COMMISSIONING OF CRAB CAVITY SYSTEM

K.Nakanishi*,K.Hara, A.Honma, K.Hosoyama, A.Kabe, Y.Kojima, H.Nakai
K.Akai, K.Ebihara, T.Furuya, S.Mitsunobu, Y.Morita, M.Ono, Y.Yamamoto
KEK, Tsukuba, Japan

Abstract

The electron positron collider KEKB is operating at KEK. At KEKB, the electron and positron bunches cross at an angle of 11 x 2 mrad. It is called finite angle collision. In this scheme, non-overlapping of the beam bunches at collision point causes beam instability. To cure this problem, the crab cavity was proposed. In the crab cavity, time varying magnetic field is applied to bunches. The field kicks the head and tail of bunches to opposite direction. And the axis of bunches are tilted. We called the motion crab motion. Effective head-on collisions can be realized using the crab motion while retaining the crossing angle. We called that crab crossing. The crab crossing is effective to boost the luminosity. According to the computer simulation, it is expected that the luminosity will be doubled with crab crossing.

The history of crab cavity was started about 20 years ago. The crab crossing scheme was proposed by R.B.Palmer for linear colliders in 1988[1]. K.Oide and K.Yokoya showed the scheme for storage rings in 1989[2]. The baseline design of crab cavity was shown by K.Akai et al in 1993 in collaboration with a Cornell university group/citeakai. In that design, the shape of cavity that was called squashed cell cavity was not axial symmetric. And it has the coaxial coupler and notch filter. R&D of the crab cavity for KEKB was started in 1994. Two crab cavities were finally installed to KEKB in 2006. The first crab crossing was realized on February@20, 2007. KEKB has been operated about one year with crab cavity. Some problems appeared and were overcome.

HARDWARE

Assembling the coaxial coupler

The cryostat for HER crab cavity was assembled first. The coaxial coupler assembling was started at the end of February 2006. A hard barrier was found soon. The coaxial coupler has two mechanical joint. To assemble them easily, the connections were designed like a single lens reflex. An installation tool that was prepared first was not sufficiently strong. It was expected that parts align by themselves, because it can move. But that is very difficult. The axis should be kept accurately. The improved installation tool is shown in figure 1. New tool was strong enough, and it can be measured the position and be adjusted well. To use the new tool, the coaxial coupler for HER crab cavity was assembled at the end of April. The HER crab cavity was opened long time. During assembling, dry and clean nitrogen gas was fed from another side of cavity. Even that, we expect that the property of the cavity was much degraded. But after RF processing, 1.8MV peak kick voltage was achieved. It is not needed to wash the cavity again. Later, The LER crab cavity was assembled smoothly.

Figure 1: The improved installation tool.

Tuner

To keep the resonance frequency constant, tuner was attached to the cavity. The coaxial coupler was moved longitudinally by tuner. The tuner is driven by a motor and a piezo stack. The tuner driven by motor that called motor tuner can move widely. But it is not suited for fine motion. The piezo stack is suited for fine motion. But the stroke of the element is only 0.2mm.

The properties of motor tuners are shown in figure 2. They are almost same, but the hysteresis of LER tuner is larger than HER's. The properties of tuner driven by piezo stacks that is called piezo tuner are shown in figure 3. The hysteresis width of LER is comparable with the piezo tuner stroke. In this situation, the piezo tuner for LER can not work to make fine tuning. And the piezo tuner for LER has one more problem. Each strokes of LER piezo tuner are not monotone function. To start decrease the frequency, the frequency should be increased once. This property make big frequency fluctuation. In practice, wide distribution of tuner phase is observed (figure 4). This fluctuation is suppressed by low level RF control system (LLRF). The phase distribution improved by LLRF is shown in figure 5. The LER phase distribution is improved from 9.5°to 0.046°

These tuners have another purpose. If the tip of coaxial coupler is moved horizontally, operation frequency RF can propagate coaxial coupler to HOM dumper as TEM mode.

* kota.nakanishi@kek.jp

To avoid the situation, the position of coaxial coupler can be adjusted by another motor that is called sub tuner. That function works well.

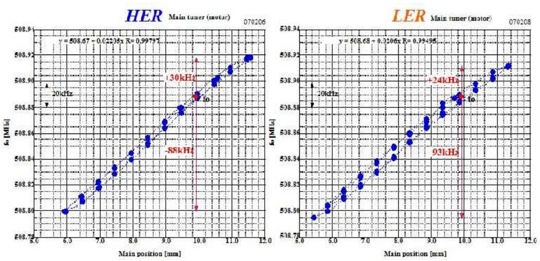

Figure 2: Properties of motor tuner.

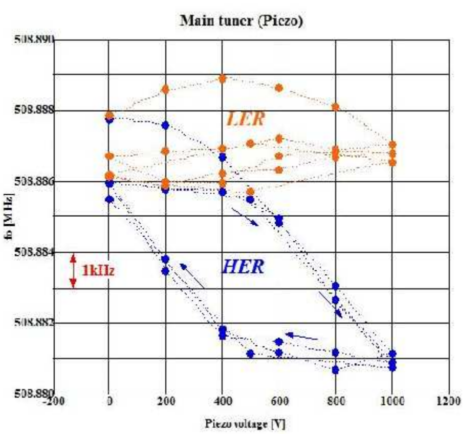

Figure 3: Properties of piezo tuner.

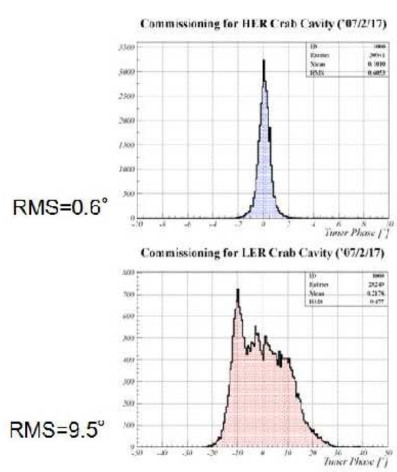

Figure 4: Response of resonance frequency of cavity for piezo voltage.

Ice balls

Boiled He gas returns to refrigerator through isolation pipe. To cool down the coaxial coupler, Liquid He was taken from He vessel. That gas return to suction of compressor through the normal (not isolated) pipe. Because the amount of He flow was expected very small (less than $10m^3/h$). Because only tip is exposed to high magnetic field, liquid He is supplied to tip of coaxial coupler. But the temperature of the tip of coaxial coupler is not measured. The temperature of the He outlet of coaxial coupler is measured. If outlet temperature is kept 4.2K, the tip of coaxial coupler can be kept 4.2K. It may be excessive. Now ice balls stick the He return pipe. They should be improved.

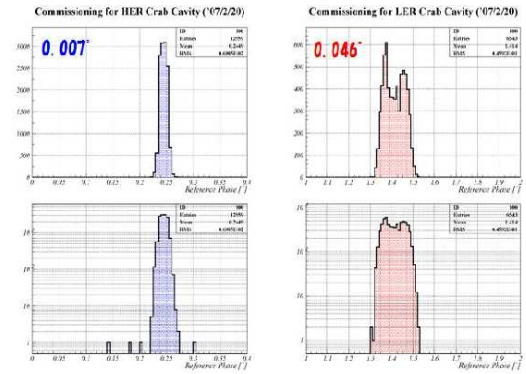

Figure 5: Response of resonance frequency of cavity for piezo voltage.

OPERATION

Instability in high current operation

In the high-current crab-crossing operation, we encountered a large-amplitude oscillation of beams and the crabbing field caused by the beam loading on crab cavities together with the beam-beam force at the IP[4]. We found that the oscillation can be avoided by shifting the crabbing phase, shifting the tuning offset angle, and adjusting the loop gain appropriately. Shifting the crabbing phase make actual beam kick. It is compensated by DC magnets.

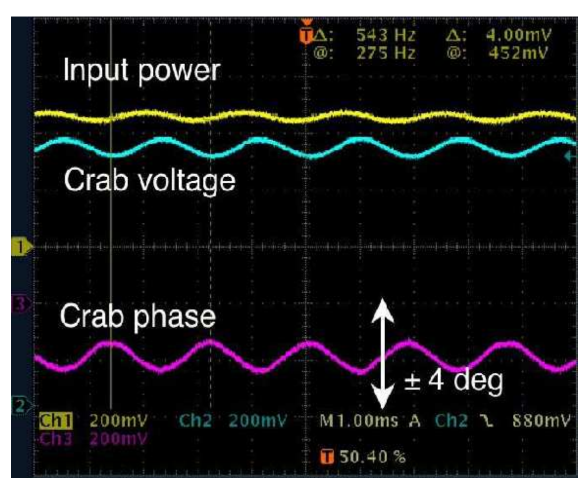

Figure 6: Instability in high current operation.

RF trip

The history of RF trip rate is shown in figure 7. KEKB operation with crab cavities was started in February 2007. Figure 7 is included data from February 2007 to March 2008. RF trip rate is looks influenced by operation condition namely kick voltage and beam current. The history of kick voltage and beam current is shown in figure 8. In November 2007, the LER kick voltage was set to 0.95MV. This kick voltage is much higher than before. The trip rate of LER is increased quickly, and KEKB parameter was changed to decrease the required LER kick voltage.

In almost case, degraded cavity's property can be recovered by a few hours aging effort. But big quench was occurred on March 17, 2007. The reachable kick voltage of LER crab cavity decrease from 1.36MV to 0.98MV. To cure this trouble, aging was done. But it was not recovered. Crab cavities were warmed up to 80K. After that, the reachable kick voltage was increased to 1.1MV The reachable kick voltage was gradually increased to 1.14MV by steady aging effort.

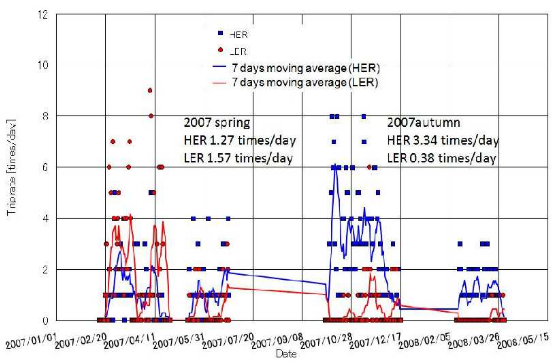

Figure 7: History of RF trip rate.

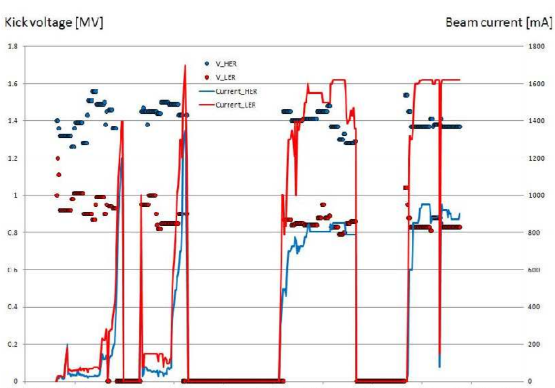

Figure 8: History of kick voltage of crab cavities and maximum beam current.

The luminosity

Specific luminosity of KEKB is shown in figure 9. The light blue line was shown the specific luminosity without crab cavities. At least, in low current operation, the specific luminosity was doubled by crab crossing. The detail of commissioning efforts may be introduced in other presentation.

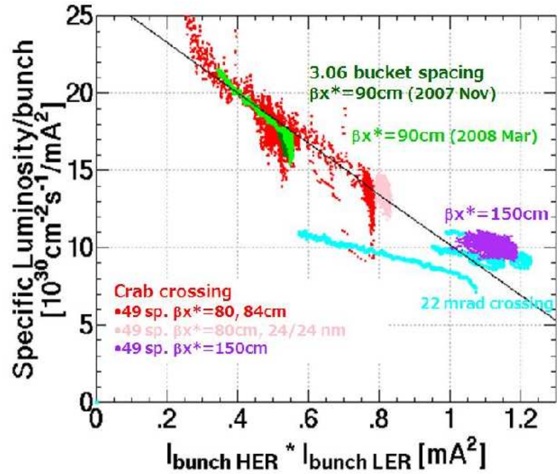

Figure 9: Specific luminosity versus product of bunch current.

SUMMARY

Two crab cavities were installed to KEKB. Crab cavities made kick voltage more than 1.8 MV at KEKB, at least they were new. The luminosity was increased at low bunch current operation with crab cavity. The peak luminosity reached to 15.1/nb/sec with crab cavities. The record of luminosity is 17.1/nb/sec without crab cavity. The tuner for LER crab cavity has big fluctuation. It is compensated by low level RF control system. At high current operation, RF instability was observed. It is suppressed by adjusting crabbing phase, tuning offset and feedback loop gain.

REFERENCES

[1] R.B.Palmer, SLAC-PUB-4707 (1988).

[2] K.Oide and K.Yokoya, Phy rev. A40, 315 (1989).

[3] K.Akai et al, Proc.IEEE Part. Accel. Conf., 757 (1993).

[4] K.Akai, Proc. of the 13th Workshop on RF Superconductivity (2007).