COMMISSIONING SCENARIO FOR L-BAND ELECTRON ACCELERATOR BY PARMELA CODE*

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Abstract

An intense L-band electron linac is being installed at CESC (Cheorwon Electron-beam Service Center) for industrial applications. It is capable of producing 10-MeV electron beams with average 30-kW. The beamline consists of an E-gun, a pre-buncher, an accelerating column with a built-in bunching section, focusing solenoids and a beam scanner. The beam dynamics simulation is conducted by the PARMELA code. The nominal capability of the accelerator is obtained by the input RF power into the accelerating column and the input beam current. The optimum operation condition is also obtained by the input RF power into the pre-buncher and the input RF phase difference between the pre-buncher and the accelerating column. As per the simulation on the misalignment effect, focusing solenoids can reduce this effect. In this paper, we present simulation results for the beam commissioning scenario.

INTRODUCTION

For industrial irradiation applications, in general, the output electron beam of a linac has following requirements; the beam energy under 10 MeV due mainly to neutron production, the higher current for high power beams. With increased beam currents, the beam loading effect comes into play in reducing the beam energy. In the past, there were a few RF linacs built in the range of 25-30 kW [1]. For 30-kW beams with a single klystron and the vertical arrangement of accelerator beamline, we designed an intense L-band linac with a 25-MW pulsed klystron [2]. In order to obtain the operating condition for the maximum output power condition, simulation studies for the beam dynamics are conducted by the PARMELA code [3]. This paper presents results of the beam dynamics and commissioning scenario for a 30-kW RF linac.

BEAMLINE

The beamline of the linac consists of an E-gun, a pre-buncher, a drift tube with steering coils, an accelerating column with a built-in bunching section, focusing solenoids, and a beam scanner. The E-gun is a diode type one powered by a 6-μs, 80-kV modulator. The beam is bunched by the modulating voltage in the pre-buncher, and is injected to the drift tube. The direction of the beam is adjusted by the steering coils in the drift tube. The beam is bunched in the bunching section, and it is accelerated in the normal accelerating section. The RF power of pulsed 25 MW is introduced into the first cavity of the bunching section, and the RF wave travels through all the cavities, and it is drained from the last cavity into a dummy load. At the end of the accelerating column, the energy of electron beam is up to 10 MeV with the beam current of 1.4 A. This beam enters into a beam scanner and is swept horizontally by magnets of the scanner. The accelerator is mounted vertically.

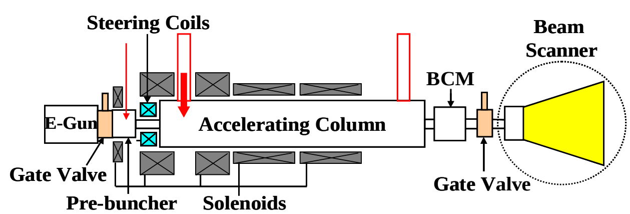

Figure 1: Schematic of the beamline of the L-band electron linac.

BEAM DYNAMNICS

The output beam properties are changed by the following conditions; the input RF power into the accelerating section, the input current, the input RF power and phase into the pre-buncher, and the misalignment between the E-gun and the drift section. The beam properties are obtained by PAMELA simulation with the input beam radius of 2 mm at the beam waist.

RF Power and Input Current

In Figure 2, the beam transmission rate is the maximum at the operation condition with the 10-MW input RF power into the accelerating section. Since, when the electric field in the bunching section exceeds a critical value, the capture rate is reduced [4]. However, it is difficult to reduce the electric field in the bunching section due to the built-in structure. Even though the beam transmission rate is decreased a little, 25-MW power should be introduced in order to obtain more than 10-MeV beam.

In Figure 3, the energy gain is proportional to the square root of the input RF power into the accelerating column. The energy gain of the particle in the accelerator defined by [5]

$$\Delta W / q = (2r_s L P_{in})^{1/2} \cos\phi \left(\frac{1-e^{-\tau_0}}{\sqrt{\tau_0}}\right) - i r_s L \left(1 - \frac{1-e^{-\tau_0}}{\tau_0}\right). \quad (1)$$

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The energy gain with the beam current change is also consistent with Eq. 1, that is, the energy gain decreases linearly as the input beam current increases, due to the beam loading effect.

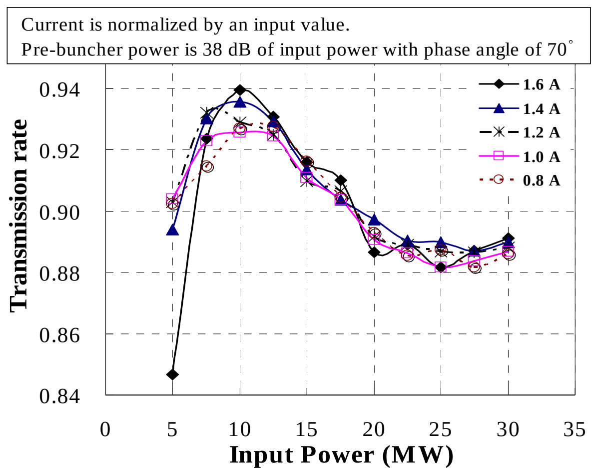

Figure 2: Beam transmission vs. input RF power into the accelerating column.

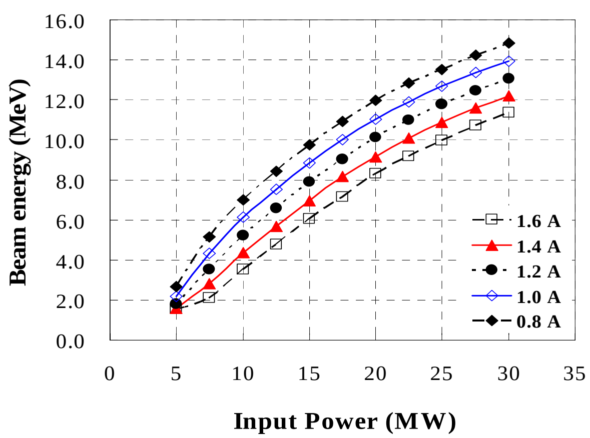

Figure 3: Beam energy vs. input RF power into the accelerating column.

RF Power and Phase into Pre-buncher

The input RF power introduced into the pre-buncher affects only the modulating voltage not the average of the beam phase. Since the higher modulating voltage makes the beam to be concentrated to the bunch center much more, the transmission rate is slightly increased as the input RF power increases, as shown in Figure 4. However, the beam energy depends on the synchronous phase and the input RF power into the accelerating column so that the beam energy is not changed.

For a higher beam transmission, the phase of the beam into the buncher is matched with the phase of the input RF wave into the bunching section. Most of particle loss is occurred at the entrance of the bunching section due to the mismatching of the phase difference. The accelerator should be operated with the phase difference between -60˚ and 120˚ to obtain more than 85% beam transmission. The beam energy mainly depends on the beam transmission due to the beam loading effect. With the 330˚ phase difference, the output beam has the highest power. At this condition, the energy gain is also maximum since the beam bunch center is placed on the crest of the RF wave, as shown in Figure 6.

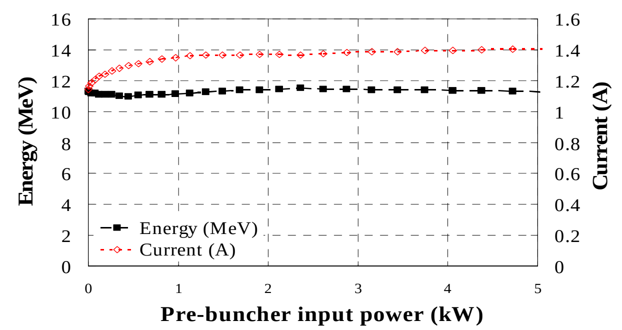

Figure 4: Output beam energy and current vs. input RF power into pre-buncher.

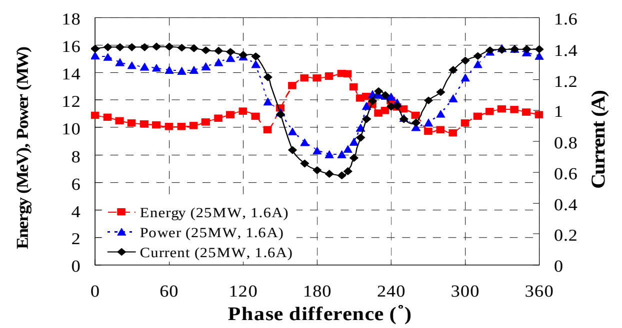

Figure 5: Output beam energy, power and current vs. input RF phase difference.

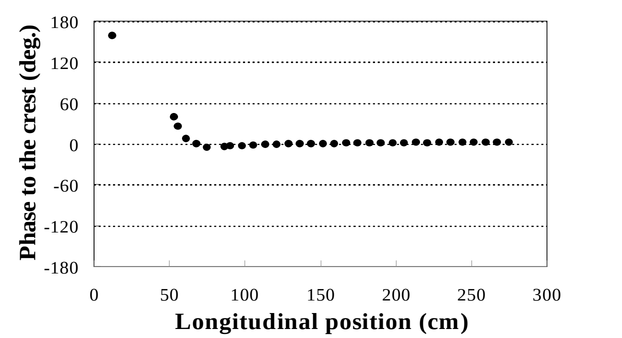

Figure 6: Variation of beam phase relative to crest of the wave through the beamline at the 330˚ phase difference.

Misalignment

The beam energy and the transmission are decreased simultaneously as the misalignment angle of the E-gun to the axis of the beamline becomes larger, in Figure 7-(a). When the misalignment angle is 3˚, the beam power is decreased to 95% of the value with right alignment. If there is no focusing, the beam with 3˚ misalignment from the E-gun is lost to the wall of the drift tube. However, the solenoids compensate this effect by the magnetic focusing, as shown in Figure 7-(b).

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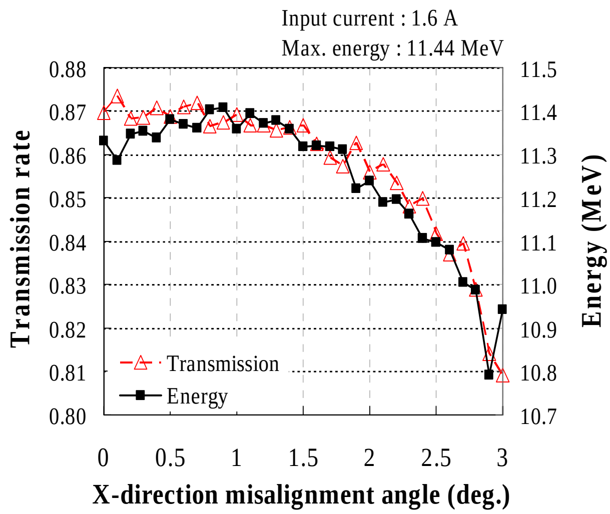
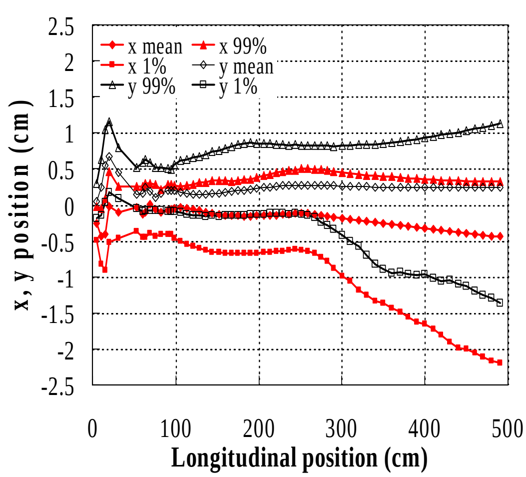


(a)



(b)

Figure 7: (a) Misalignment angle vs. beam transmission and energy, (b) Variation of the beam size and the directions through the beamline at the 3˚ misalignment.

CONCLUSION

The beam dynamics simulation on the beam energy and the transmission is conducted with input RF power into the accelerating column, input current, input RF power into the pre-buncher, input RF phase difference between the pre-buncher and the accelerating column, and the misalignment angle of the E-gun to the axis of the beamline for the commissioning scenario of an intense L-band travelling-wave linac. From the simulation results with the input power into the accelerating column and input current, the nominal capability of the accelerator can be obtained. As per the simulation results with input power into the pre-buncher, the power is not sensitive to the output beam. With the phase difference, to achieve 85% of the optimum value, the phase difference should be -60˚~120˚. The misalignment does not critically affect the beam transmission due to the focusing effect of solenoids.

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REFERENCES

[1] Y. Kamio, “10 MeV, 25 kW Industrial Electron Linacs,” *in Proc. Int. Linac Conf.* (Geneva, Switzerland, Aug. 26-30, 1996), 836 (1996).
[2] S. H. Kim, B. Park, S. I. Moon, H. R. Yang, S. D. Jang, Y. G. Son, S. J. Park, J. S. Oh, M. H. Cho, and W. Namkung, J. Korean Phys. Soc. 50, 1416 (2007).
[3] PARMELA is a trademark of LANL.
[4] M. Chodorow, E. L. Ginzton, W. W. Hansen, R. L. Kyhl, R. B. Neal, and W. K. H. Panofsky, Rev. Sci. Inst. **26**, 2 (1955).
[5] J. E. Leiss, “Beam Loading and Transient Behavior in Traveling Wave Electron Linear Accelerators,” *Accelerators* (North-Holland Publishing Company, Amsterdam, 1970).