DEVELOPMENT OF HIGH BRIGHTNESS INJECTOR AT NSRL*

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Abstract

A high brightness injector based on photocathode RF gun is developing at National Synchrotron Radiation Laboratory. This article shows the parameter of a BNL 1.6 cell type S band rf gun and the measurement result of a compact solenoid. Laser system parameter from high Q Company is given also.

INTRODUCTION

Different kinds electron gun have been developed at National Synchrotron Radiation Laboratory for different application. The secondary emission microwave electron gun [1] is used to produce high average current, low emittance beam. An Independently Tuneable Cavity Thermionic RF Gun [2] is tuning for short pulse generation. Beside these, we are developing a high brightness injector based on photocathode RF gun supported by 985 project.

Photocathode RF gun can fulfill the needs of FEL facilities, high average power infrared FEL, coherent THz radiation source, laser-wakefield acceleration and so on. We develop the photocathode RF gun as a platform for coherent THz radiation source study, advance beam diagnostic technology development, FEL injector and for other advance needs.

GENERAL LAYOUT OF EXPERIMENT

The injector locates in a tunnel built in nuclear hall. The tunnel is 25m long and 3.5m width. The injector layout is shown in figure 1. The injector includes a photocathode rf gun, a emittance compensate solenoid and beam diagnostic system for emittance, energy spread, bunch charge and bunch length and so on. The tunnel is long enough to add one or two 6m long SLAC acceleration section to accelerate the beam energy high enough to keep the beam's low emittance. The radiation safety of tunnel designs for 250MeV electron beam.

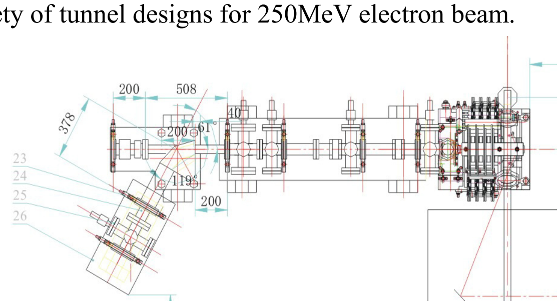

Figure 1: Layout of injector.

A clean room for laser system locates at the outside of tunnel. The klystron and power of solenoid locates at the outside of tunnel but in the nuclear hall also. The long-distance control is achieved in the control room outside of nuclear hall.

Each separate parts of system have finished manufacture at the present time. The installation of subsystem is undergoing now. We hope it can get first beam this summer.

PHOTOCATHODE RF GUN

Because the experience of theory study and the experience of gun of shanghai DUV FEL project, we adopt a BNL type IV photocathode RF gun. The gun is fabricated at accelerator laboratory of department of engineering physics of Tsinghua University. Figure 2 show the picture of the photocathode RF gun.

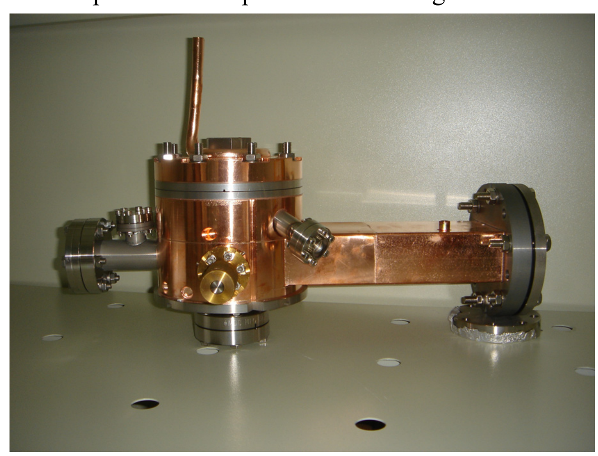

Figure 2: The photocathode rf gun.

Table 1: Parameter of Injector

Parameters	Value
Cell type	BNL 1.6 cell
Repetition rate	10Hz
Charge per bunch Q_0	1nC
Cathode material	Cu
Peak RF field	100MV/m
Beam energy at gun exit	>4.MeV
rf frequency	2856MHz
Input rf peak power	10MW
Quantum efficiency	$>10^{-5}$ at 262nm

The main design parameters of photocathode RF gun are given in the table 1. Gun is BNL 1.6 cell type and

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working at 2856MHz. The design working charge per bunch is 1nC. Material of cathode is Cu and we hope its quantum efficiency is above 10^{-5} at 266nm wavelength. The input peak rf power is about 10MW, so in the rf gun cavity a peak rf field of 100MV/m can be established. Beam can be accelerated to greater than 4MeV. The power from klystron can reach a maximum 20MW. So the capacity of RF gun peak field can reach above 120MV/m. The final peak field for the experiment will be determined by the control of dark current.

Cold measurement is carried at Tsinghua University. The measured parameter of photocathode rf gun is shown in the table 2. The measured frequency of π mode is 2856.181MHz. Woking temperature of gun is 40^0C. The delta frequency of π mode and 0 mode is 3.21MHz. The Q factor for full cavity is 14174. Unloaded Q_0 of π mode is 8350. Loaded Q_0 of π mode is 3970. The couple factor β of π mode is tuned to a little over couple state.

PARMELA simulations indicate the ratio of the field in the half cell to full cell should be close to unity [3,4]. Unbalanced fields can lead to large correlated energy spreads exiting the gun and subsequent emittance growth. So the field balance is measured also. The result is shown in the figure 3. The ratio of the field in the half cell to full cell is about 0.97.

Table 2: Cold Measured Parameter of Gun

Parameter	Value
f_π	2856.181MHz
f_π-f_0	3.213MHz
E_{half}/E_{full}	0.97
Q_0 of π mode	8350
Q_e of π mode	6960
Q_L of π mode	3970
β of π mode	1.2

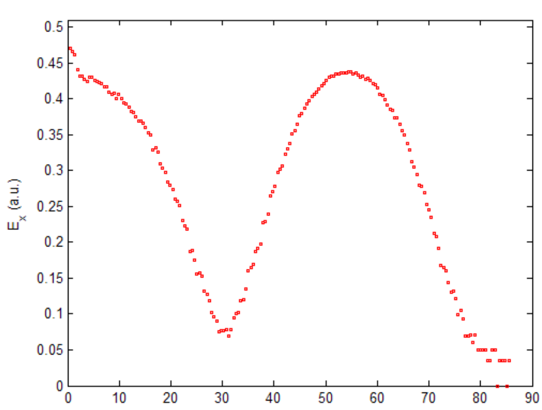

Figure 3: Balance of field.

LASER SYSTEM

The laser system is the key to guarantee production of low emittance beam of photocathode rf gun. A Nd:VAN laser system produced by High Q Laser Production GmbH is adopt. As shown in figure 4, it includes a seed laser, a regenerative amplifier, a pockels cell, a post amplifier and a pulse picker. The parameter of Nd:VAN laser system is given in the table 3. The rms time jitter between the laser and external RF is less than 400fs. It is capable of producing 500μJ energy per pulse in 266nm at the output of laser system. The spatial and temporal shape of the optical pulse from picoREGEN is nominally Gaussian. The 266nm pulse length is 8.3ps (FWHM). The repetition rate of laser system in the experiment is 10 Hz.

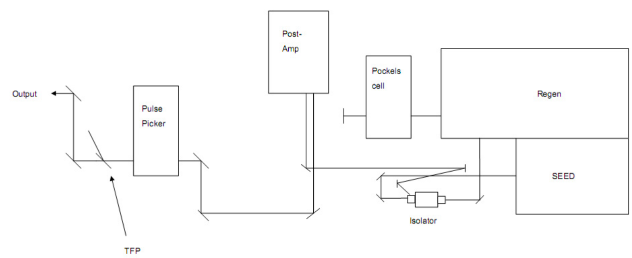

Figure 4: Principal optical setup of IC-10000 ps ND:VAN REG AMP.

Table 3: Initial Testing Parameters of LASER [5]

Parameter	Value
LASER media	YAG
Wavelength	266nm
Pulse length	8.3ps(FWHM)
Energy per pulse	500μJ
Jitter	0.4ps(rms)
beam quality	M^2<1.5
Stability Long Term	<2% rms
Stability P-P	<1.2% rms
beam divergence	0.5mrad

Simulations indicate that an emittance-compensated beam at the exit of the injector will have a lower transverse emittance if uniform spatial distributions of charge are extracted at the photocathode. Temporal shape of the optical pulse from picoREGEN can not be shaped. The spatial shape of the optical pulse will be accomplished by carefully designed transport system to gun cathode. A uniform transverse profile with an adjustable radius, nominally a hard edge at 1.5 mm will be accomplished at rf gun cathode. The optical beam will transport in a vacuum tube to an optics platform next to the gun and be imaged to rf gun photocathode with same wave front in time and uniform transverse profile.

EMITTANCE COMPENSATION SOLENOID

For emittance compensation, a solenoid with precisely defined field symmetry and positioning will be used at the gun exit. We have designed a compact solenoid and the solenoid was fabricated in the factory of Shanghai Institute of Nucleus. The geometry of the solenoid used in Superfish simulation is shown in figure 5 and result of simulation is shown also.

The solenoidal magnet is constructed out of eight double layer hollow core copper conductor pancakes. Each pancake includes 2 layers and has 33 circles hollow core copper conductor. The dimension of hollow core copper conductor is 7*7. The inner radius of hollow core copper conductor is 2mm. different pancakes are insulated by polyimide film and glass filament. The eight coils of solenoid are powered in series. The max excitation current can reach 220 Amperes.

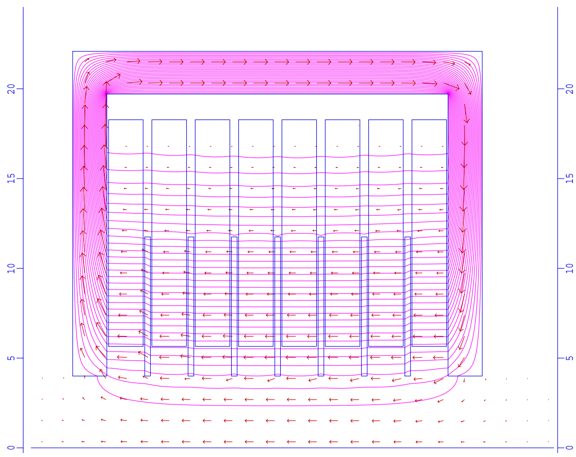

Figure 5: Geometry of the solenoid.

We measured the B_z on axis for different current. Figure 6 represents the longitudinal magnetic field produced by the emittance compensation solenoid for the following excitation currents: 20, 50, 100, 150, 200 and 220 Amperes. For maximum excitation current 220A, a longitudinal magnetic field, B_z of 3716.7 gauss can be generated at the center of solenoid. An important feature of the single emittance compensation magnet is the lower magnetic field on the cathode, B_z (z = 0). For excitation current 220A, B_z =17.88 gauss is generated at the plane of the cathode.

The excitation plot of peak magnetic field versus excitation current is shown in figure 6. A linear fit to these data can be represented by Eq. 1 and shown in figure 7.

$$B_{z,\max} = 16.8 \frac{Gauss}{A} I + 19.78 Gauss \qquad (1)$$

Similarly, a linear fit to magnetic field at cathode plane, B_z (z = 0) can be represented by Eq. 2.

$$B_{z,z=0} = 0.0825 \frac{Gauss}{A} I - 0.59 Gauss \qquad (2)$$

The off axis longitudinal magnetic field was also measured. For an excitation current of 200A, the maximum difference between B_z (r = 0) and B_z (r = 5mm) is less than 0.6%.

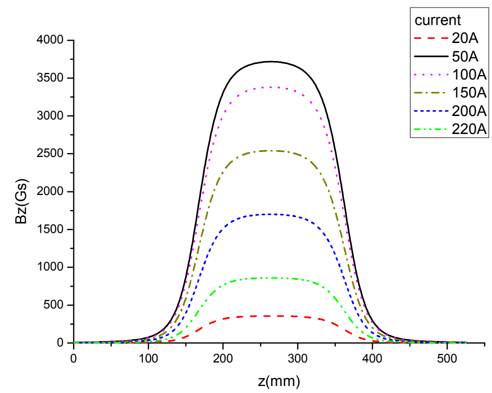

Figure 6: Measured axial magnetic field of the emittance compensation solenoid for different excitation current.

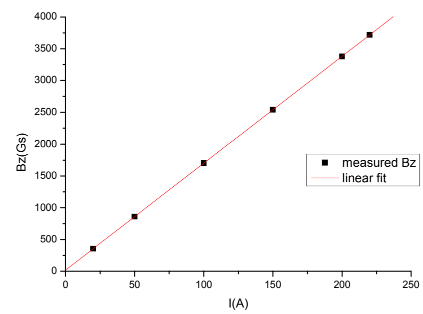

Figure 7: Peak magnetic field versus excitation current.

CONCLUDING REMARKS

The measured parameters of photocathode rf gun and emittance compensation solenoid have reached the design goals. All systems are installing now. The beam experiment will be carried this summer. We hope a beam with normalized emittance smaller than 4mm·mrad can be generated. The dark current of gun will be studied carefully. The emittance affected by the residual magnetic field at gun cathode plane will be studied carefully also.

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