DEVELOPMENT OF A HIGH BRIGHTNESS PHOTO-INJECTOR FOR LIGHT SOURCE RESEARCH AT NSRRC

W.K. Lau, J.H. Chen, C.S. Chou, G.Y. Hsiung, K.T. Hsu, J.Y. Hwang, A.P. Lee, C.C. Liang, G.H. Luo, D.J. Wang, National Synchrotron Radiation Research Center, Hsinchu 30076, Taiwan.
C.H. Chen, N.Y. Huang, Y.C. Huang, W.K. Luo, National Tsing Hua University, Hsinchu 30013, Taiwan.

Abstract

A high brightness electron beam injector system is being developed for light source R&D at NSRRC. Recently, a test stand for testing the photo-cathode rf gun system is being constructed. The photo-cathode rf gun cavity has been modified from the BNL 1.6-cell structure for 2998 MHz operation. A 798 nm Ti:Saphire laser seeded 3 mJ amplifier is employed to produce 300 microjoules UV pulses at 266 nm wavelength from a third harmonic generator crystal for emission of photo-electrons from the Cu-cathode in the rf gun. First operation of this system with Gaussian laser pulses is scheduled in this summer. Electron beam dynamics in the photo-cathode rf gun test stand has been studied with PARMELA. The results showed that the normalized emittance can be as low as 0.75 mm-mrad for a 10 psec flattop beam with emittance compensation solenoid.

INTRODUCTION

A high brightness electron beam injector (HBI) system that based on rf gun technology is under construction at NSRRC for light source research such as intense THz radiation sources, high gain free electron lasers and femto-second X-ray and electron pulses [1]. This will be a 2998 MHz, 200 MeV beam injector with a thermionic cathode rf gun and a photo-cathode rf gun as electron sources. For the photo-cathode rf gun, solenoid magnetic field as well as laser shaping (transverse and temporal) will be applied for beam emittance control. The two electron guns share one of the three 5.2 m travelling-wave constant gradient accelerating structures located downstream (Figure 1). An alpha magnet will be used to bend the beam from thermionic cathode rf gun and compressed the electron bunches into femto-second scale [2]. Therefore, this injector can be operated in two modes. Namely, the high brightness beam mode and ultra-short bunch mode.

In the high brightness beam mode, only the photo-cathode rf gun will be used, the high brightness beam will go straight through the linacs and will be accelerated to 200 MeV for single pass high gain free electron laser experiments. Chicane bunch compressor to increase beam brightness is under designed. In the ultra-short bunch mode, only the thermionic cathode rf gun and the alpha magnet bunch compressor will be used. Beam accelerated (up to ~30 MeV) by the second linac section will be used to generate coherent THz radiations and ultrafast X-rays. To generate ultrafast X-ray from the femto-second electron beam, a Thomson back scattering experiment is being designed.

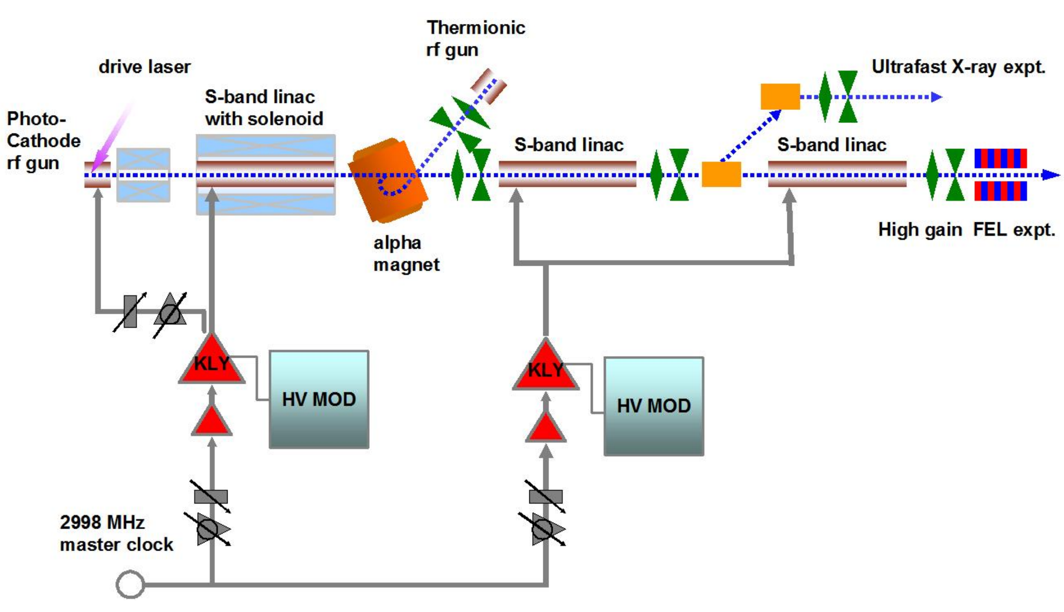

Figure 1: The NSRRC high brightness injector system

THE PHOTO-CATHODE RF GUN TEST STAND

In the first phase of the project, a teststand equipped with beam diagnostics elements for measuring the performance of the 2998 MHz photo-cathode rf gun is being installed (Figure 2).

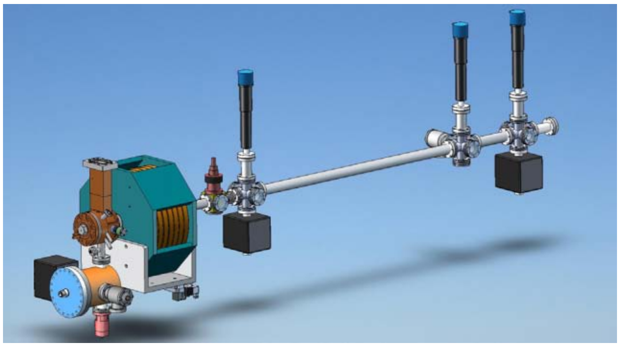

Figure 2: Setup for testing the 2998 MHz photo-cathode rf gun

The Photo-cathode RF Gun

The photo-cathode rf gun cavity is a 1.6-cell π-mode standing wave structure operating at 2998 MHz. Its dimensions are scaled from the original 2856 MHz BNL GUN-IV design. With emittance compensation solenoid and laser shaping techniques, our goal is to produce 1 nC, ~10 psec electron bunches at 1 mm-mrad normalized transverse emittance. In order to improve pumping speed of the vacuum system near the Cu-cathode, the drift tube located at down stream of the photo-cathode rf gun cavity is coated with getter material on its inner wall. Furthermore, we used both ion pump and NEG pump at the gun cavity pumping port.

The UV Drive Laser System and Optics for Beam Transport

The UV drive laser at 1 to 15 pico-second pulse duration has been setup to produce photo-electrons from the Cu-cathode in the gun cavity. In the laser system (Figure 3), a 3 mJ, 798 nm Coherent Legend-Elite F-HE Ti:Saphire amplifier is employed to pump a third harmonic generator (THG) crystal for generation of the 300 μJ, 266 nm UV light. For high stability and reliability, a diode laser (Coherent EVOLUTION-30) is used to pump the amplifier which is seeded by a 0.65 W Coherent Mira 900-F Ti:Saphire laser. The laser system is synchronized to the phase of the 2998 MHz microwave system with rms jitters as low as 250 fsec.

The UV output power of the system is adjustable by an IR optical attenuator (a half-wave plate plus a polarizer) before the THG. Output pulse duration of the laser system will be adjusted by a UV stretcher after the THG. To avoid emittance degradation due to nonlinear space charge forces, transverse profile of laser beam is flattened by a refractive UV beam shaper with deviation from flattop less than 15%. Laser shaping for a temporal flattop pulse is under study. A virtual cathode is designed to help us in pointing and focussing the laser beam to the cathode (Figure 4).

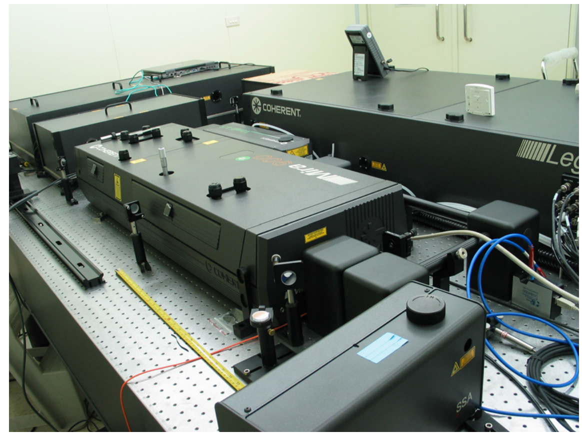

Figure 3: The UV drive laser for the 2998 MHz photo-cathode rf gun.

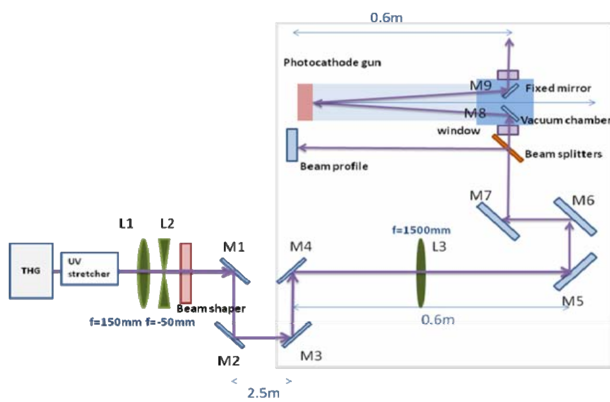

Figure 4: Optics for laser beam transport and virtual cathode.

PARMELA STUDY

Electron beam dynamics in the 2998 MHz photo-cathode rf gun has been studied with PARMELA.

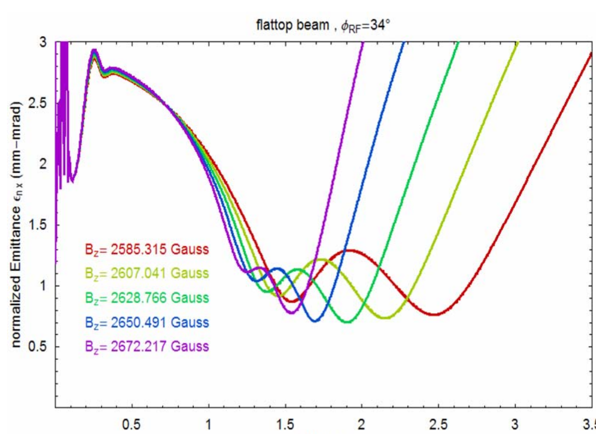

Figure 5: Evolution of normalized emittance at various solenoid magnetic field strength for a 10 picoseconds ideal temporal flattop electron beam.

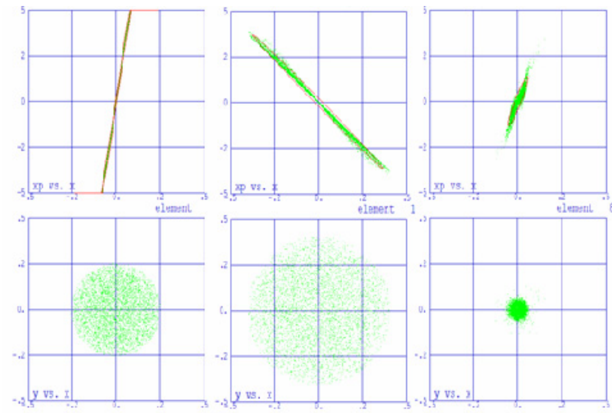

Figure 6: Electron distributions in x-y plane (lower plots) and transverse trace space (upper plots) at gun exit (left), after the emittance compensation solenoid (middle) and at second emittance minimum in the drift section (right) respectively.

With a 2 mm diameter, 10 picoseconds ideal temporal flattop electron beam, the second normalized emittance minimum as low as 0.75 mm-mrad is occurred in the drift section at 0.2629 T solenoid magnetic field strength. After the minimum, emittance grows linearly as distance from cathode increses. The injection phase is 34°. Figure 6 is the electron distributions in x-y plane and transverse trace space at gun exit, after the emittance compensation solenoid and at second emittance minimum in the drift section respectively. Our next step will be carried out to match the beam to the first rf linac section for acceleration and find the conditions to preserve normalized emittance during acceleration.

CONCLUSION

A high brightness electron beam injector system is being developed at NSRRC. A test stand for testing the photo-cathode rf gun performance is being constructed. The 266 nm UV drive laser with pulse duration adjustable from 1 to 15 pico-seconds for the photo-cathode rf gun has been installed. First operation of this system with Gaussian laser pulses is scheduled in this summer. Electron beam dynamics in the photo-cathode rf gun test stand has been studied with PARMELA. The results showed that the normalized emittance can be as low as 0.75 mm-mrad for a 10 psec flattop beam with emittance compensation solenoid. This results agrees with those for a 2856 MHz photo-cathode rf gun studied elsewhere.

ACKNOWLEGEMENT

The authors would like to express our appreciation to Dr. Xijie Wang and Dr. Max Cornnachia for giving us many helpful suggestions and critical comments on photo-cathode rf gun and high brightness injector design.

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] Y.C. Wang, S.Y. Hsu, C.S. Hwang, J.Y. Hwang, W.K. Lau, F.Y. Lin, T.T. Yang, S. Rimjaem, "Generation of Ultra-short Electron Bunches for Light Source Research", International Journal of Modern Physics B, Vol. 21, Nos. 3-4 (2007) 430-437.C.