OPERATION STATUS OF THE KEKB SUPERCONDUCTING DAMPED CAVITY

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Abstract

In the summer of 2000, four modules of superconducting (SC) damped cavities were added in D10-site of High Energy Ring (HER), and the SC cavity system of eight modules was completed. Since then, the beam intensity of HER is again on the increase and has reached 870mA. As a result, the peak luminosity of KEKB achieved 44.37 $\times$ 10^{32} $cm^{-2}s^{-1}$. All SC cavities have provided the accelerating voltage of 1.1 - 1.4 MV and the RF power of 250 - 300 kW to the beam in usual operation mode of 780 mA. The power of higher order modes reached 7.4 kW in each cavity, which was sufficiently damped by ferrite absorbers and no beam-instability has been observed so far.

1 SUPERCONDUCTING DAMPED CAVITIES OF KEKB

The commissioning of the KEKB started on December 1, 1998. The RF system of High Energy Ring (HER) was commissioned using four superconducting (SC) damped cavities on the downstream side of NIKKO-straight section (D11-site) together with six normal conducting (NC) cavities in OHO-straight section [1]. In the five-months-operation for accelerator tuning without a detector, these SC cavities provided a accelerating voltage of 5-8 MV and an RF power of 1.4 MW to an electron beam up to 514 mA. In a following physics run with the BELLE detector, which was installed in May of 1999, the beam intensity gradually went up and reached 500 mA before the summer shutdown of 2000, which was limited by an available power of the RF cavities. The

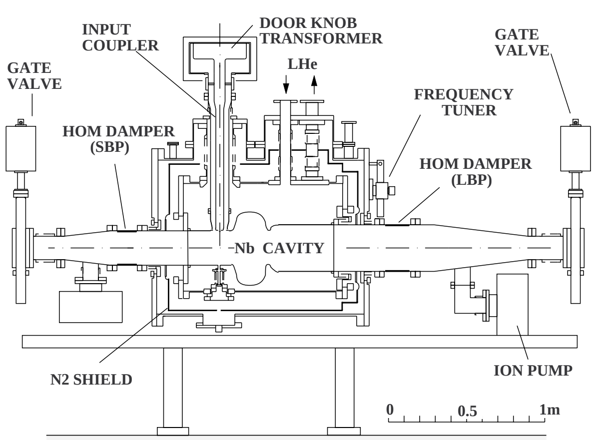

Figure 1: A cross sectional view of the 508 MHz SC module for KEKB.

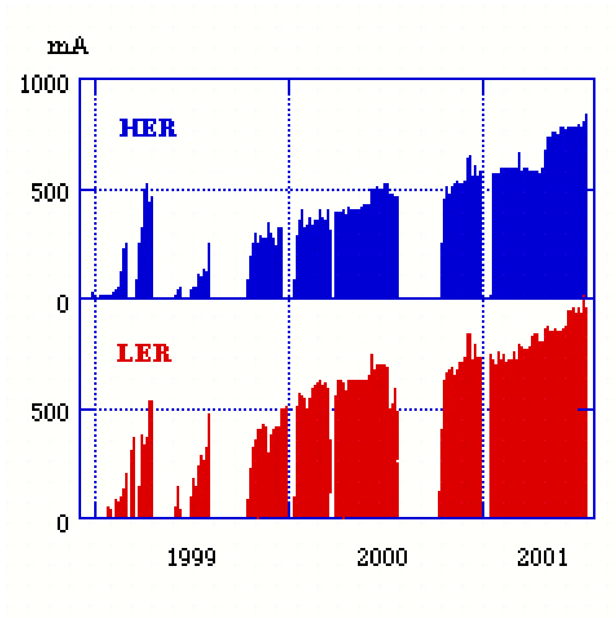

Figure 2: Current growth of High Energy Ring (HER) and Low Energy Ring (LER) of KEKB.

peak luminosity at this moment was 2 x 10^{33} $cm^{-2}s^{-1}$.

In this period, not only the operation of these cavities but the fabrication of another four SC modules had been done and finished just before the summer shutdown of 2000. These new cavities were installed on the upstream side of NIKKO-straight section (D10-site), so that the RF system of HER became a combination of eight SC cavities and ten ARES cavities at this moment. Since then, the beam intensity is growing up and has reached 870 mA. The peak luminosity of 4.49 x 10^{33} $cm^{-2}s^{-1}$ was achieved. In such a high luminosity operation, each SC cavity has routinely provided the accelerating voltage of 1-1.4 MV smoothly as occasion demands and a RF power of 250-300 kW to the beam. Because of the operation in the smaller number of bunches with the higher bunch current than the design ones, the broadband higher-order-modes (HOM) induced by the beam has already reached to the design value of 5 kW in each SC cavity. This operation condition has been chosen to avoid the electron-cloud instability of the positron ring (LER). To overcome this instability, a lot of efforts have been continued [2]. A cross sectional view of the SC module is shown in Fig.1 and the current growth of both rings is given in Fig.2.

2 BEAM PROFILE

An example of one-week-operation is shown in Fig.3, in which beam intensity of HER and accelerating voltage of D11-SC cavities are shown. To obtain the highest integral luminosity, the beam is filled up frequently to keep the intensity at 600-780 mA, where the repetition of injection is optimised from both beam injection rate and beam life-time. Whenever the beam is dumped, all SC cavities trip by the quench-interlock. This is not a real breakdown but the fast change of a cavity voltage due to sudden disappearance of heavy beam loading works the interlock, and switches off the RF power.

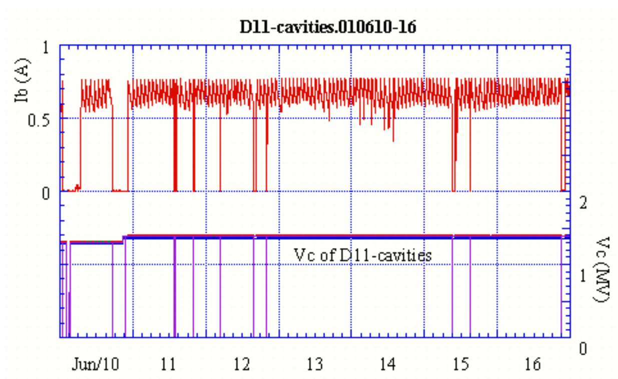

Figure 3: An example of one-week-operation of KEKB and an accelerating voltage of SC cavities.

The bunch configuration of HER is in Fig.4. To avoid the beam-blow-up of Low Energy Ring (LER) which is caused by the electron-cloud instability, the beams of both rings have to be distributed in 1154 bunches with a bunch space of 2.4 m. As a result, a bunch charge of HER has reached 6 nC that is three times higher than the design value. This intense bunch charge causes a new limitation of HOM power on various machine components. The space of 500 empty buckets of a circulating beam is used for a fast beam-abort kicker, which can dump the beam within one turn of 10 µs.

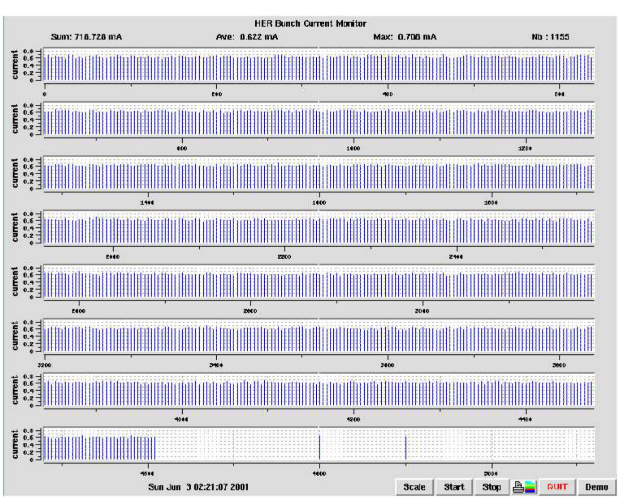

Figure 4: Bunch configuration of KEKB-HER.

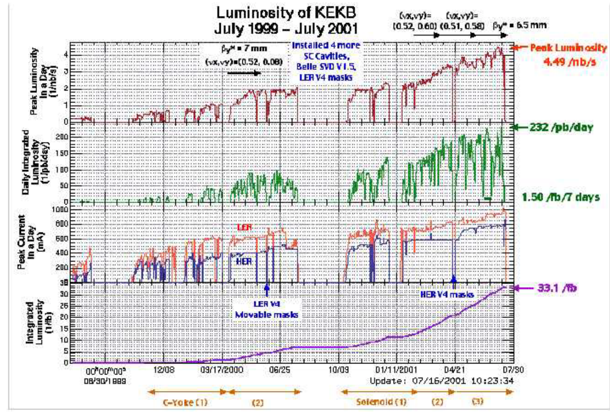

Figure 5: History of KEKB luminosity.

Fig.5 shows a history of luminosity of KEKB. The maximum peak and integral luminosity per day have been achieved 4.49 x 10^{33} $cm^{-2}s^{-1}$ and 232 $pb^{-1}day^{-1}$ so far.

3 RF POWER OF SC CAVITIES

The RF system of KEKB-HER is a combination of SC damped cavities and normal conducting ARES cavities. The current system of eight SC cavities and ten NC cavities can provide an accelerating voltage of 21 MV and a RF power of 3.7MW in maximum. In a usual operation, however, the total RF voltage has been kept at 12 MV, and SC and NC cavities have shared the voltage of 1.1 MV/cavity and 0.35 MV/cavity, respectively. At the same time, a beam loading ratio of each cavity can be changed by giving an offset to each cavity phase, and the loading of SC cavities has always been set so as to keep the maximum power at 250 – 300 kW/cavity as shown in Fig. 6. Details of coupler conditioning will be described in reference [3].

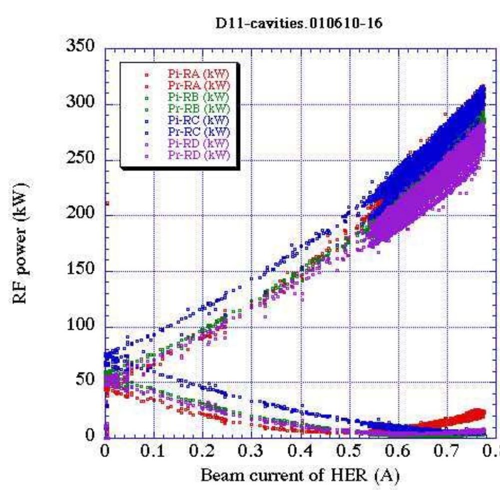

Figure 6: RF input and output power of D11 cavities as the beam intensity.

4 HOM POWER

As mentioned before, KEKB has currently been operated in the 1153-bunches mode, which is due to the electron-cloud instability of LER. The broadband HOM power is inversely in proportion to the number of bunches, therefore, the power absorbed by ferrite dampers has already reached the design value, and is becoming a serious problem for SC cavities. Each SC cavity has ferrite dampers on both sides. In Fig. 7, the power absorbed by such dampers of D11-cavities is plotted as a function of the beam intensity in various bunch configurations, where solid lines show the calculated power using loss factors obtained by ABCI. The measured power has already exceeded 5 kW that is one expected for a beam of 1.1 A in 5000 bunches. Although the dampers have been powered at a test stand up to 12 kW and have showed no damage on the ferrite, out gas from the ferrite surface may cause a trip of the cavities. Therefore, the beam intensity has been increased gradually and carefully not to damage the cavity performance.

5 SUMMARY

The SC damped cavity system for KEKB was completed in the summer of 2000. Since then, the beam intensity of HER has been improved and reached 0.87 A. All SC cavities have worked well, and have provided the accelerating voltage of 1.1 – 1.4 MV. The RF power of 250 kW can be transferred smoothly to the beam of 0.78 A in usual physics run, and no beam instability caused by the SC cavities has been observed so far. The parameters achieved by the SC cavities are summarised in Table 1.

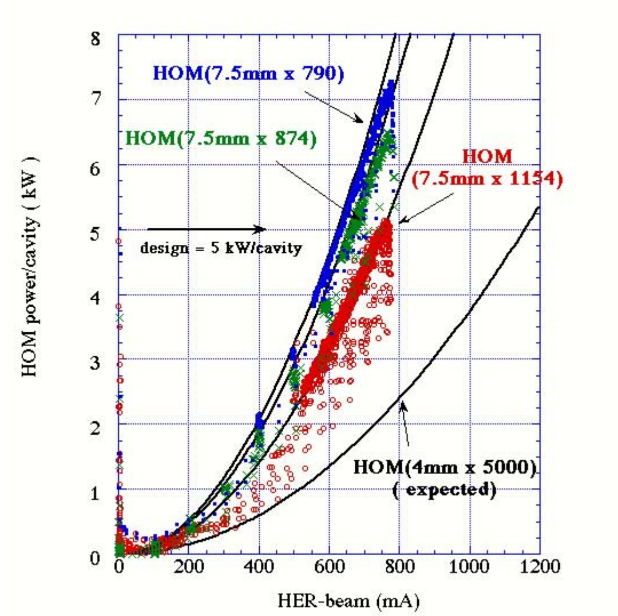

Figure 7: The total power absorbed by the ferrite dampers of D11-cavities. Solid lines show the calculated power for the bunch length of 7.5 mm.

Because of the operation in less number of bunches and a high bunch charge, the ferrite dampers of each cavity have been exposed to the power of 7.4 kW that is 50 % higher than the design value. However, no damage and no change of performances of both cavities and dampers has been observed so far. To decrease this HOM power, a new operation condition with 3 buckets spacing has been studied.

Table 1: Parameters achieved by the SC cavities in KEKB.

	design	achieved
Number of SC cavities	8	4 at commissioning 8 since Sept. 2000
Beam current	1.1 A in 5000 bunches	0.87 A in 1537 bunches (5.7 nC/bunch)
Bunch length	4 mm	6 – 8 mm
RF voltage without beam	-	>2.5 MV/cavity
RF voltage with beam	1.5 MV/cavity	1.1 - 2.0 MV/cavity
Q value	1×10^9 at 2 MV	$1 - 2 \times 10^9$ at 2 MV $0.3 - 1 \times 10^9$ at 2.5 MV
The max. power to the beam	>250 kW/cavity	370 – 380 kW/cavity
HOM power	5 kW/cavity at 1.1A	7.4 kW/cavity at 0.78A

6 REFERENCES

[1] T. Furuya, et al., Proc. of the 9th SC-RF Workshop, Los Alamos, Santa Fe, USA, 1999, p. 31
[2] E. Kikutani edited, KEKB Accelerator Papers, Nucl. Inst. Method Series A, to be published.
[3] Y. Kijima, et al, This conference.