STATUS OF THE PHOTOCATHODE RF GUN RESEARCH AT TSINGHUA UNIVERSITY

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Abstract

An S-band high gradient photocathode RF gun test stand is in construction at Tsinghua University. The photocathode RF gun test stand is a primary step of a femtosecond hard x-ray source based on Thomson scattering. The photocathode RF gun system adopts BNL IV type 1.6 cell RF gun, compact compensation solenoid and Ti:Sapphire laser. We foresee to use this photocathode RF gun to Thomson scattering experiments. Current status of the RF gun system, including the status of the RF gun, solenoid, and the laser system will be reported in this paper. The RF measurement result of the RF gun and magnetic measurement results of the solenoid will be given.

INTRODUCTION

X-ray source produced by Thomson scattering may have potential in various research fields, such as solid-state physics, medical science and industrial applications. A hard X-ray source based on Thomson scattering between Ti:Sapphire laser and electron linac was proposed to be built in Tsinghua University[1]. Two preliminary steps has been taken for this purpose. One is carrying out preliminary Thomson scattering experiment using the existing 16MeV backward traveling wave linac in Tsinghua university[2], the other is developing a photocathode RF gun system in Tsinghua university, to supply high quality electron beam for the Thomson scattering X-ray source. With this photocathode RF gun test stand, we may also perform some photoinjector related researches, such as thermal emittance due to surface roughness and emittance compensation.

The photocathode RF gun test stand in Tsinghua University employs S-band BNL type IV 1.6Cell RF gun, compact single solenoid without bucking coil, and Ti:Sapphire laser. A pop-in YAG profile monitor which can also function as a Faraday cup is also integrated in the photocathode RF gun test stand. The designed parameters of the gun test stand are listed in table 1.

STATUS OF THE PHOTOCATHODE RF GUN TEST STAND

The fabrication, tuning and brazing of the RF gun has been finished. Magnetic measurements of the solenoid has also finished. Except the waveguide connecting the RF gun to the klystron, all parts of the photocathode gun test stand has been installed. The in-situ baking of the RF gun has been started. The picture demonstrating the current status of the gun test stand is shown as figure 1. The detailed information on the RF gun, the solenoid and the laser system will be given in the following subsections.

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Table 1: Design Specifications of the photocathode gun test stand in Tsinghua University

RF gun	
Gun type	BNL type IV
Electric field at cathode	≥100MV/m
Cathode material	Cu or Mg
Freqency	2856MHz
Microwave pulse length	2-4μs
Repetition rate	≤50Hz
Temperature	45^{o}C
Field balance	1.0
Location of solenoid center(to cathode)	223mm
Location of YAG profiler (to cathode)	531mm
Laser	
Laser media	Ti:Sapphire
Wavelength	266nm
Pulse length	FWHM10ps
Energy per pulse	250μJ
Jitter between laser and external RF	RMS500fs

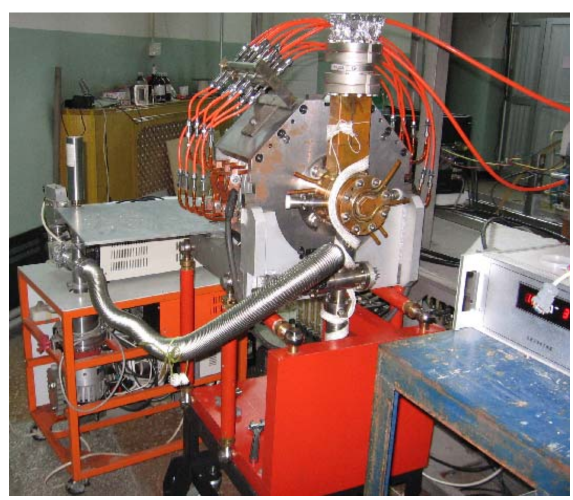

Figure 1: picture the photocathode gun test stand.

The BNL type IV RF gun

We designed a photocathode RF gun similar to the original BNL type IV gun[3] with several modifications. The insertable tuners at full cell are removed in our design.

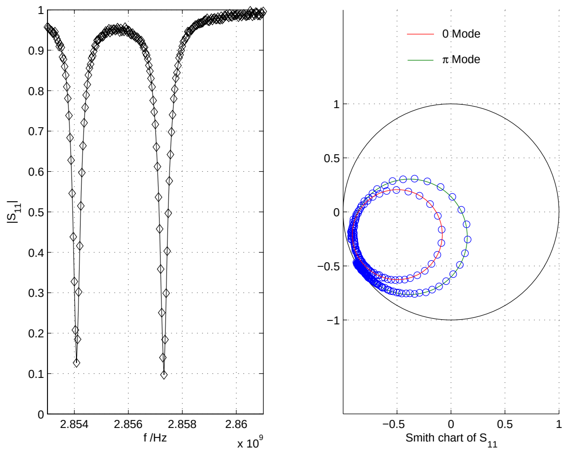

Figure 2: S_{11} measurement result

The coupling hole between waveguide and the full cell is lengthened to provide enough coupling of π mode. The tuning of the cavity is accomplished by measure&cut technique. After final brazing and cathode assembling, the RF properties of the gun are measured by vector network analyzer 8720B. The measured S_{11} of the waveguide port is shown in figure 2.

The measured data of the RF gun and their computed values by SuperFish are listed in table 2. The coupling coefficient listed in table 2 is computed by the following formulas,

$$\beta = 1/(Q_{e,f}/Q_{0,f} + 0.6FB^2 Q_{e,f}/Q_{0,h}), \qquad (1)$$

where $Q_{e,f}$ is the external quality factor of the full cell, $Q_{0,f}$ and $Q_{0,h}$ are the intrinsic quality factor of full cell and half cell respectively, FB is the ratio of the E_z at cathode center and at the center of full cell. In our case, $Q_{e,f}$ computed by MAFIA T3 is 5000 when the coupling hole length is 24.5mm, $Q_{0,f}$ and $Q_{0,h}$ are 14887 and 7829 respectively.

Table 2: Measurement result of the 1.6Cell RF gun

	Measured	Computed
$f_\pi - f_0$(MHz)	3.234	3.230
E_{half}/E_{full}	NA	1.08
f_π in vacuum(MHz)	2857.37@23^oC	2856@45^oC
Q_0 of π mode	10327	10863
β of π mode	1.19	1.28
Q_0 of 0 mode	9503	9629
β of 0 mode	0.78	0.77

We also measured sensitivity of the frequency change due to cooling water temperature change. We measured the frequency of π mode by 8720B, and measured the temperature of cooling water at the same time. The result is shown in figure 3. The sensitivity of the frequency change due to cooling water temperature is about 50kHz/Centidegree,

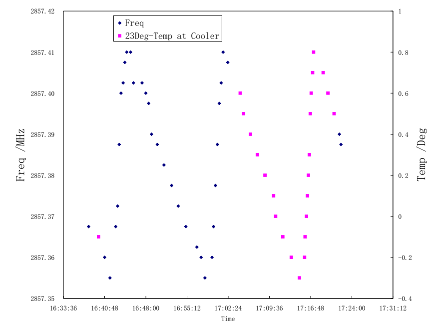

Figure 3: Frequency of π mode VS time and cooling water temperature VS time

which is close to theoretical value 48kHz/Centidegree. And the measurement result imply that there is no significant delay between the frequency change of the RF gun and the temperature change at the cooler. A new cooler which can control the temperature of cooling water to be within $\pm 0.1^oC$ will be used to tune and stabilize the temperature of the RF gun.

Compact solenoid without bucking coil

A compact solenoid without bucking coil is designed and fabricated in Institute of High Energy Physics in China. The geometry of the solenoid used in SuperFish simulation is shown in figure 4. When the current is 150A, the measured Bz on axis is shown in figure 5 together with SuperFish computation result. The difference between measurement result and SuperFish computation result is about 0.3%. At cathode plane, Bz is 8.2Gauss when Bz at the center of solenoid is 2400Gauss. The eight coils of the solenoid can be powered independently. If only the upstream four coils are powered, the peak of the Bz field will be closer to the cathode. The computed profile of Bz field along axis when only the upstream four coils are powered is also shown in figure 5.

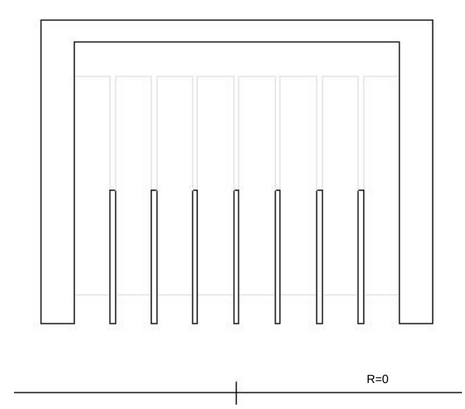

Figure 4: Geometry of the Compensation Solenoid used in SuperFish

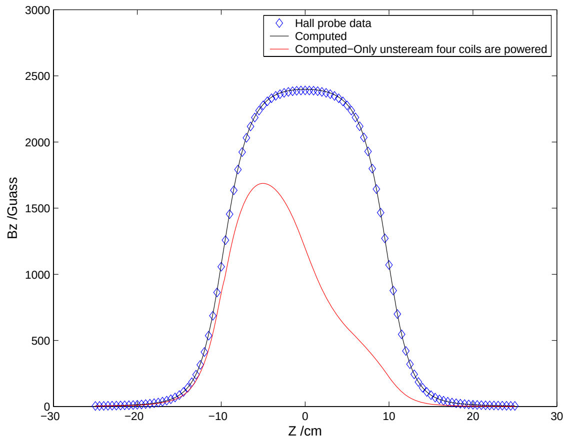

Figure 5: Measured and computed Bz on axis when current is 150A

Laser system

The laser system installation has been finished. The laser system include a Ti:Sapphire passive mode-lock oscillator(Verdi Pumped MIRA), a regenerative amplifier(Legend), three harmonic generator, and pulse stretcher in UV. The picture of the laser system is shown in figure 6.

Figure 6: Picture of laser system

The achieved parameters of the laser system is shown in table 3.

Table 3: Achieved parameters of the laser system of photocathode RF gun test stand in Tsinghua University

Bandwidth in IR	10nm,FWHM
Central wavelength in IR	799nm
Pulse duration in IR	110fs,FWHM
Pulse energy after UV stretcher	0.25mJ

OUTLOOK

The installation of the photocathode gun test stand has been almost finished. After installing the waveguides connecting the RF gun to the klystron, the laser transportation from clean room to experimental hall will be installed quickly. Then, the conditioning of the RF gun will be started. It is expected to observe photoemission electron beam in July or August. After that, basic features of the electron beam (charge, energy) will be characterized.

REFERENCES

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