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KEK ATF INJECTOR UPGRADE*

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Abstract

The main goal at the Accelerator Test Facility (ATF) at the KEK laboratory in Japan is to develop the technology that can stably supply the main linac with an extremely flat multi-bunch beam. The injector for this accelerator was upgraded to produce greater than 2 x 10^{10} in electrons a single bunch at 80 MeV in a very narrow bunch

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The main goal at the Accelerator Test Facility (ATF) at the KEK laboratory in Japan is to develop the technology that can stably supply the main linac with an extremely flat multi-bunch beam. The injector for this accelerator was upgraded to produce greater than 2 x 10^{10} in electrons a single bunch at 80 MeV in a very narrow bunch.

1 INTRODUCTION

The ATF accelerator consists of an injector up to 80 MeV, the main S-band linac up to 1.3 GeV and a Damping Ring [1]. The injector consists of a thermionic gun, two 357 MHZ subharmonic bunchers, an S-band buncher, a 3-m accelerator structure, many solenoids and diagnostics. The injector was upgraded to produce more than 2 x10^{10} electrons in 20 ps of a single bunch and with the potential for greater than 80% charge transmission from the gun to the end of the linac.

2 BEAMLINE MODIFICATIONS

The modified beam line is shown in figure 1. The main aspects of the modification include relocation of the existing subharmonic bunchers for improved bunching thus the potential for a small energy spread at the end of the linac and redistribution of the solenoids for smaller beam size and better transmission through the injector 3-m accelerator structure. Additionally some beam-pipes were replaced to allow for larger apertures, and some steering coils were added to allow for more adiabatic steering correction in the solenoid region. One of the considerations during the design of the upgrade was to use as much of the existing hardware as possible to save costs. Figure 1 shows a diagram of the modified injector beam line. All the major components, the gun, the bunchers, the 3-m accelerator section and all but one of the solenoids are the original hardware on the ATF injector beam line.

Almost all the diagnostics in the modified injector came from the old injector [2] except for an external bunch length monitor cavity [3] between the S-band buncher and the accelerator section. This monitor as well as one solenoid, some steering coils and some power supplies came from SLAC.

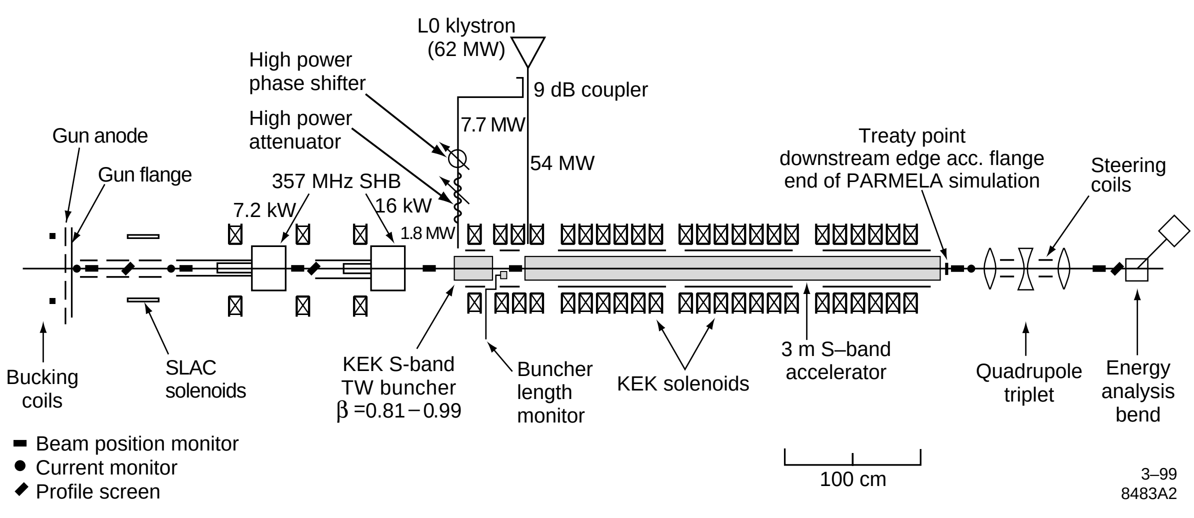

Figure 1. Schematic diagram of the new KEK ATF injector beam line.

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3 SIMULATION

Simulations for the beam line upgrade were conducted using PARMELA. As input to PARMELA the simulated beam parameters of the existing gun [4] and the simulated and measured parameters of the existing bunchers [5] were used. The locations and strengths of the bunchers were optimised for best bunching and the locations of solenoids and their strengths were optimised for optimum beam spot size in the bunching and acceleration region up to 80 MeV. After the ideal locations were determined, we found that it was impossible to fit some of the solenoids near the subharmonic bunchers exactly where we wanted them to be on the beam line because of physical obstacles that would be too costly to remedy. Thus, we did the best we could on the beam line and ran the simulations again with the actual locations of the solenoids. We found that this only cost us a few percent in transmission in the simulation, but it also reduced the margin between the beam envelop and the aperture at the entrance to the S-band buncher.

Figure 2 shows the axial magnetic field profile from the gun up to the end of the accelerator section at 80 MeV, known as the treaty point where the injector ends and the linac begins. Simulations downstream of the treaty point are conducted using codes which do not take into account space charge forces and are not the subject of this paper. The gun anode tip is at Z=0, the S-band buncher spans from 287 cm to 314 cm, and the accelerator spans from 339 cm to 646 cm. The axial magnetic field is about 100 Gauss from the gun to the S-band buncher and rises rapidly to about 1.7 KG on the accelerator section.

Figure 3 shows the simulated beam envelop from the gun up to the treaty point. The solid lines represent the physical apertures in the beam pipe, the subharmonic bunchers, in the S-band buncher, and in the accelerator

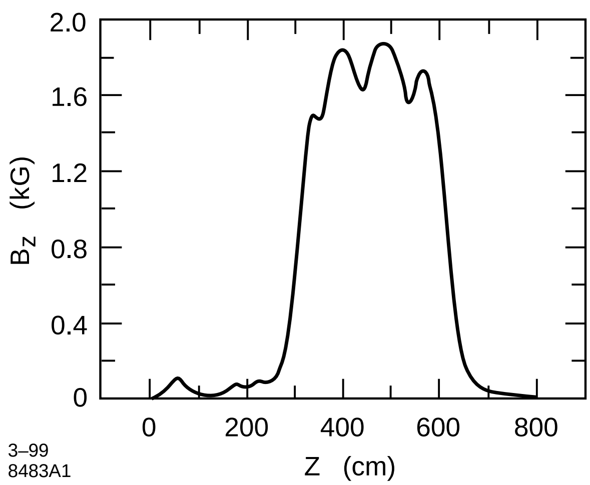

Figure 2. Simulated axial magnetic field profile from the gun to the end of the injector.

section. As it can be seen in the figure, the smallest margin between the beam envelop and the aperture is at the entrance to the S-band buncher.

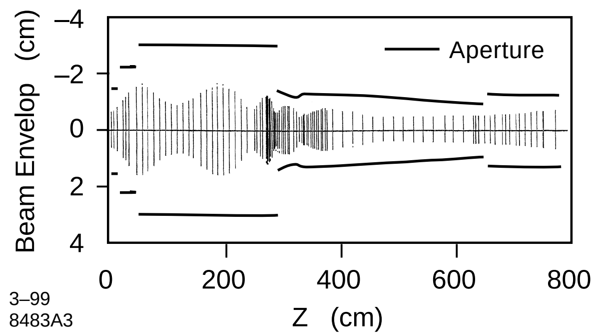

Figure 3. Simulated beam envelop from the gun to the end of the injector.

Figure 4 shows the beam parameters at the end of the 3-m accelerator section (treaty point) where the beam energy is 78.3 MeV.

In the simulations 96% of the charge from the gun reaches the treaty point, but only 83% is in the 20 ps constituting the main bunch. The rest of the charge is in the low energy tail or in satellite bunches. Most of the low energy particles are lost in a real beam line where steering is required to minimise the deviation of the bunch orbit from the centre line. The steering is optimised for

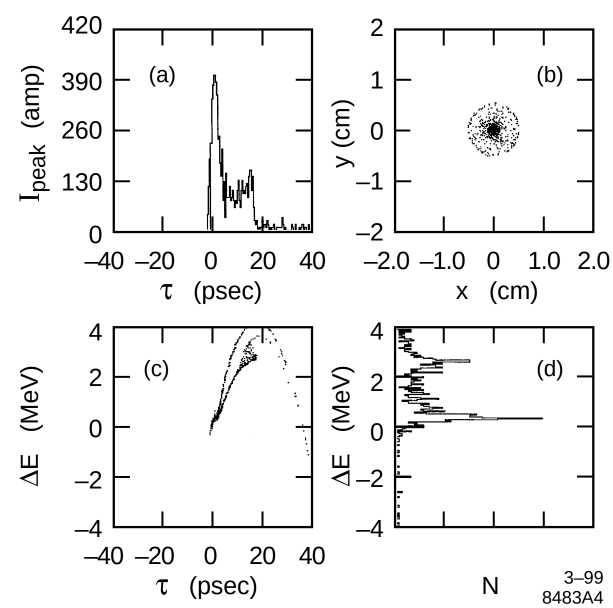

Figure 4. Simulated electron beam parameters at the end of the injector at nominal 80 MeV. a) temporal distribution, b) X –Y space, c)longitudinal phase space, d) energy distribution,

the main bunch energy and particles with much lower energy tend to be intercepted by the beam line aperture. The total energy spread is about 4 MeV or about 5%. Since the first portion of the accelerator structure contributes to the bunching process this energy spread is inevitable. However since this energy spread is correlated with bunch length, it can be taken out in the next accelerating structure by phasing it such that the bunch rides slightly behind the crest of the RF. The transverse beam profile shows that there is a dense, 3mm diameter core and a halo that spans out to 10 mm in diameter. The halo is mainly composed of the low energy particles.

4 INITIAL COMMISSIONING

Once the physical beam line modifications were complete and systems were checked out, we spent about 4 shifts to commission the new beam line. We set the amplitudes of the bunchers and the strengths of the solenoids to the simulated values and adjusted the phases of the bunchers to minimise the bunch length at the streak camera screen at the end of the injector accelerator section. In addition we adjusted a few of the solenoid strengths very slightly and steered the beam.

Figure 5 shows a photograph of one of the streak camera signals for a bunch with 2.2 x 10^{10} electrons in 24 ps at the end of the first accelerator section (the treaty point). In this case we set the gun for 2.7 x10^{10} electrons per bunch.

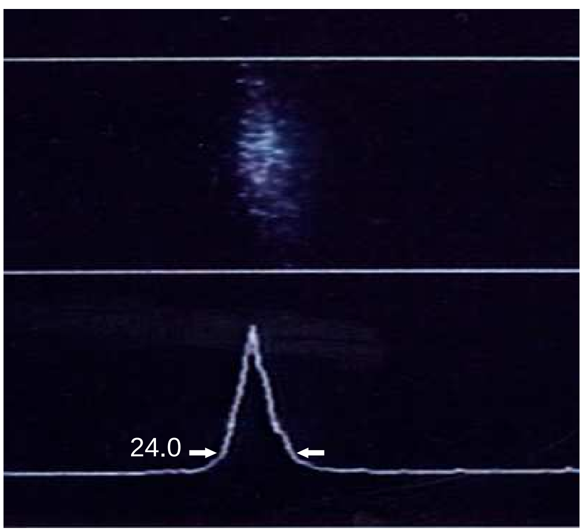

Figure 5. Streak camera picture of the bunch length at the end of the injector for 2.2 x 10^{10} electrons.

Table 1 shows the simulated and achieved beam parameters. All the parameters are in good agreement with respect to the simulations except for the energy spread which was higher than the simulated 5.8%. This value was very difficult to measure and even more difficult to set. One of the complications is that in order to adjust the phase of the first accelerator structure, one has to adjust the phase of the klystron which feeds both the buncher and the accelerator and then readjust the buncher. While adjusting these two knobs one has to look at a myriad of diagnostics – minimise bunch length, minimise energy spread, maximise beam transmission and minimise beam orbit.

Table 1: Simulation and Experimental Electron Beam parameters at the end of the injector (treaty point)

	Simulation	Experimental results
At the Gun		
Charge, 10^{10}e-	2.7	2.7
PW_{edge}, ns	1.2	1.2
Energy, KeV	180	180
End of Injector		
Total Charge, 10^{10}e-	2.2	2.6
Charge in 20°, 10^{10}e-	2.2	2.2
PW_{edge}, ps	20	24
Satellite bunches, no.	2	0
Emittance, mm-mrad	17	
Energy, MeV	78.3	81
$\Delta E/E_{edge}$, %	5.8	>5.8

One cause of the additional energy spread could be that in the first accelerator section the beam does not slip to the crest at the same rate as it does in the simulation. One remedy for this would be to slightly change the temperature of the accelerator structure, thus changing the its frequency. The effect is the adjustment of the phase slippage rate of the beam with respect to the RF in the accelerator.

As expected the total transmission from the gun to the treaty point is less than the simulations results, but the bunch charge and width are very close to the predictions. We were able to accelerate 2.2 x 10^{10} electrons in a 24 ps FW bunch with 82% transmission from the gun to the end of the injector.

5 REFERENCES

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