# THE PRESENT PERFORMANCE AND FUTURE UPGRADE OF THE KEKB ELECTRON LINAC

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*Abstract*

The KEKB linac injects 8-GeV electrons and 3.5-GeV positrons into the KEKB asymmetric collider rings designed for the B-physics study. The KEKB has recorded the highest luminosity records to which the linac contributes with an advanced operational stability. In order to further improve the luminosity, the new schemes of dual-bunch injection and continuous injection were studied and have been adopted. It is also planned to upgrade KEKB for a luminosity of $10^{35}/cm^2/s$ with exchanged beam energies (3.5-GeV electrons and 8-GeV positrons). Upgraded linac is being designed and studied with a higher acceleration gradient and others to realize such a super B factory.

## 1 INTRODUCTION

The performance of the KEKB[1] has improved gradually and recently it has recorded a daily integrated luminosity of 399/pb/day and a peak luminosity of $7.35 \times 10^{33}/cm^2/s$. Such a high luminosity reinforces the achievement of the important results in the study of CP-violation with the Belle detector[2] .

The injector linac also had to improve the injection rate and it has been planned to adopt a higher beam quality control and advanced operation modes, which includes dual-bunch injection and continuous injection.

With such a success in the B-physics study, it was proposed to build an upgraded factory machine, SuperKEKB, with 10-times higher design luminosity, $10^{35}/cm^2/s$[3]. It is the major challenge for the linac because the both positron energy and the beam charge have to be upgraded. It is planned to study the upgrade possibilities at first with a C-band high gradient scheme[5].

## 2 OPERATION STATUS

The linac operates very stably these days and it seems that the difficulties such as a discharge issue were overcome, which we experienced in the bunching section and the positron target section[4].

### 2.1 Statistics

Table 1 shows operation statistics in these three years, where a machine down means that the machine was not ready including rf trips and short maintenance works between injections, and a beam loss means that the machine was not available while an injection was requested. The linac injects beams into Photon Factory (PF) and PF-AR as well as KEKB rings. Table 2 shows the typical beam mode parameters for four storage rings. The beam modes are switched about fifty times a day, without any beam quality degradation. Recently we started 3-GeV injection into PF-AR instead of 2.5 GeV, which seems to cure the instability issues in the ring.

Table 1: Linac operation time (hours)

| | FY1999 | FY2000 | FY2001 |
|---|---|---|---|
| Operation Time | 7297 | 7203 | 7239 |
| Machine Down | 768 (10.5%) | 601 (8.3%) | 385 (5.3%) |
| Beam Loss | 74 (1.0%) | 54 (0.8%) | 22 (0.3%) |

Table 2: Four beam modes of the linac

| Ring | Energy (nC) | Charge (GeV) | Injection (/day) | Inj. Time (min.) |
|---|---|---|---|---|
| KEKB $e^-$ | 1.28 | 8.0 | ∼14/18 | ∼1.5 |
| KEKB $e^+$(1) | .64×1 | 3.5 | ∼14 | ∼8 |
| KEKB $e^+$(2) | .64×2 | 3.5 | ∼18 | ∼4 |
| PF $e^-$ | 0.2 | 2.5 | 1 | ∼5 |
| PF-AR $e^-$ | 0.2 | 2.5/3.0 | 12 | ∼4 |

KEKB $e^+$(1),(2) denotes single- and dual-bunch operations.

### 2.2 Beam and Machine Quality Control

Because of the characteristics of the factory machines, especially at KEKB, the continuous operation of the rings and the linac through a year is crucial. Thus, in order to keep the beam quality, we monitor several machine parameters routinely. Here are examples of such parameters.

- Number of rf-trips and the reason for each klystron

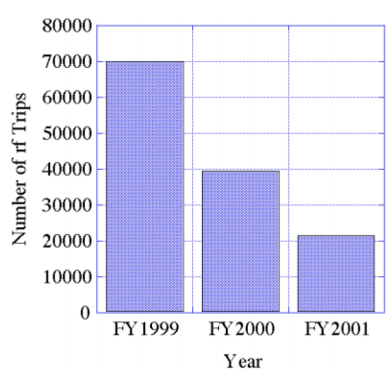


Figure 1: Number of rf trips per year

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(every week).

- rf phasing at each klystron (every other week).
- Twiss parameters and matching condition Bmag (every day).
- Energy spread (every day).

If those parameters are not optimal, machine tuning is carried immediately. For example, if a matching condition parameter Bmag for a certain location is large, beam optics matching is carried out using the Twiss parameter measurement by wire scanners. Figure 1 shows that the number of rf trips per year is decreasing rapidly. The reason is mainly because we gradually became to choose the optimum high voltage values for klystrons, besides the quality improvement of klystrons and modulators.

### 2.3 Double-bunch Acceleration

During the beam injection to the KEKB rings the experiment cannot be performed. Most of the injection time is used for positron since the stored current is larger and the lifetime is shorter in the ring.

Thus, in order to double the positron injection efficiency the dual-bunch acceleration had been studied[6] and necessary equipment had been installed[7, 8]. In this year we tried this injection scheme for more than one-month period, and that was successful.

However, because of the common frequency between the linac and the ring, the bunch selection in the ring is restricted. That led to the heating of the beam pipes in the rings, and it also affected the luminosity tuning. While we may need some more studies on those issues, the luminosity increased by 4 to 8%.

### 2.4 Continuous Injection

As the stored beam currents in the rings decrease between injections, the luminosity decreases accordingly. In two rings the positron beam reduction is larger since the lifetime is shorter. Thus we started studying the continuous injection of the positrons during physics experiments

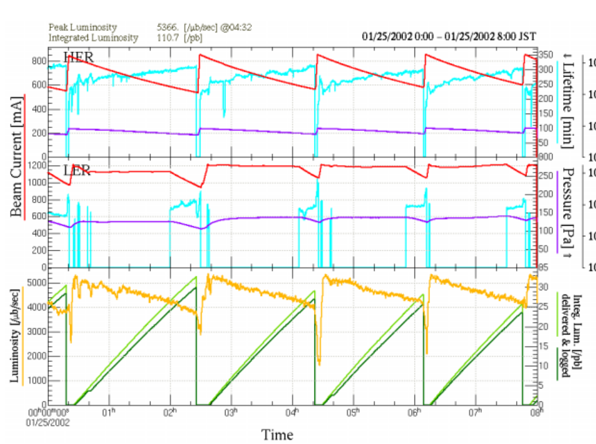


Figure 2: Continuous injection to keep the positron beam constant

after careful tests against detector noises. In this scheme positrons are injected continuously in 5 to 10Hz instead of a maximum rate of 50Hz. As shown in Fig. 2, the positron current was kept almost constant and the reduction of the luminosity was relaxed. A beam-current reduction before each injection was caused by a PF-AR injection.

Although a part of the detector needs some more preparation against injection noises and heatings, the integrated luminosity may increase by 20% with this scheme in a rough estimate. However, if we inject positrons in this scheme, the measurements and corrections to keep beam quality may become a issue. This is discussed later.

After those successful adoptions of the both dual-bunch injection and continuous injection schemes we will further utilize them in the comming operation periods.

## 3 UPGRADE FOR SUPERKEKB

Based on the success of the KEKB, the new project SuperKEKB was proposed to study the B-meson system parameters precisely and to search for the new physics such as the super-symmetry. The new machine should provide ten-times higher luminosity, $10^{35}/cm^2/s$, while the design luminosity of KEKB is $10^{34}/cm^2/s$. In the new design the factor of ten is achieved by squeezing the beta function at the interaction region and by increasing the stored beam currents in the rings, both of which should provide a factor of 3.2.

However, because of the electron cloud in the beam pipe of the positron ring, the luminosity may be limited. Thus, in order to cure the issue the energy exchange is planned, where the energies of electron and positron should be 3.5GeV and 8GeV. The positron injection energy of 8GeV is the major challenge at the linac as well as the increase of the injection rates. The machine design is being done in two schemes, for one of which we started developments.

### 3.1 High Gradient C-Band Scheme

Since the linac site is limited, the energy upgrade of the positron beam from 3.5GeV to 8GeV needs restructuring of the linac. After investigating several possibilities, two options are considered. The first option is to employ C-band structures to double the energy gain at a part of the

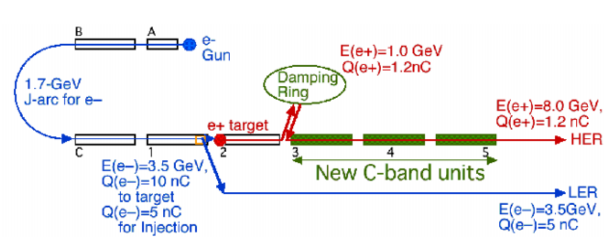


Figure 3: Energy upgrade with high gradient structures as a first option

linac and a damping ring to lower the emittance as shown in Fig. 3.

The damping ring is necessary not only for the smaller aperture of the C-band structure but also to relax the design criteria of the improved interaction region at the ring. It will be installed after the positron capture section, where the positron energy is 1GeV.

C-band structures will be installed in the 24 units after the damping ring. Currently each unit contains a 40-MW klystron, a SLED pulse compressor and four 2-m long S-band structures, which provide a energy gain of 160MeV. It will be replaced by two 40-MW C-band klystrons, two pulse compressors and four C-band structures, with which the energy gain will be 320MeV per unit (42MeV/m). The maximum positron energy will be 8.7GeV.

The C-band technology will be based on the development by the JLC C-band group[9]. However, the components are being optimized and simplified for our needs, since we don't need multi bunches and we want to simplify the maintenance. In the first design, the klystron will be a non-PPM type, the pulse compressor will be a LIPS type and the accelerating structure will be just the scale-down of the current S-band structure without HOM damping. Those components have been designed and are being fabricated. Their high-power test and the beam test will be carried in 2003.

### *3.2 Recirculation*

Another scheme considered utilizes a recirculation in which the generated low-energy positron will be kept in a damping ring for the next rf pulse and will be recirculated from the head of the linac. There can be several variations in this scheme. Although it does not require any new accelerating components, very different beams have to be accelerated in the same pulse and several bypass lines and kickers have to be installed. Thus the operation and maintenance will be complicated.

### *3.3 Beam Measurement*

Since the continuous injection was adopted and it will be more important in SuperKEKB, the beam quality control will be impossible, which is currently performed during 1-hour periods between injections. Thus a non-destructive beam measurement would be crucial. To that end, a stealth-bunch measurement is considered, in which a bunch between injection bunches will be used to measure the characteristics and will be removed by a kicker at the end of the transport line. This scheme requires these components to be developed.

- Fast actuators like phase shifters to be scanned in the measurement.
- Fast and synchronous data acquisition system.
- Fast kicker.
- Timing system modifications.

Some of those items are being developed for other purposes like a fast beam-feedback system[10]. The development will be continued since the beam-quality control is indispensable.

### *3.4 Summary*

The KEKB linac has been operated stably and has contributed much to improve the KEKB luminosity with its improved operation, which includes the beam quality control and the advansed injection modes, the dual-bunch injection and the continuous injection. On the other hand, in order to meet the injection specifications of the newly proposed SuperKEKB project, several upgrade schemes are considered and designed. The Development has started for one of the schemes, which is an upgrade with higher gradient by C-band structures. The beam quality control for the future is also planned with a better beam measurement scheme.

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