Design of the Injection System for JEARI FEL Linac

M.Sawamura
Japan Atomic Energy Research Institute

Abstract

The design parameters of the injection system are described for the JAERI FEL superconducting linac. The general design considerations are first discussed for the high quality beams suited to FEL. The injection system consists of the electron gun, the sub-harmonic buncher, the buncher and two superconducting cavities of single-cell. Several beam trace examples are demonstrated.

1.Introduction

The outline of the JAERI FEL scheme will be presented elsewhere.[1] There are several constraints for the qualities of the electron beam intended for the use in the FEL. In order that the electron and optical beams interact coherently over the undulator length, the fractional energy spread of the beam must be less than about 1/2N, where N is the number of periods in the undulator. Since the gain of the system is directly proportional to the peak current of the electron beam, it is desirable to achieve the narrow phase spread.

As the periods in the undulator are intended to be from 30 to 100, the energy spread must be less than 0.5%. The injection system is designed to be less than 0.3% for the safety, which corresponds to less than 75keV energy spread because the energy after the main accelerator will be 20-25MeV. In order to maintain this energy spread through the main accelerator, phase spread must be less than 9 degrees.

The parameters of the injection system are designed under following constraints.

1) Space charge effects are fundamentally unavoidable. One method for reducing the magnitude of the space charge forces is to increase the dimensions. This implies low frequency operation. So the frequency of the main accelerator is determined to be 508MHz. Another method for reducing the importance of the space charge forces is to accelerate the charge bunch as rapidly as possible in order to take advantage of the relativistic effects. This argues in favor of high voltage of the injection system.[2] Then the DC voltage of the gun is chosen to be more than 200kV.
2) As the pulse width of the electron gun will be less than 4ns, the injection system is designed to accept the 4ns-bunched beam for the high peak current.
3) A pre-accelerator consists of two superconducting single cell cavities. Each cavity has the RF power drive in order to change the magnitude and phase of the RF field independently.
4) As the building for the FEL experiment limits the length of the linac, the length from the gun to pre-accelerator must be less than about 7m.

A program code PARMELA[3] is used in order to estimate the beam dynamics with the space charge effects, but it does not optimize the parameters of the elements. A program is made to optimize the parameters of longitudinal phase space in the case of no space charge effects. It calculates the phase and energy spread after a set of injection chain which consists of buncher, drift and cell and searches the optimized phase and energy spread by changing the parameters.

2.Example of the design

As the frequency of the pre-accelerator is 508MHz, whose periodic time is 2ns, a sub-harmonic buncher (SHB) is necessary to accept 4ns-bunched beam.It is difficult to make the phase spread narrow with the only use of the SHB because of the nonlinearity of the bunching voltage and the relativistic effects. After the SHB, the buncher, whose frequency is equal to that of the main accelerator, is located. By adjusting the voltage of the SHB and the buncher and the length after the SHB and the buncher it is possible to make the longitudinal phase space small to a certain extent. Figure 1 shows the optimized phase and energy spread as a function of the voltage of the SHB and the buncher. In the case of 4ns-bunched beam and 250kV injection voltage (Fig.1(b)), the energy spread is over the constraints described before. So the two superconducting single-cell cavities are also used to get the small phase space.

The structure of SHB is considered to a quarter wave coaxial type. Small sub-harmonic number makes the range of the linearity of the sinusoidal voltage wide, but the peak voltage high, i.e. high power RF source is necessary, and the length of the SHB long. Therefore the sub-harmonic number is chosen to 1/6. Figure 2 shows the optimized longitudinal phase space in the case of 60kV SHB voltage and 7.5kV buncher voltage. The phase and energy spreads are 7.6degrees and 74.6keV respectively. Figure 3 shows the block diagram of the injection system.

3.Conclusion

It is possible to achieve the small longitudinal phase space which satisfies the constraints in the case of no space charge effects. If the less phase spread is desired, the element which chops the bunched beam length or compresses the phase spread will be necessary. Further calculation will be done with the space charge effects and the transverse emittance growth will be investigated.

Author thanks JAERI FEL's group, Y.Kawarasaki, M.Ohkubo, K.Mashiko, M.Sugimoto, H.Yoshikawa and M.Takabe, for discussions and comments on this work.

References

1)M.Ohkubo et al., in this proceedings

2)T.I.Smith,"Intense Low Emittance Linac Beams for Free Electron Lasers",1986 Linear Accelerator Conference Proceedings

3)K.Crandall and L.Young,"PARMELA:Particle Motion in Electron Linear Accelerators",Los Alamos National Laboratory

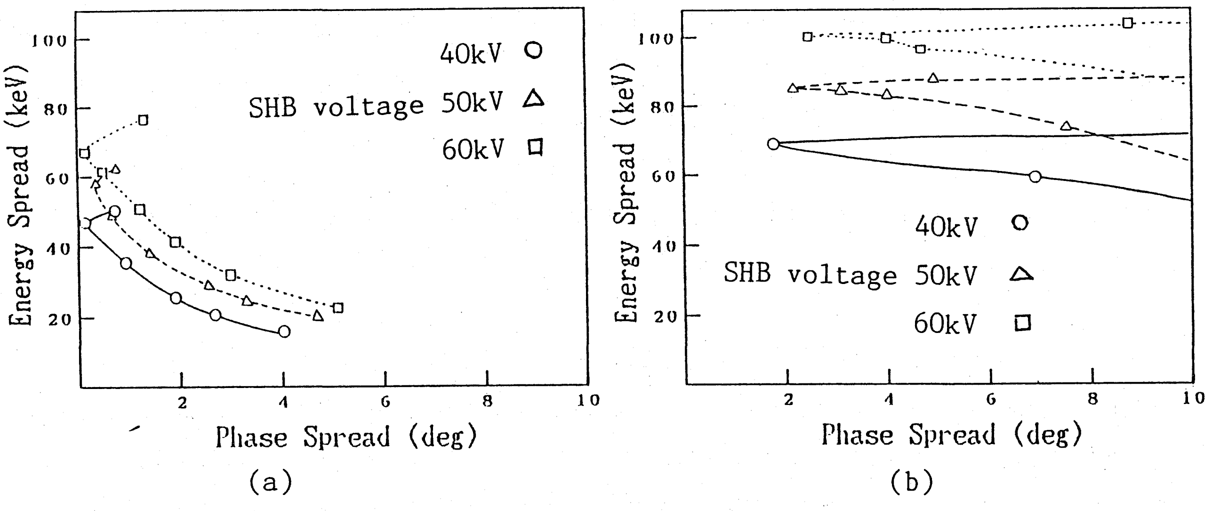

Fig.1 Optimized phase and energy spreads with the SHB and the buncher as a function of the voltages of the SHB and the buncher. Injection voltage is 250kV. Bunched beam length from the gun is 2ns (a) and 4ns (b).

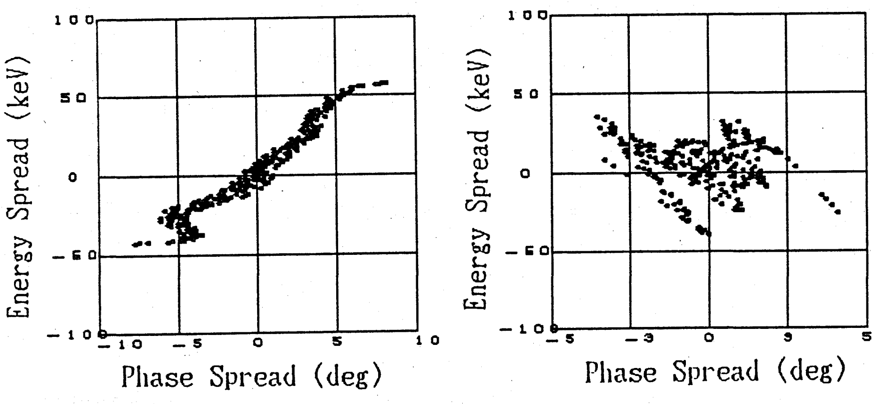

Fig.2 Longitudinal phase space before the pre-accelerator (left), and after the pre-accelerator (right).

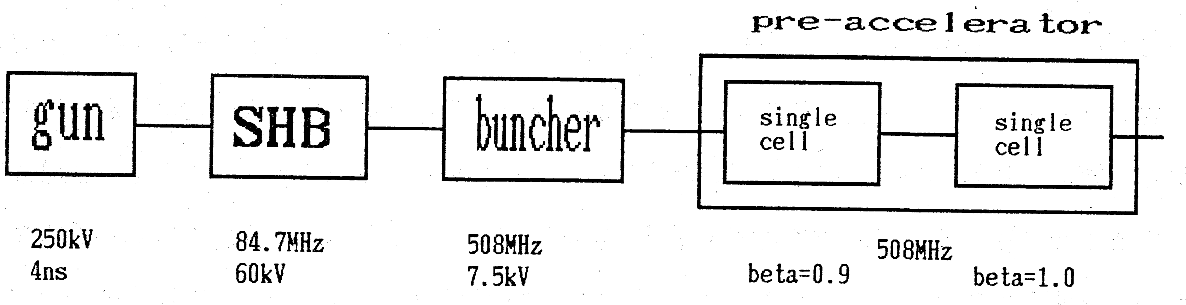

Fig.3 Block diagram of the injection system.