UPGRADING OF LOW LEVEL CONTROL OF NEWSUBARU RF

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Abstract

We installed additional feedback loops in the RF low level control system, which effectively reduced the voltage ripple of the klystron DC power supply. The additional PLL loop almost eliminated the low frequency beam ripple. This was an important step for a time resolving experiment, which requires a small timing jitter.

1 INTRODUCTION

The synchrotron radiation facility NewSUBARU [1] is an EUV and Soft X-Ray light source at the SPring-8 site. Laboratory of Advanced Science and Technology for Industry (LASTI), at the Himeji Institute of Technology is in charge of its operation collaborating with SPring-8. The main parameters of NewSUBARU are listed in Table 1. The ring has two operation modes for users. In the 1.5 GeV mode, the beam is accelerated to 1.5 GeV and stored, while in 1.0 GeV top-up mode, the beam current is kept at 250±0.15 mA by an occasional injection with the gaps of undulators closed

NewSUBARU has another special operation mode, a quasi-isochronus operation adopting extremely small momentum compaction factor α [2]. The small α means short bunch length and low synchrotron oscillation frequency. In that case an experiment would suffer for a klystron noise-induced coherent synchrotron oscillation. We have reported that a main source of the coherent phase oscillation at NewSUBARU was the klystron noise [3]. Its amplitude was ±2ps of synchrotron oscillation (5kHz) and ±1ps of 120Hz. There were other weaker oscillations with harmonic frequencies of 60Hz, the frequency of primary AC power line. It was not harmful in the normal operation with bunch length of 40ns (FWHM). However it was not acceptable when we shortened the bunch length down to a few ps.

In the summer of 2002 we added an additional Automatic voltage Level Control (ALC) and Phase Lock Loop (PLL), to compensate the ripple of the klystron output power in addition to the existing ALC and PLL loops. We refer the new feedback loops by klystron feedback loops and the existed feedback loops by cavity feed back loops. Here we report the effectiveness of the klystron feedback loops.

2 NEW FEEDBACK LOOPS

Fig.1 shows a schematic view of the low-level control system. The thick lines in were the added loops. The existed cavity feedback loops were to cancel the beam loading. The frequency range of the feedback loops was different for the cavity and for the klystron as shown in Fig.2. Their gains go down by 3dB at 12Hz (cavity ALC), 70Hz (cavity PLL), 11kHz (klystron ALC) and 10.3kHz (klystron PLL). The frequency range of the cavity ALC was set low because it works as a positive feedback of phase with heavy beam loading [4].

The noise reduction by the new loops was measured without electron beam (Fig.3). The reduction of the voltage level noise was efficient (roughly -20 dB) in the range from 100 Hz to a few kHz. The reduction of the phase noise worked in more wide range, from a few Hz to a few kHz. The 120 Hz noise was reduced by about -34 dB. This is the frequency range of the synchrotron oscillation with small α.

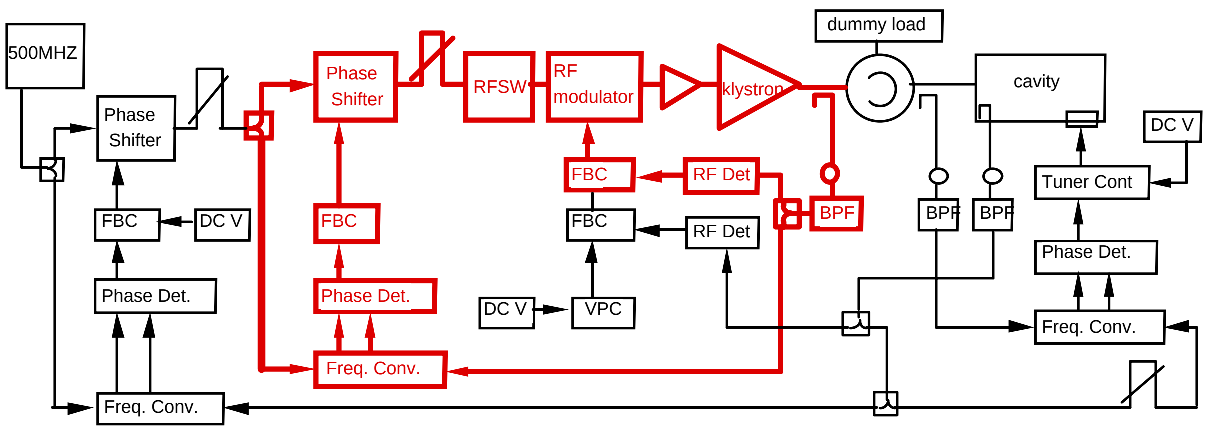

Figure 1: Feedback loops of the low level control system of NewSUBARU. The thick lines are the new loops introduced in the summer of 2002 to reduce beam ripple due to the klystron noise.

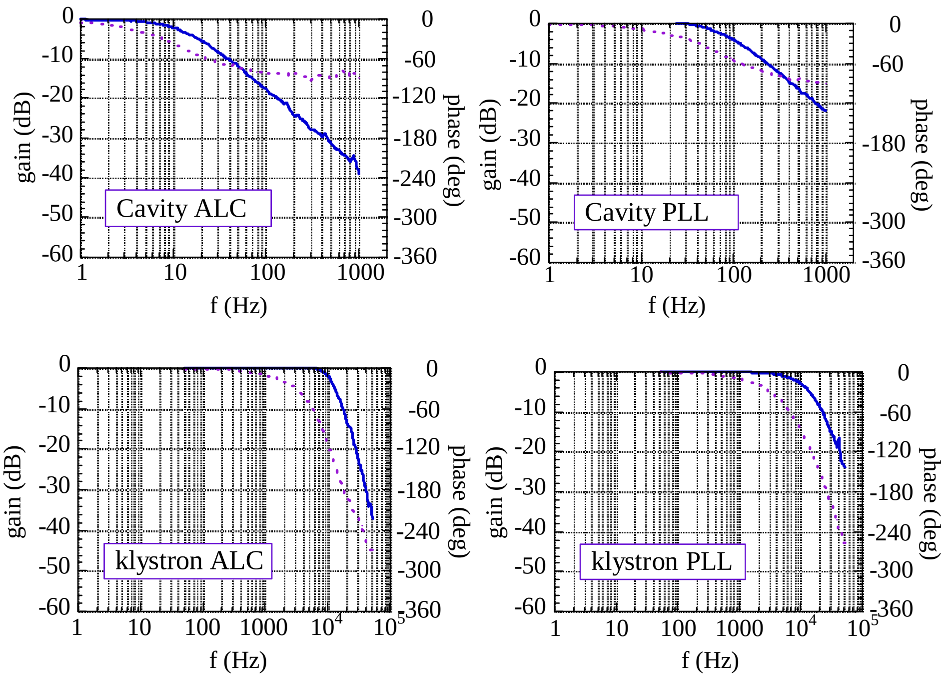

Figure 2: ALC feeedback loop and PLL feedback loop gains for the cavity feedback and for the klystron feedback. The solid lines and dotted lines represent gain and phase, respectively.

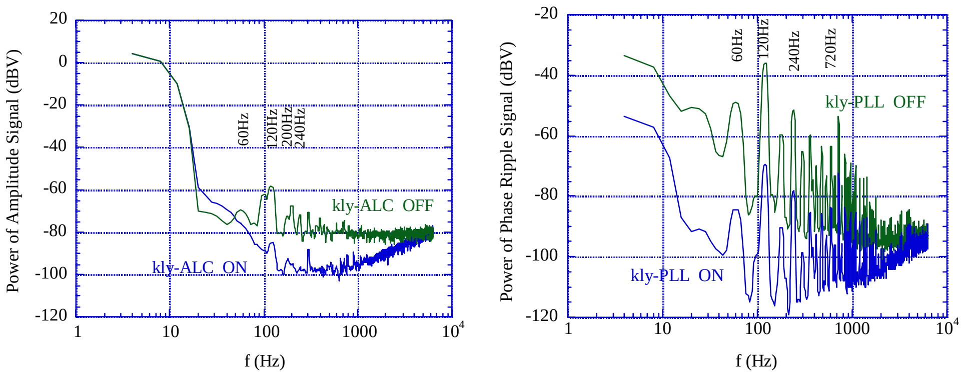

Figure 3: ALC and PLL noise signal with the klystron feedback loops turning on and off. The frequency range of the klystron feedback is wider than that of the cavity feedback. The voltage signal (ALC) of 1V corresponds to 100kV. The phase signal (PLL) of 1V corresponds to 20 degrees.

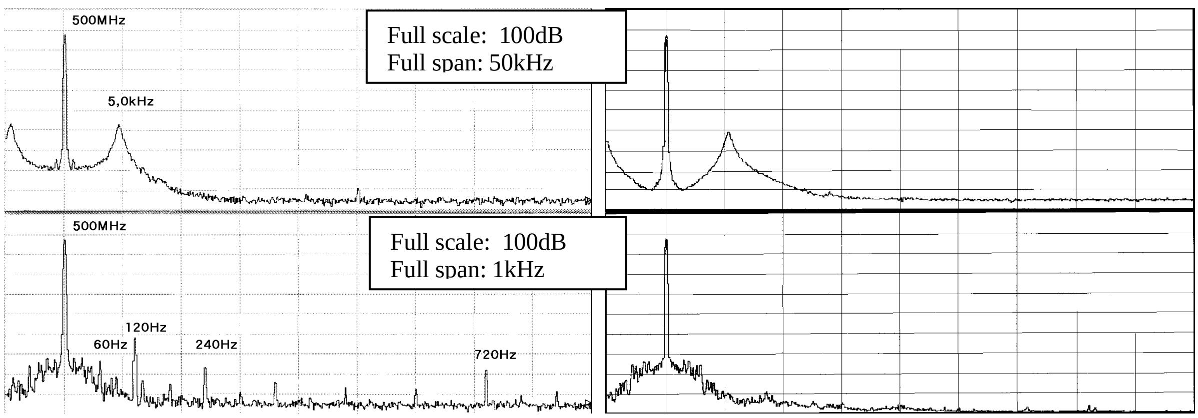

Figure 4: Side bands of the RF frequency of the beam signal. The left plots are before and the right plots are after the installation of the new loops. The vertical scale is 10dB/div. The horizontal axes are the same for the right and for the left. The highest narrow peaks are the RF frequency. The broad peaks in the above are synchrotron oscillation sidebands.

3 OSCILATION OF STORED BEAM

3.1 Picked Up Signal

The signal of coherent electron bunch oscillation in the storage ring was obtained from a pick up electrode. The electrode is set at the dispersion free section, so that the signal is sensitive to the timing arrival and the vertical movement. The signal was FFT analysed and the timing oscillation, in other wards a phase ripple, appeared as side bands of the acceleration frequency (f_{RF}) signal. Fig. 4 shows the side band structure at before and at after the installation. The main low frequency ripple peaks disappeared. The phase ripple amplitude of frequency Δf_{BEAM}, that is an amplitude of coherent oscillation in time axis, was calculated from the peak ratio of side bands of the RF frequency f_{RF} as

$$\Delta\phi_{BEAM}[\text{deg.}] = (360/2\pi)\ (V[f_{RF} \pm f_{RIP}]/V[f_{RF}]\ ),$$

here f_{RIP} is an frequency of the ripple. The phase oscillation amplitudes of beam for the main ripple frequencies are listed in Table 1. The oscillations came from the klystron power supply was reduced to the acceptable level.

Table 1: Main frequency components and amplitudes phase oscillations of beam at before and at after the installation of the new feedback loops.

frequency	**side band (dB)**		**beam ripple (degree)**	
(Hz)	**before**	**after**	**before**	**after**
60	-62	-	0.046	-
120	-50	-	0.181	-
240	-64	-	0.036	-
720	-65	-85	0.032	0.003

3.2 Measurement with Streak Camera

The coherent movement was also observed with streak camera during the user operation time. The camera was operated in double sweep mode. The fast sweep frequency was 1/6 of the f_{RF}. Two beam signals are recorded in the same frame with the opposite fast time axis. We occasionary observed a coherent synchrotron oscillation as large as 27ps p-p (left image of Fig.5). The PLL signal at that time (Fig.6) did not have such a large oscillation signal, neither the FFT spectrum did.

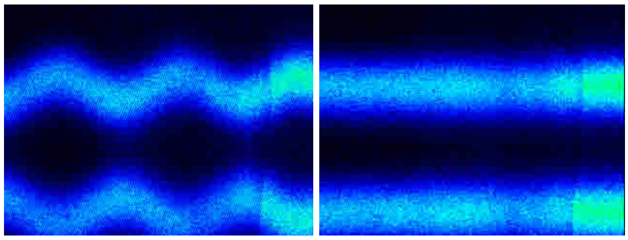

Figure 5: Streak camera image of the beam. The full range of the vertical axis (fast sweep axis) was 220 ps and the full range of the horizontal axis (slow sweep axis) was 0.5 ms. The image was different for a different shot. The two images were extreme two cases, with large oscillation and with no oscillation.

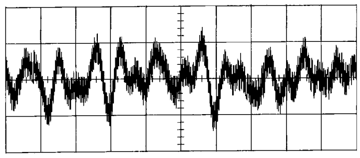

Figure 6: PLL signal with stored beam current of 250mA. The horizontal full scale was 2msec, and the vertical full scale was 0.8 degree (4.4 ps).

4 CONCLUSION

New klystron feedback loops reduced the ALC and PLL noises in low frequency region by about -20dB and -30dB, respectively. The coherent beam oscillation was drastically reduced. However we still observe large oscillation at some instance.

5 ACKNOWLEDGEMENT

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6 REFERENCES

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