BEAM DYNAMICS STUDIES FOR A L-BAND PHOTOINJECTOR*

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Abstract

The simulation studies were performed for a L-band photocathode RF gun injector for the proposed Photoinjected Energy Recovery Linac (PERL) light source at the BNL using computer program PARMELA. The injector consists of a 2.6 cell RF gun and a 20 MeV linac. To reduce the heat load, we have performed beam dynamics studies for a peak acceleration field of 15 MV/m. The transverse emittance less than 1 mm-mrad and pulse length 3 ps (FWHM) can be achieved for a 150 pC charge. Both transverse and longitudinal emittance dependency on the laser pulse length and distribution were also investigated. The injector was also considered for high duty-factor operation (≈1%) for FEL applications. For a peak acceleration field of 30 MV/m, simulation shows that normalized rms emittance are 0.5 and 0.8 mm-mrad for charges 0.5 and 1.0 nC, respectively.

1 INTRODUCTION

Both single-pass high-gain SASE FEL and energy recovery linac now under consideration for next generation light source. Both are linac driven, and capable of producing transverse coherent, 100 fs round beam. The proposed Photo-injected Energy Recovery Linac (PERL) at the NSLS [1] should be able to deliver 100 to 200 mA electron beam with not only small transverse emittance (normalized emittance less than 1 mm-mrad), but also small longitudinal emittance capable of producing 100 fs bunches.

A dedicated photoinjector workshop was help at the BNL [2] to examine possible options which have potential to produce electron beam required for the PERL application. One of the most important considerations for the PERL photoinjector is the preservation of transverse emittance during the bunch compression. From beam dynamics point of view [3], high-repetition rate, low charge, short bunches with little energy spread at birth in the gun are more preferable. We considered electron beam energy either 10 MeV or 25 MeV cases, the later one was chosen mainly for easy beam quality preservation. Electron beam bunch length should be less than 3 ps (rms) with uncorrelated energy spread 0.1% or less at 25 MeV. A L-band (1.3 GHz) photocathode RF gun with either 150 pC (200 mA) or 75 pC (100 mA) was investigated for PERL application.

L-band photocathode RF gun injector has several attractive advantages over other options. By operating at the longitudinal emittance compensation mode [4], longer laser can be used to minimize the space charge effect. Generally speaking, the electron beam energy produced by photocathode RF gun is at least a factor of four higher than DC photoinjector, this corresponding to a factor of 64 reduction in transverse space-charge effect, and three orders of magnitude in longitudinal space-charge effect.

One of the major challenges in operating a CW photocathode RF gun is the heat load and the stress induced. To minimize the heat load, lower peak acceleration field and longer RF gun was considered. 2.6 cell RF gun is a reasonable compromise. Figure 1 is the field distribution for the 2.6 cell RF gun.

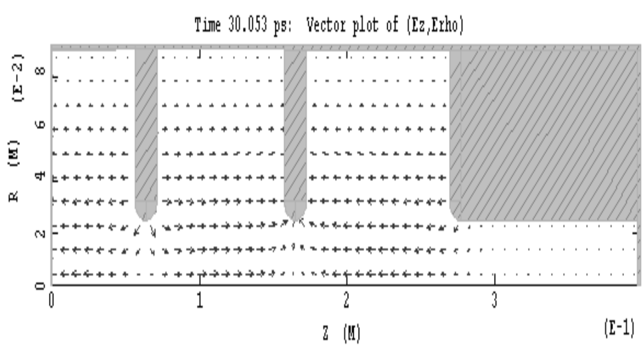

Figure 1: 2.6 cell RF gun.

In the following sections of this report, we first present the simulation study of the L-band photoinjector for CW operation using LANL computer program PARMELA. Low charge (<150 pC) and lower accelerating field (<15 MV/m) were considered. We also consider the L-band photoinjector for high-duty operation (1%), such as FEL application, for charges 0.5 nC and 1 nC at the acceleration field of 30 MV/m.

2 L-BAND PERL INJECTOR

2.1 Photoinjector System

Figure 2 is the general layout of the L-band photocathode RF gun injector system. It consists of a 2.6 cell RF gun, solenoid magnets and two sections of L-band linac. Two solenoid magnets provide both focusing and emittance compensation. A buckling solenoid magnets required for the solenoid magnet near the photocathode.

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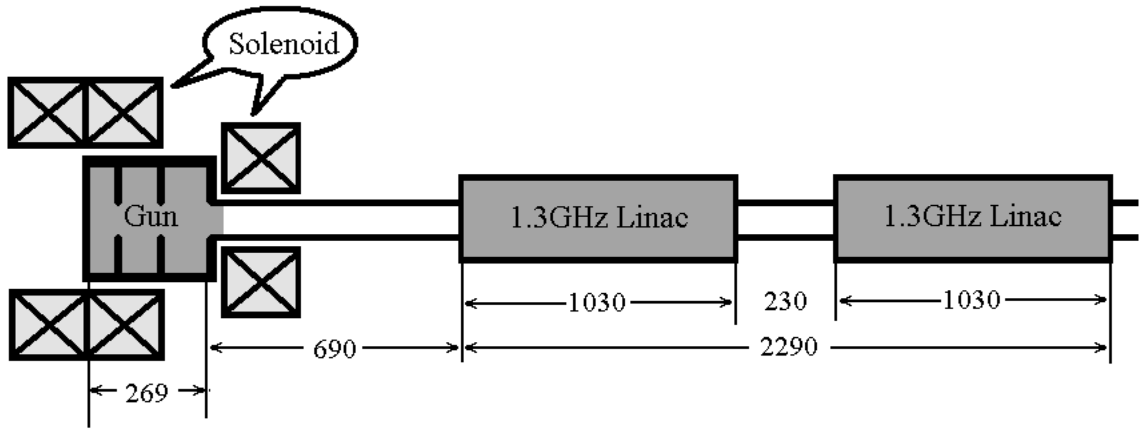

Figure 2: The schematic set-up of L-band Photoinjector.

2.2 6-D Emittance Optimization

For the simulations presented in the rest of this paper, uniformed transverse laser distribution is assumed. Both Gaussian and uniformed longitudinal laser distribution are considered. The main reason for considering Gaussian longitudinal laser distribution is to reduce the laser system complexity and improve the system reliability. Further more, figure 3 shows Gaussian laser produces less nonlinearity in longitudinal phase while uniformed laser produce smaller local energy spread.

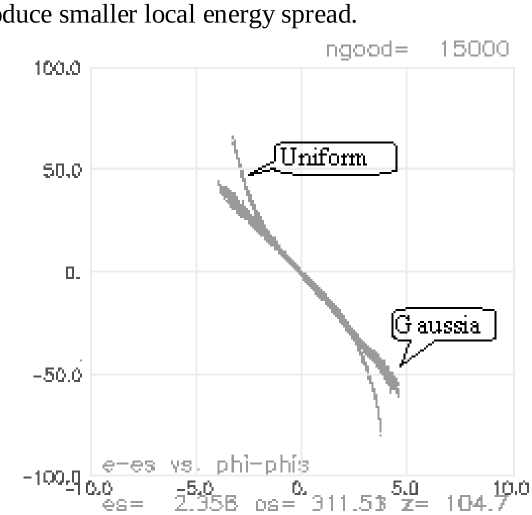

Figure 3: photoelectron beam longitudinal phase space distribution for uniform and Gaussian lasers.

For PERL application, it is the 6-D electron beam phase space needs to be considered besides transverse emittance. Figure 4 shows the product of transverse and longitudinal emittance as function of the laser spot size operating at the RF gun phase 20 degree from zero cross. Figure 5 shows both uniform and Gaussian lasers prefer a pulse length about 3 ps (rms). Those simulations show L-band photoinjector can produce PERL required beam provided RF heating problem can be handled.

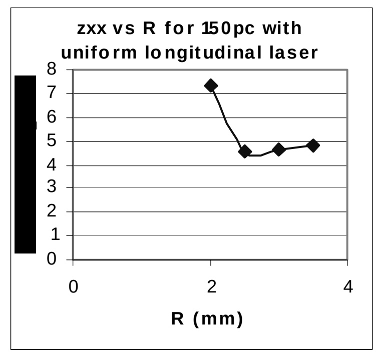

Figure 4: 6-D emittance optimization for laser spot.

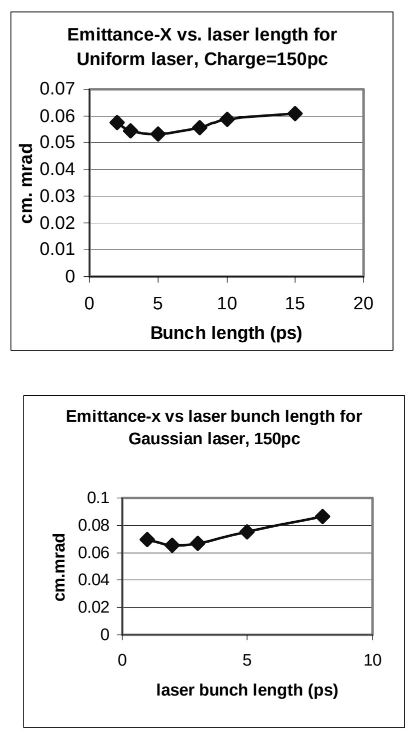

Figure 5: transverse emittance as a function of laser pulse length.

3 L-BAND FEL INJECTOR

We now consider the PERL injector for FEL application. Presently TTF FEL photoinjector [5] is a 1.6 cell L-band RF gun, optimized for 50 MV/m field with 1% duty factor. For the 2.6 cell photoinjector, our simulation shows that, by operating at a lower field (30 MV/m), we can achieve similar performance with a factor of four reduction in heat load.

For L-band FEL injector, only uniformed laser distribution was considered. For a 20 ps laser, optimized laser radius is 2.5 mm. Figure 6 show the transverse emittance and bunchlength as a function of the RF gun phase for a charge of 0.5 nC. The optimized transverse emittance is about 0.5 mm-mrad (rms, normalized). Figure 7 shows the emittance and bunchlength as the function of the laser pulse length.

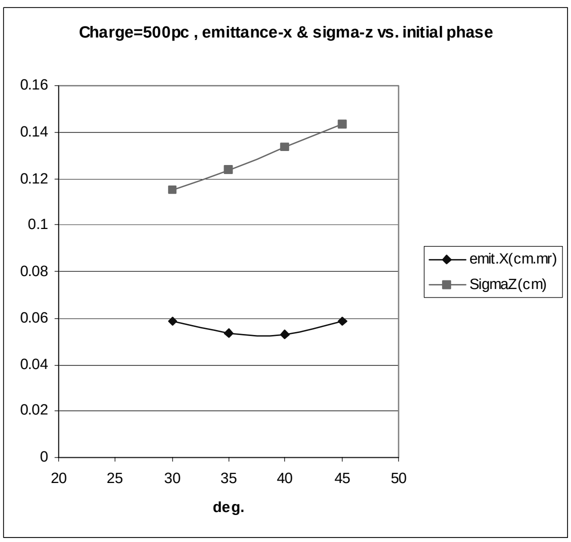

Figure 6: the transverse emittance and bunch length as a function of the RF gun phase for a 0.5 nC charge.

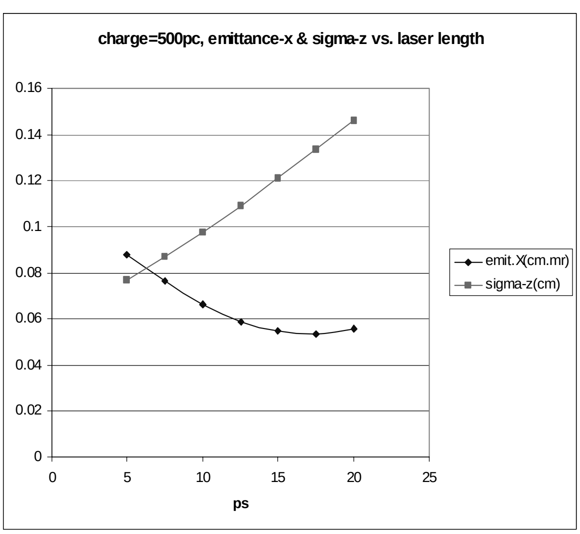

Figure 7: transverse emittance and bunch length as a function of the laser pulse length for a 0.5 nC charge.

Figure 8 shows the transverse emittance and bunch length as a function of the RF gun phase for a charge of 1.0 nC. Here the optimized transverse emittance is about 0.8 mm-mrad (rms, normalized)

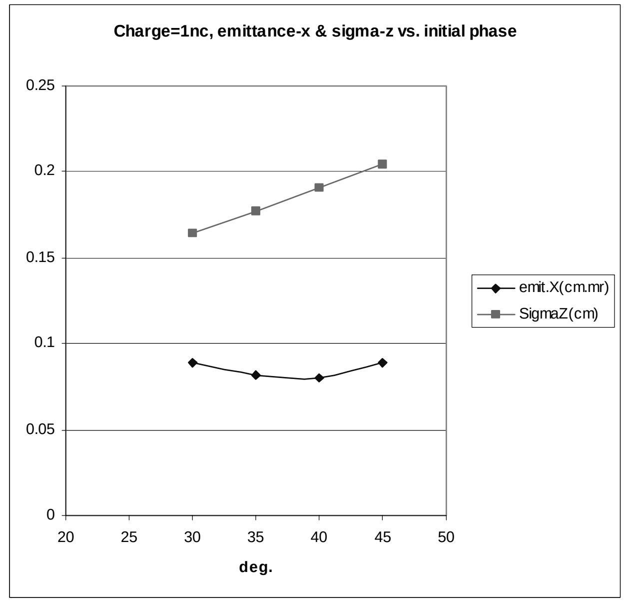

Figure 8: the transverse emittance and bunch length as a function of the RF gun phase for a 1.0 nC charge

4 ACKNOWLEDGEMENT

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5 REFERENCES

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