STATUS OF THE PHOTO-INJECTOR DEVELOPMENT AT NSRRC

A. P. Lee , C. H. Chen, C. C. Chou, J. Y. Hwang, W. K. Lau, C. C. Liang,
NSRRC, Hsinchu 30076 Taiwan.
J. H. Chen, N. Y. Huang, W. K. Luo, National Tsing Hua University, Hsinchu 30013 Taiwan.

Abstract

A high brightness photo-injector for light source research applications is being built at NSRRC. This injector consists of a laser driven RF gun with an emittance compensation solenoid and linac sections that booster the beam energy up to 150 MeV. A 266 nm pico-second UV laser system which generates a 300 μJ laser pulse with pulse which can be varied by a UV stretcher from1 to15 ps have been installed and laser shaping techniques will be developed to reduce the emittance growth. The RF gun is a 1.6 cell cavity operating at π mode and the solenoid used to compensate the emittance growth due to the space charge effect will be set up in the spring of 2009. Beam dynamics study is performed by PARMELA and simulation results show that a normalized rms transverse emittance of 0.7 mm-mrad with a 10 ps flattop pulse at 1 nC charge can be achieved.

INTRODUCTION

Ultra-short and low emittance electron beams have been studied intensively. It can be used in many research fields such as free electron laser, ultra-fast electron diffraction and using inverse Compton scattering to generate short pulse X-ray which are required in material, biology and medical science, so many laboratories in the world have engaged in research and development on the next-generation light source.

The high brightness injector program at NSRRC started in 2006 is to construct a light source for researches of high gain FEL and inverse Compton scattering as a THz radiation source [1]. This injector system consists of three linac sections which can accelerates a electron beam up 150 MeV and two electron sources which are a thermionic rf gun and the a photo-cathode rf gun. These two guns share with the second one of the tree linac sections. The electron beam generated from the thermionic rf gun is pass through a alpha magnet which acts as a compressor and a linac share with the photo cathode rf gun to be velocity bunching. After the compression the electron bunch length can be reduced to about 14 fs. It can be used to generate ultra-fast X-ray source by using inverse Compton scattering [2]. While the photocathode rf gun is used, the emittance of the electron beam can be controlled by a compensation solenoid the shaping techniques of the laser beam. The electron beam will go straight through the linacs and will be accelerated to 150 MeV for single pass high gain free electron laser experiments. In the initial phase, the injector will set up inside the booster building at NSRRC as shown in Fig.1.

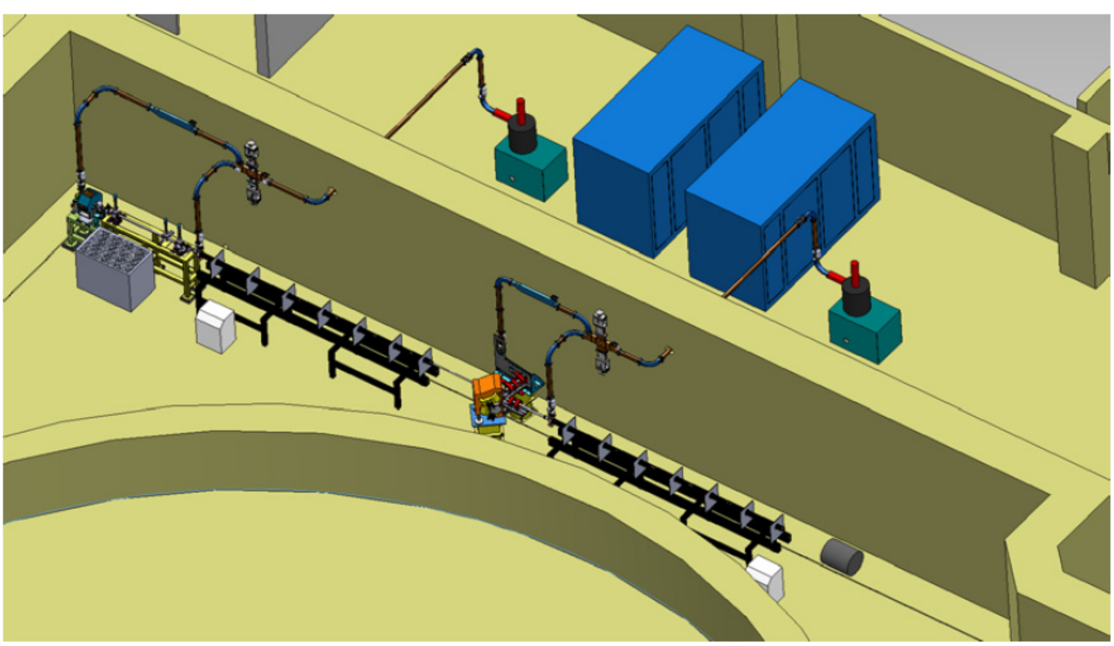

Figure 1: Layout of the photo-injector at NSRRC.

PHOTO-INJECTOR SYSTEM

RF Gun System

The NSRRC photocathode RF Gun is similar to the BNL 1.6 cell structure [3] except that our operating frequency is set at 2998 MHz. A modified design have been performed to adopt the frequency to 2998 MHz. SUPERFISH were used to simulate the electromagnetic characteristics of the new design cavity. The geometry of the cavity was shrunk by a factor 0.96 to scale the resonant frequency to 2998 MHz. The frequency separation between π mode and 0 mode is 3.5 MHz, so the suppression of the 0 mode is not necessary. The field in the fullcell and halfcell are 180° out phase and the maximum points are at the middle of the fullcell and the surface of the cathode. The field balance (FB) also was adjusted to be equal to 1. The simulation results are shown in Table.1 and Fig.2.This gun is under fabrication and fine tune for good operation.

Table.1: Results of SUPERFISH Simulation

	π mode	0 mode
Resonant frequency	2997.83MHz	2994.22MHz
Quality factor	15492	16271
Shunt impedance	49.77MΩ	57.07MΩ
Field balance	1	0.578

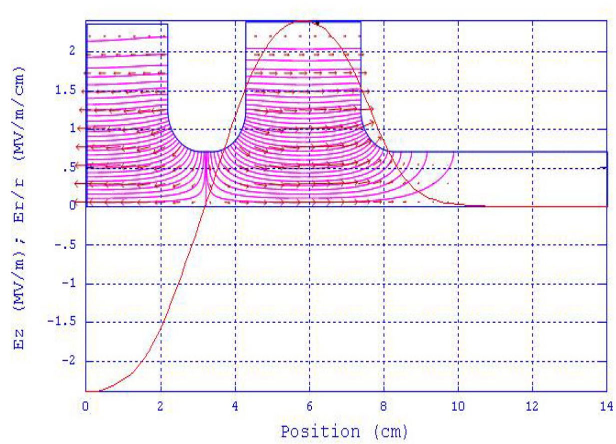

Figure 2: Ez profile of π mode on axis at 2998MHz.

Compensation Solenoid

The solenoid was simulated by POISSON program. It was constructed with an outer yoke shape and eight double layer hollow copper coil sections. Between coil sections, there are seven flux aligner irons which are used to eliminate dipole fields arising from the asymmetries of coil sections and misalignment during assembly. The Bz on axial of the solenoid was measured by Hall probes as shown in Fig.3 and the result is shown in Fig.4.

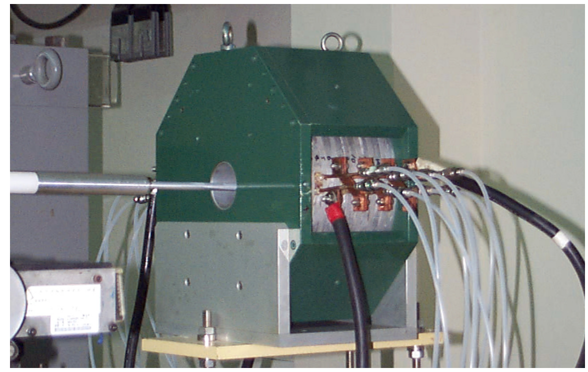

Figure 3: Solenoid and Hall probe.

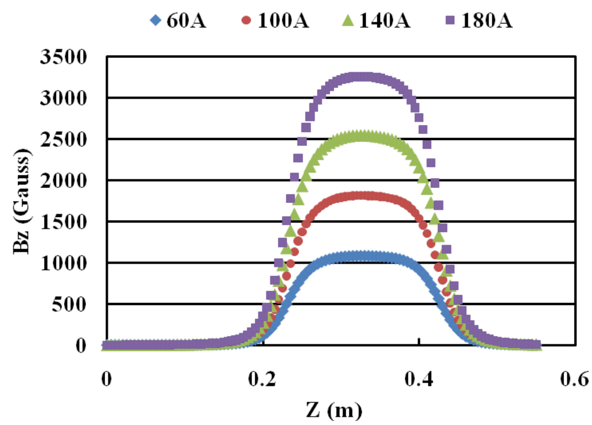

Figure 4: Bz on axis of the solenoid for four different currents.

Drive Laser System

The drive laser system purchased from Coherent Inc. has been installed at NSRRC as shown in Fig.5. It consists of a mode-locked IR oscillator as seed laser, a regenerative amplifier, a third harmonic generator (THG) and a UV stretcher. The mode-locked oscillator generates a 798nm, low energy laser pulse train at 74.95MHz to seed the regenerative amplifier. The regenerative amplifier pumped by a Q-switch laser raises the energy of the seed laser pulse to 3.85 mJ. After passing through THG, it can generates third harmonic laser beam at 266nm with an energy of 0.9mJ. Then the UV stretcher can stretch the pulse width of the beam from 1 ps to 15 ps with the output energy of 350 uJ.

In order to reduce the emittance growth in the RF gun, the spatial and temporal profiles of the Gaussian beam were converted into a flat-top profiles. The spatial profile was shaped by using a refractive UV beam shaper. The beam was transferred into the beam shaper then refracted by aspheric optics with less than 10% energy loss. The temporal beam profile was shaped by using the pulse tacking technique. First, two sets of half-wave plates and beam splitter cubes were used as a pulse stacker. The original pulse of 4ps was stacked optical delay at each set to generate a pulse of 10ps. More pulses will be needed to improve the pulse rise time and flatness [4].

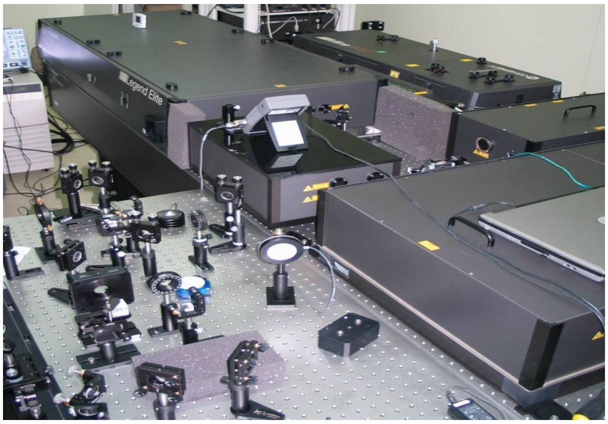

Figure 5: Laser system at NSRRC.

It requires two signals to synchronize the seed laser with RF system. One is the 74.95 MHz derived from 2998 MHz master oscillator frequency by using a frequency divider electronics (1/40) and the seed laser is locked to this signal. The other signal (1 kHz) is for the pump laser of the regenerative amplifier. The laser jitter is less than 250 fs [5].

Beam Dynamics Simulation

Beam dynamics study was performed by PARMELA. The simulation parameters and results are shown in Table.2 Using only the RF gun and solenoid, the normalized rms emittance of the electron bunch with uniform cylindrical spatial and temporal distributions shows a double minimum behavior in the drift section after the solenoid as shown in Fig.6. The second minimum was optimized by varying the magnetic field strength and injection phase. The optimized emittance of 0.7 mm-mrad with a 10 ps uniform cylindrical pulse can be achieved at 1 nC charge, when using 2628 Gauss magnetic field and 34° injection phase.

Table.2: Parameters of PARMELA Simulation

Bunch charge	1 nc
Bunch shape (special/ temporal)	uniform/uniform
Bunch radius	1 mm
Bunch length	10 ps
Peak rf field	140 MV/m

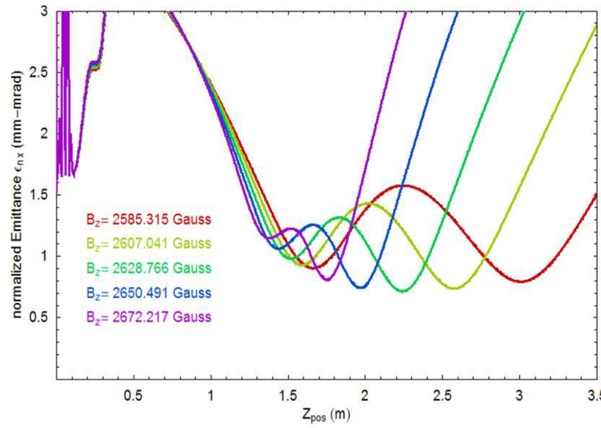

Figure 6: Results of PARMELA simulation.

SUMMARY

The drive laser system has been installed in 2008. We will continue to develop laser shaping techniques in transverse and temporal beam profiles. The RF gun cavity has already been fabricated and is under microwave test as well as tuning. RF gun vacuum brazing will be performed afterward. System integration of the photo-injector will be started in summer of 2009 for rf gun high power microwave processing and linac installation.

REFERENCES

[1] W.K. Lau, J.Y. Hwang, G.Y. Hsiung, D.J. Wang, G.H. Luo, J.R. Chen, "Conceptual Design of a High Brightness Injector at NSRRC", NSRRC Technical Report NSRRC-TR00022(2006).

[2] N.Y. Huang, S.S. Yang, C.C. Liang, A.P. Lee, C.S. Chou, J.H. Chen, "Generation of Sub-Hundred Femtosecond X-ray via head-on Inverse Compton Scattering", in these proceedings.

[3] X. J. Wang et al., Physical Review E 54-4, p. 3121 (1996).

[4] C.S Chou, J.H Chen, S.B Hong, N.Y Huang, A.P Lee, C.C Liang, W.K Lau, "Drive Laser System for the NSRRC Photoinjector", in these proceedings.

[5] C.C. Liang, J.H. Chen, C.S. Chou, K.T. Hsu, W.K. Lau, A.P. Lee, S.H. Lee, " Laser Jitters Measurement for the NSRRC Photo-injector System.", in these proceedings.