STATUS OF THE KEK INJECTOR LINAC

S. Anami, H. Baba, S. Fukumoto, K. Ito, T. Kakuyama, C. Kubota, Y. Mori, T. Sakaue,
I. Sato, A. Takagi, T. Takenaka, S. Takano and J. Tanaka
National Laboratory for High Energy Physics
Oho, Tsukuba, Ibaraki, 300-32, Japan

Summary

In April 1977, the KEK proton synchrotron started to run for experiments in high energy physics. Typical beam intensities of the injector are currently: 620 mA from the preinjector column 250-mA beam into the linac and 130 mA at the linac exit at 20 MeV. The rf system was modified to feed more power into the buncher and the debuncher. Rf windows, isolators, control system of the Cockcroft generator and an optical fiber data transfer system have been developed or improved. The linac beam of 200 mA has been achieved by removing grids from the buncher and lowering the column pressure of the preinjector. Although beam loading is not completely compensated in the accelerating field of the tank, the momentum spectrum of the beam is not seriously affected by the beam loading.

Introduction

The first beam was accelerated in the KEK linac to 20 MeV in August of 1974. Its design goal for intensity was 100 mA and it was achieved in the early stage of operation.[1,2] In April 1977, the KEK proton synchrotron started to run for high energy physics experiments. Typical beam intensities of the injector are presently as follows: the column current of the 750-kV preinjector is 620 mA, 250 mA is injected into the linac and 130 mA is delivered from the linac. Some modifications have been done to ensure more stable operation and efforts are being continued to get a more intense beam of high quality.

Operation and Modifications

Table 1 shows the total operation time of the KEK proton synchrotron complex with downtime due to the accelerator failure from October 1976 to July 1979. The operation time has increased steadily and the machine ran 10 or 11 days in every two weeks in the last period. It should be noticed that downtime due to the trouble in the 20-MeV beam line was included in the linac failure until March 1979, whereas it is excluded later. Troubles of the linac rf were reduced by improvements of various power supplies.

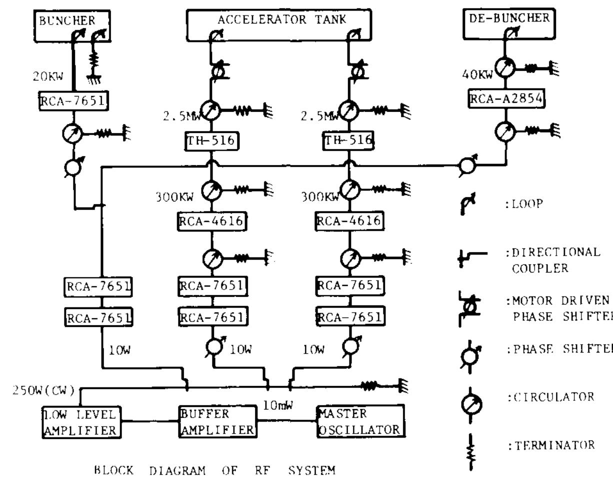

Fig.1 Block diagram of rf system.

The rf system has beem modified as shown in Fig.1. The maximum available power was raised from 6 kW to 20 kW in the buncher and from 20 kW to 40 kW in the debuncher. Medium and high power isolators were developed.[3] They are installed between an RCA-4616 tube and a TH-516 power tube, and between the power tube and the linac tank. They reduce reaction of the power tube to its driver as well as coupling between two power tubes in the two-feed system.

New rf windows were made and put into the tank. In the old window, a metal ring was brazed to periphery of a ceramic disk, and a viton O-ring was inserted between the ring and the flange for vacuum seal. Unfortunately, breakdown had sometimes occurred on the ceramic surface due to sharp edges of solder alloy. Thus, brazing is avoided in the new one, and vacuum is sealed with a metal gasket of Al Helicoflex between the ceramic disk and the flange as shown in Fig.2. They have worked well for more than a year.

The control system of the Cockcroft-Walton generator was renovated. It has two modes of operation: stabilized mode and high impedance

	OCT.'76 ∫ MAR.'76	APR.'77 ∫ SEP.'77	OCT.'77 ∫ MAR.'78	APR.'78 ∫ AUG.'78	SEP.'78 ∫ MAR.'79	APR.'79 ∫ AUG.'79
Total Operating Hours	1000.6	1595.4	1655.7	1706.4	2384.1	1760.3
Total % of Acc. Failure	7.7 %	8.9 %	5.8 %	4.5 %	5.2 %	6.5 %
Preinjector	0.73 %	0.43 %	0.14 %	0.28 %	0.24 %	0.24 %
Linac	2.34 %	1.52 %	1.46 %	1.34 %	1.02 %	0.40 %

Table 1 System down-times in % of total operating hours.

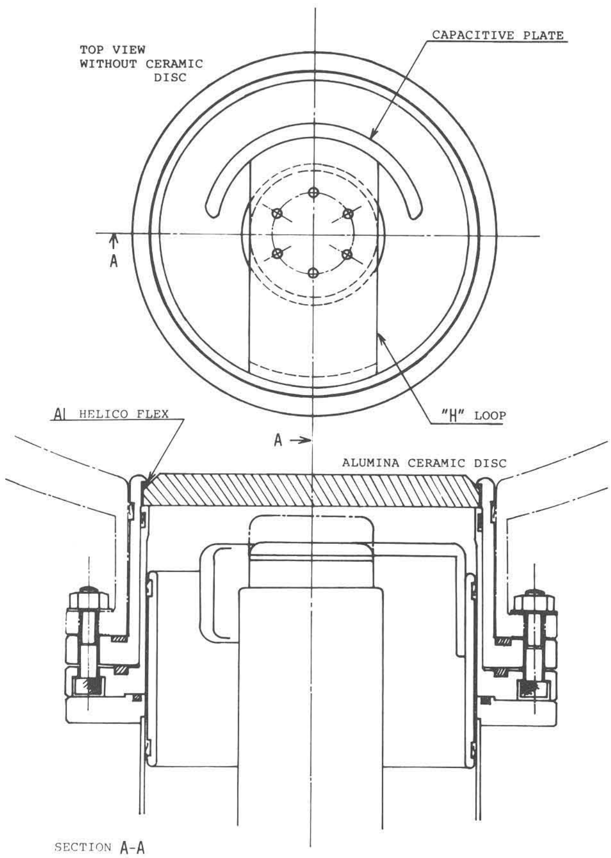

Fig.2 Rf window and coupling loop.

mode. In the stabilized mode, the generator has a feed-back loop with a feed-forward circuit. As the KEK synchrotron is a cascade machine, 9 beam pulses are injected into the 12-GeV main ring in 0.5 s, then it begins to accelerate them. Thus, the preinjector delivers 9 successive beam pulses in one main ring cycle of 2.5 s. The accelerating voltage decreases in 9 pulses by beam loading as shown in Figs.3a and 3b. It is improved by feed-forward as shown in Fig.3c. When arcing tends to occur frequently in the accelerating column, for example, after the column is exposed to the atmosphere, the high impedance mode is preferred to reduce damage to the accelerating electrodes in the column. It uses an unstabilized power supply which has an adjustable reference voltage and a comparator. If the difference between the reference voltage and the output voltage exceeds a preset limit, the output voltage is changed by 0.2 kV every 0.1 s or 1 s or according to an external program.

The high voltage terminal is equipped with a new optical fiber data transfer system.[4]

Usually, little conditioning is necessary for the preinjector as well as for the linac at the beginning of every run. So far, there are two long shutdowns a year, and the oxide cathode

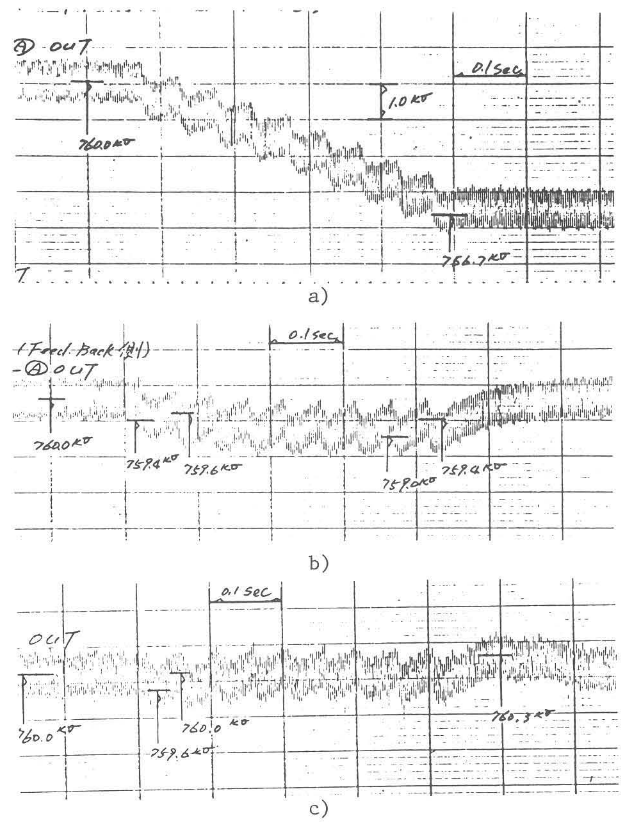

Fig.3 Output voltage of Cockcroft-Walton generator. 9 beam pulses are accelerated successively in one main ring cycle.
a) without feed-back loop and feed-forward pulse.
b) with feed-back loop, without feed-forward pulse.
c) with feed-back loop and feed-forward pulses.
Horizontal: 0.1 s/div, Vertical: 1 kV/div.

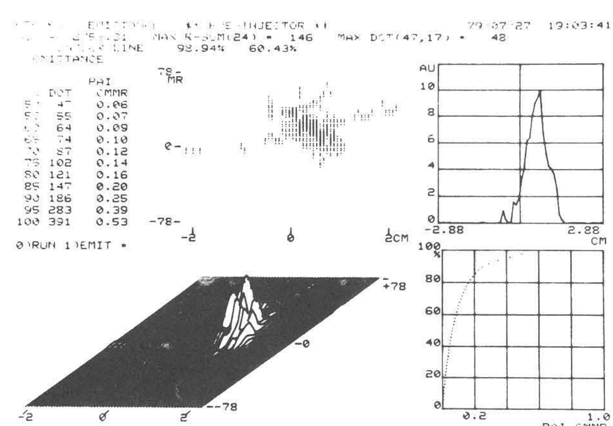

Fig.4 Horizontal emittance display at entrance of linac tank (270-mA beam).

of the duoplasmatron ion source is replaced by a new one during the long shutdown. An oxide cathode lasted more than 2300 hours without signs of deterioration.

The beam emittance is monitored at the entrance of the linac tank (Fig.4). The RMS emittance,[5] which is defined by eq.(1), is compared with the 90 % emittance for the 1-st, 3-rd, 5-th, 7-th and 9-th beam of the 9 beam pulses in Table 2.

$$E_{rms} = 4[\langle y^2\rangle\langle y'^2\rangle - \langle yy'\rangle]^{\frac{1}{2}} \qquad (1)$$

The normalized RMS emittance is denoted by ε_{rms}. If the intensity distribution is Gaussian in both directions, then 86 % of the beam is included in the RMS emittance. Twiss parameters are also shown in Table 2.

Beam Ordinal Number	$E_{90\%}$ mm·mrad	E_{rms} mm·mrad	ε_{rms} mm·mrad	α	β mm/mrad	γ mrad/mm
1	2.68	64.0	2.56	3.70	1.00	14.7
3	2.70	65.2	2.61	3.68	1.03	14.7
5	2.66	62.8	2.51	3.80	1.00	15.4
7	2.44	63.5	2.54	3.95	1.10	15.1
9	2.75	67.5	2.70	3.60	1.00	14.0

Table 2 Vertical 90 % emittance and RMS emittance for 1-st, 3-rd, 5-th, 7-th and 9-th beam in 9 beam pulses. Twiss parameters α, β and γ are shown.

New Intensity Record

When the rf field is raised in the tank, the linac beam increases rapidly at first, then it shows saturation as shown in Fig.5. Thus it seems difficult to increase the linac beam further by raising the rf level. It was noticed that some beam loss occurred from the grids of the buncher, which is a coaxial cavity with two gaps. By removing the grids, the beam which is injected into the linac is increased by about 10 %. It was already shown that higher pressure cures breakdown in the high gradient accelerating column.[6] However, this mode of operation has a drawback of poor transmission in the 750-keV beam line. This is supposed to be caused by H_2^+ or H_3^+ ions produced in the plasma cup of the ion source.[7]

By lowering the column pressure as shown in Fig.6, 420-mA beam was injected into the linac and 20-MeV beam of 200 mA was achieved. For such a high intensity beam of about 5 μs duration, it is difficult to compensate rf beam loading completely as shown in Fig.7. It affects the momentum spectrum structure in one beam pulse as shown in Fig.8. The detector has 96 segments for momentum analysis, while the first channel and the last one are devoted for the marker. Each channel corresponds

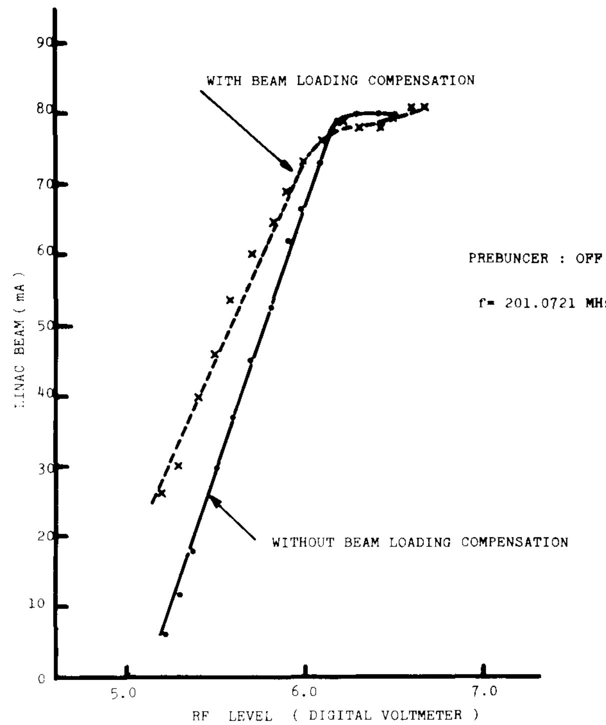

Fig.5 Tank rf level vs. linac beam intensity.

to 20 keV. The debuncher rf field was kept in routine operation level and it was very low, because the beam, with rather broad spectrum, is favorable for injection into the booster synchrotron to achieve an intense circulating beam. Thus, it seems not to be serious, that the momentum distribution changes slightly by the rf beam loading in one beam pulse. Figure 9 shows the forward rf power into the tank, and the reflected rf power from the tank. Emittance of 20-MeV beam will be measured thoroughly after completion of the device for routine operation.

References

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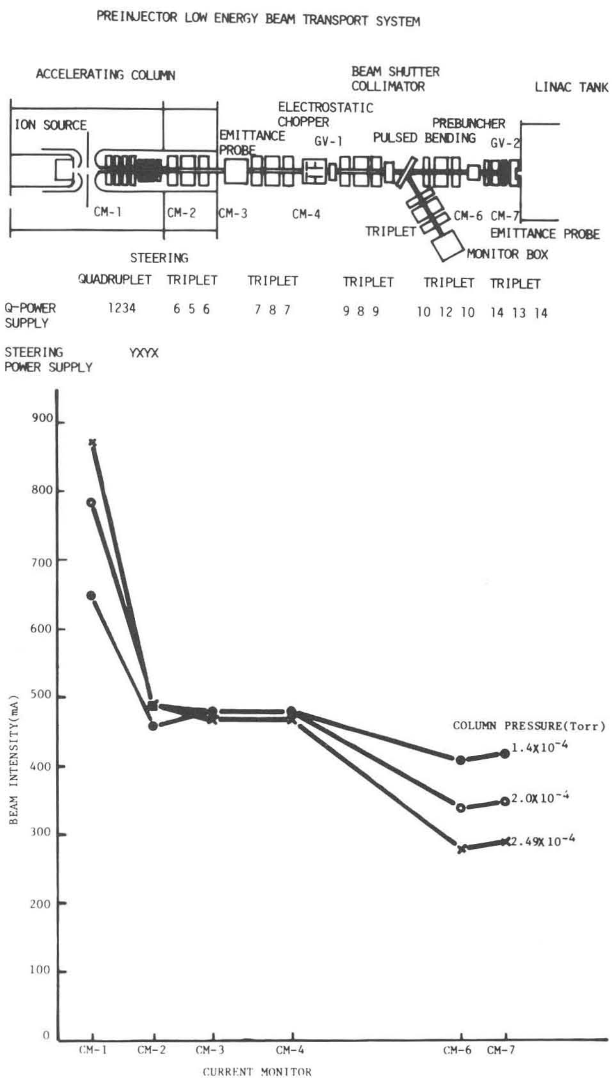

Fig.6 Beam intensities along 750-keV line.

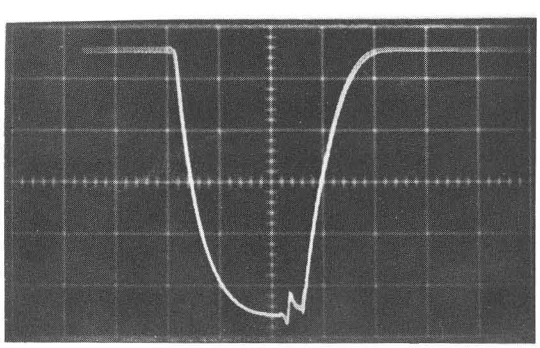

Fig.7 Rf power level in tank (180 mA beam).
Time seale: 100 μs/div.

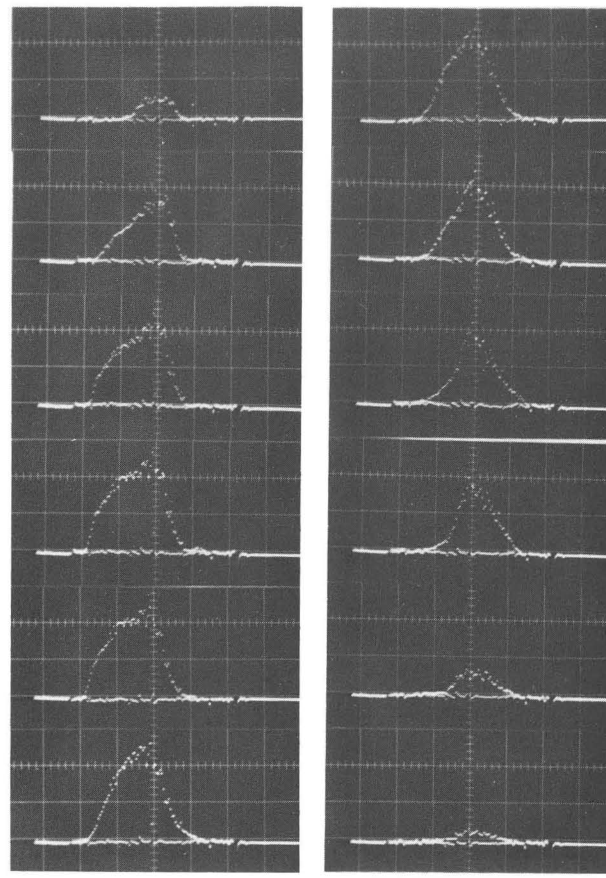

Fig.8 Momentum spectra of 5 μs beam measured every 0.5 μs.
Horizontal scale: 0.4 MeV/div.

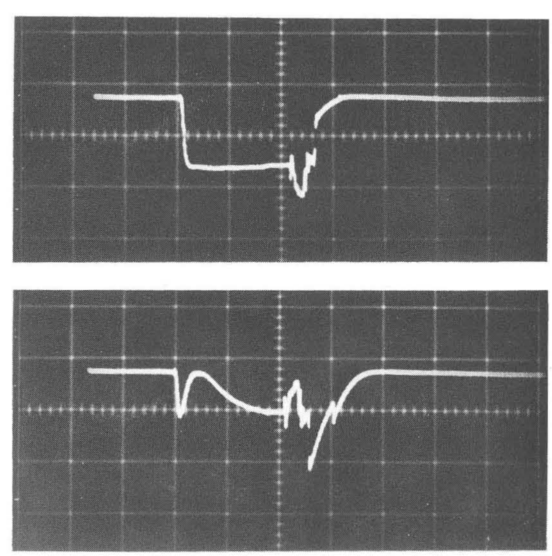

Fig.9 Rf power to tank (upper) and from tank (lower)
Time scale: 100 μs/div.