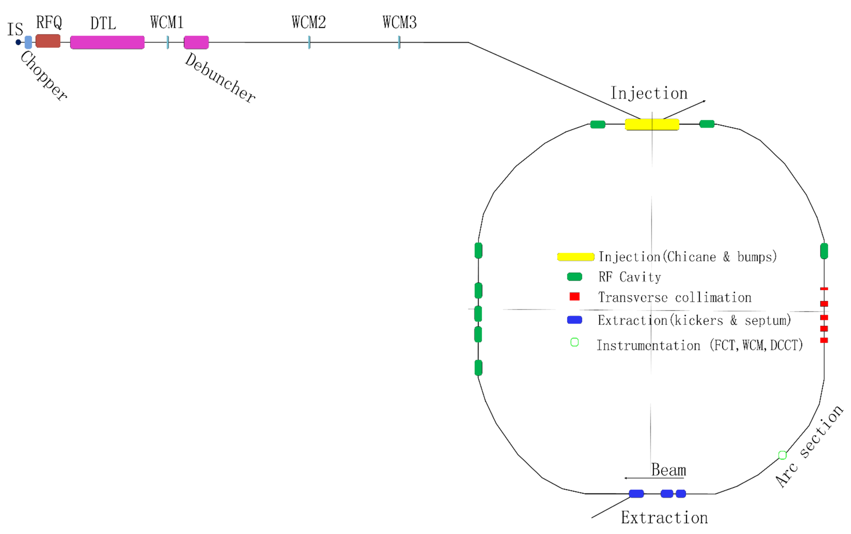
Abstract

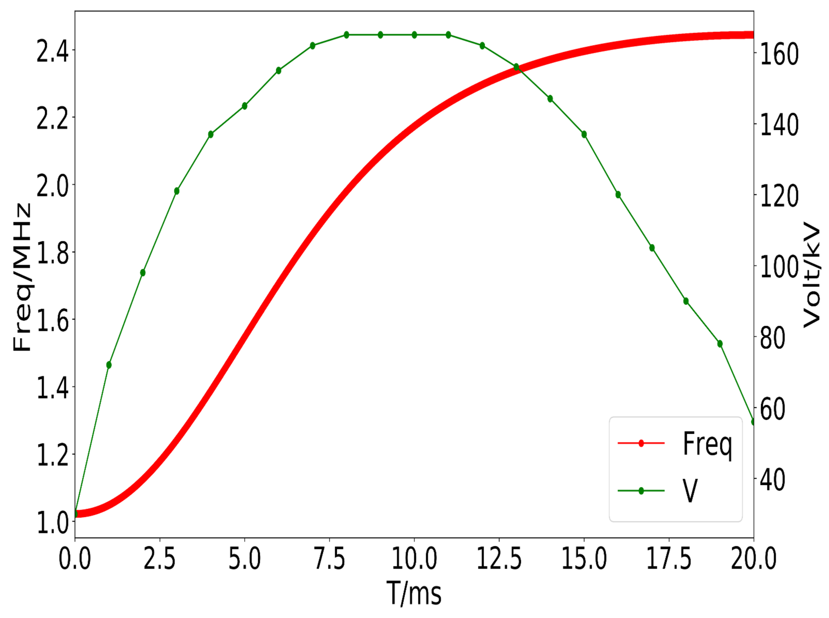
The acceleration system of the RCS consists of eight ferrite loaded cavities. The RCS is the space charge dominant machine and it is mitigated through the bunch factor optimization in the beam commissioning, thus the injected beam will occupy a larger bucket size and unavoidable mismatch with the bucket, thus the dipole oscillation is excited. The phase loop scheme is designed to restrict the oscillation in the RF system. The transmission efficiency is reduced and the beam loss is increased when the phase loop introduced and the bunch factor also increases, so the phase loop scheme is studied. To keep the phase loop but also maintain the transmission efficiency, we optimized the original phase loop scheme, but the beam loss still increases small when the loop on.

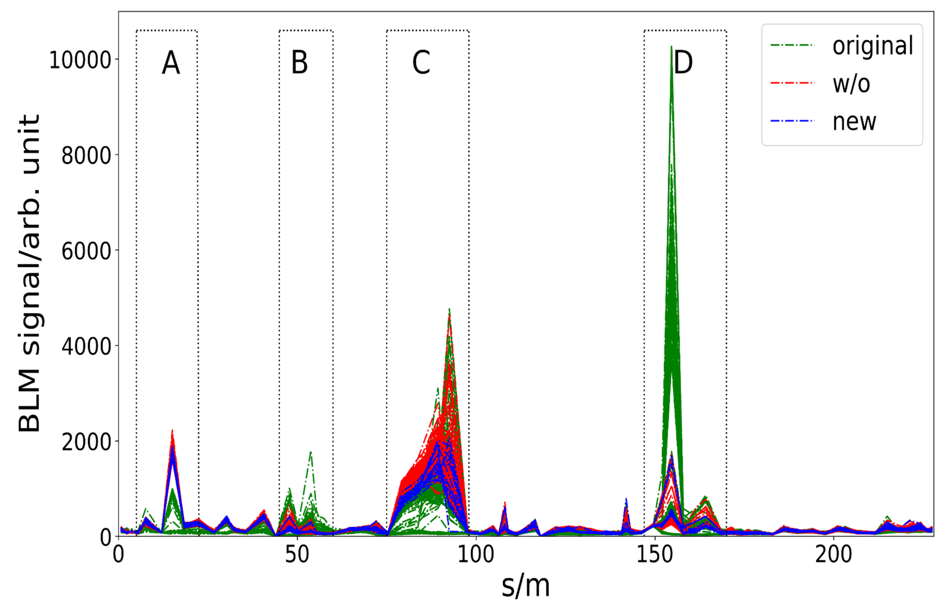
INTRODUCTION

The Rapid Cycling Synchrotron (RCS) of the China Spallation Neutron Source(CSNS) is a high intensity proton accelerator[1,2]. The beam is longitudinally painted in the RCS with the energy deviation between the injected beam energy and the RCS synchronous particle energy. The designed momentum filling is 0.82. The RF acceleration system consists of eight ferrite loaded cavities. The maximum cavity voltage is set to be 165 kV with a maximum synchronous phase of 45 degrees. The RF frequency is driven by a bias power supply, allowing it to be synchronous changed with beam energy[3]. The RCS is the space charge dominant machine. A good way to mitigate the strong space charge effects is to uniform the longitudinal beam distribution, namely to improve the bunch factor. The beam phase is given from the FCT signal after the digital I/Q demodulation. As the bunch factor increases, the injected beam will occupy a larger bucket size and unavoidable mismatch with the bucket, which will lead to the dipole oscillation. The oscillation affects the longitudinal stability region and the cavity operation. The RF system is designed with a phase loop scheme to damp the oscillation. The beam phase with a digital filter and 90 degrees shift is adopted as a feedback in the phase loop. However, the transmission efficiency is reduced about one percent after introducing the scheme, so the phase loop is studied and optimized.



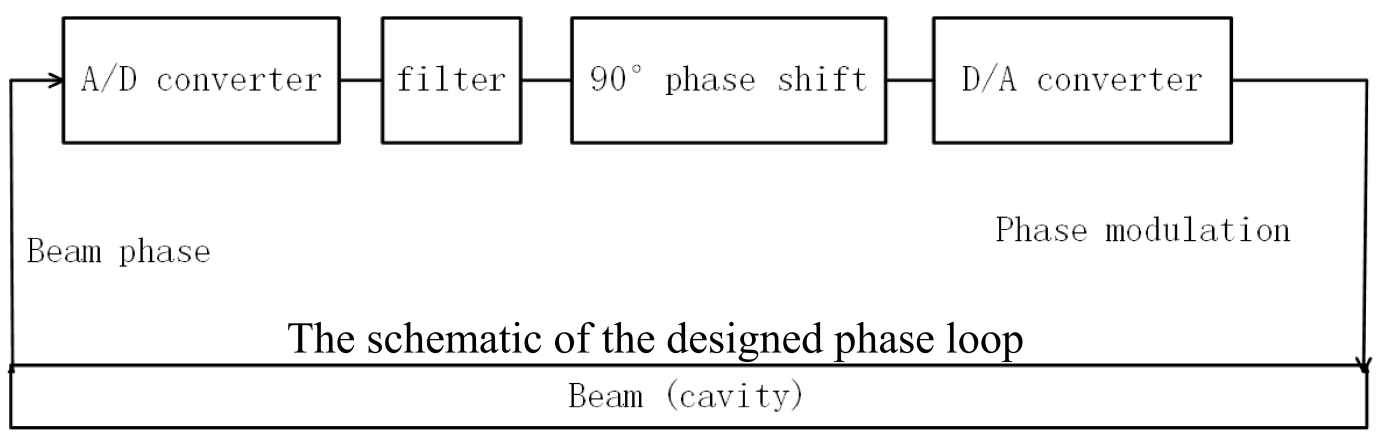
Parameters	Units	Values
Circumference	m	227.92
Injection energy	MeV	80
Extraction energy	GeV	1.6
Proton per pulse	E13	1.56
Transition γ		4.9
Repetition Rate	Hz	25
Harmonic		2
Injection energy spread	%	0.05 ~ 0.5
Cavity number		8
Cavity frequency	MHz	1.02 ~ 2.45



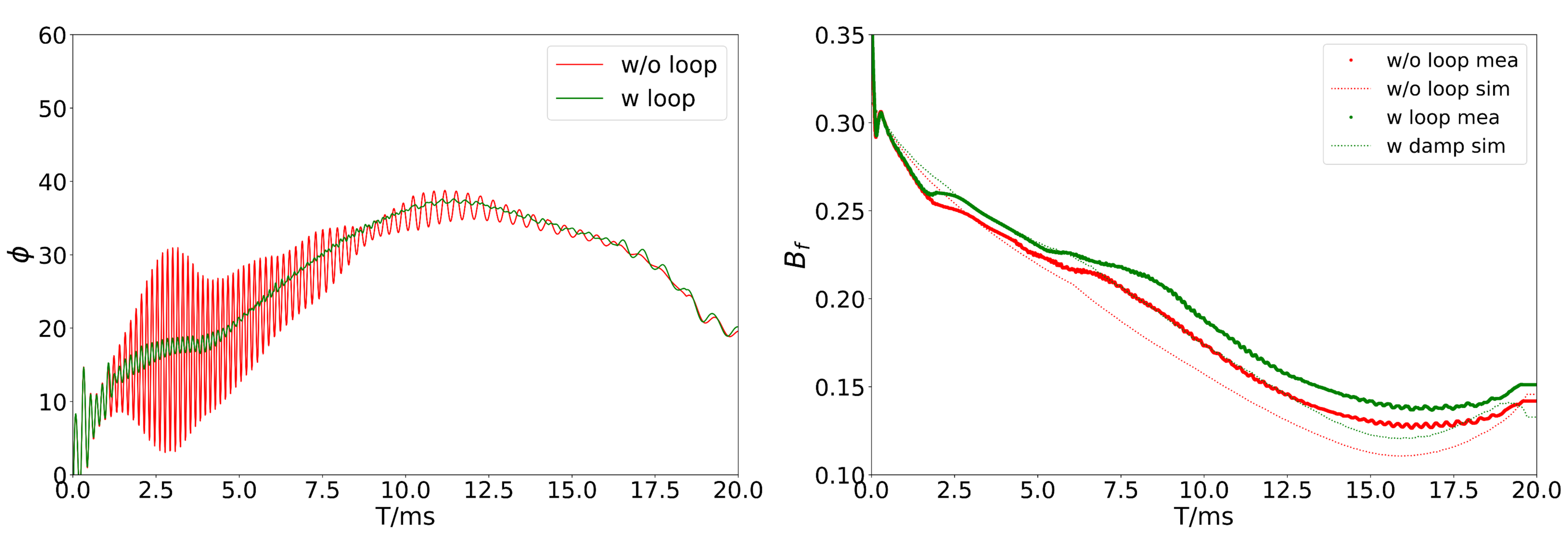


PHASE LOOP DESIGN AND TEST

The phase loop control system is designed based on the FPGA board card. The beam phase is obtained from the FCT signal after the digital A/D converting and I/Q demodulating. The feedback scalar is given after the digital low-pass filtering with the phase shift of 90 degrees. The beam phase with and without the loop is compared and the oscillation is damped quickly after introducing the loop, but the transmission efficiency is reduced about 1 %. The bunch factor also increases when the loop is used. The phase loop scheme is simulated by the code[4] and the simulated bunch factor is consistent with the measured result. The maximum feedback scalar is given for the beam without phase deviation and the biggest absolute value of the first derivative of the beam phase, so the beam distribution is changed.



The schematic of the designed phase loop

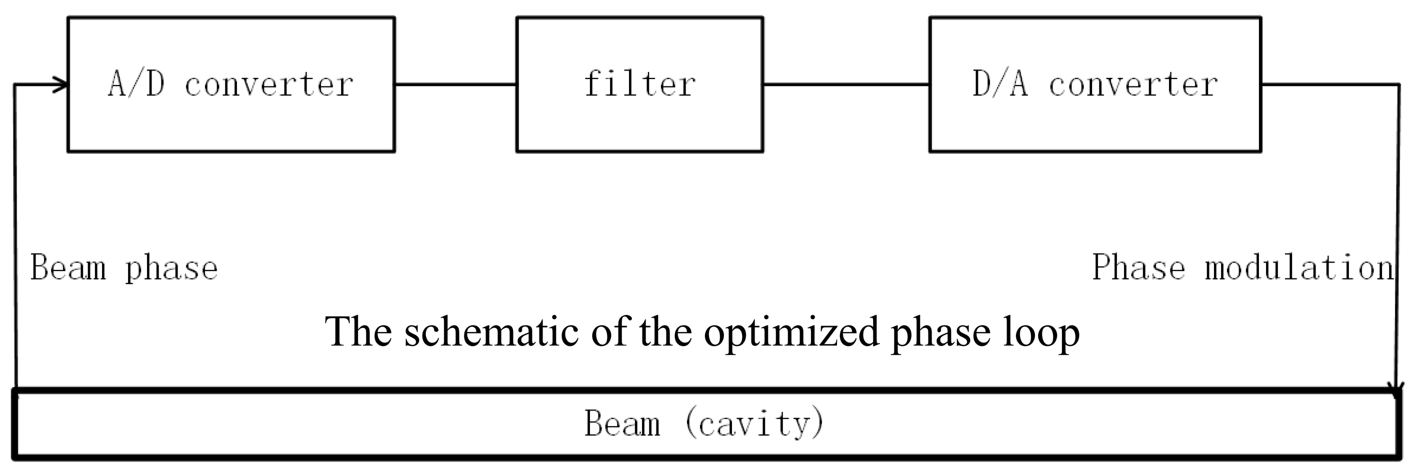


The beam phase and the bunch factor with and without the designed loop.

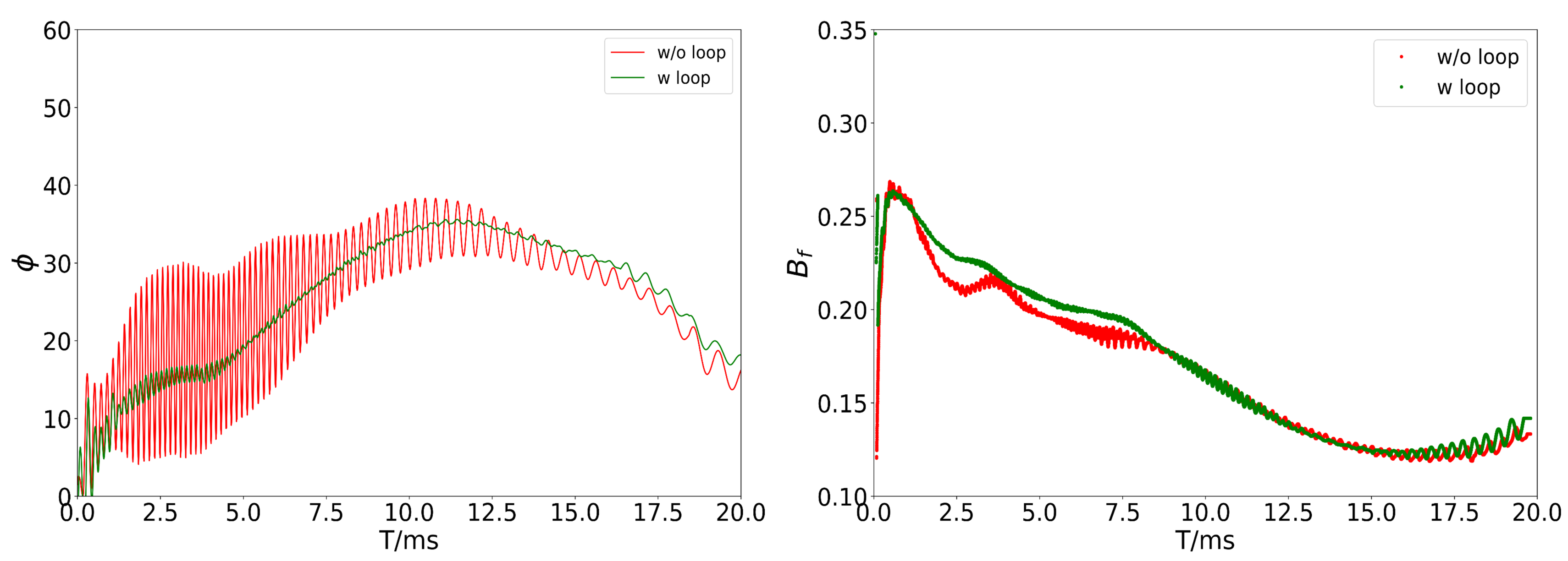
PHASE LOOP OPTIMIZATION AND TEST

The digital filtering, the phase shift, the beam phase and the second derivative of the phase are tested in the beam commissioning. The phase without the phase shift of 90 degrees is finally used as the optimized scheme, which means in fact that the feedback scalar is proportional to the beam phase deviation.

The beam phase oscillation is also damped by the optimized loop. The measured bunch factor is also same with that without the loop. The transmission efficiency is also maintained, but a little proton loses in the arc section when the loop with fast damping rate.



The schematic of the optimized phase loop



The measured beam phase and the bunch factor with and without the optimized loop.

SUMMARY

The phase oscillation is similar to the oscillation of the simple pendulum. The best way to damp the oscillation is making the first derivative of the phase to zero and it is adopted by the original phase loop, but the transmission efficiency decreases and a few protons lose for RCS beam occupied large bucket size. The point is that the beam distribution is changed by the loop. The feedback based on the first derivative means the maximum feedback is received for the beam without phase deviation, so the distribution is changed. The phase oscillation is also damped by the loop with the beam phase scheme and the beam distribution can be maintained. Unfortunately, a little proton loses when the loop with a fast damping rate. The author looks forward to the opportunity of further discussion through the introduction of the paper.

REFERENCE

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