COMMISSIONING OF A PHOTOINJECTOR IN HLS*

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Abstract

A BNL type photoinjector was installed in HLS (Hefei Light Source) and commissioning work was carrying out in last months. The dark current was measured when the high power testing of the gun was processed. The quantum efficiency (QE) of the photocathode was measured and studied, the main parameters of beam quality such as electric charge, transverse emittance and energy were measured and presented in this paper.

DESCRIPTION OF THE PHOTOINJECTOR

The gun is a BNL type S-band normal conducting 1.6 cell cavity with copper cathode, which is nested in a compensation solenoid. The distance between the cathode and the edge of solenoid is 10cm. Fig.1 is the layout of the photoinjector in HLS. The YAG screens is used to image the beam profile. Multi-slits is set at the distance of 55cm downstream from the cathode for transverse emittance measurement. The FCT and ICT are used to measure the current signal of the electron beam, the beam charge can be calculated by integrating the current signal. The energy measurement is achieved by a dipole and a YAG screen associate with a camera.

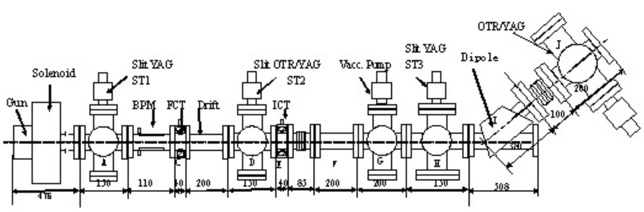

Figure 1: Layout of the photoinjector

As a key component of the system, the drive laser is consist of laser oscillator, regenerative amplifier and harmonic generation crystals. The laser pulse generated from the amplifier is 1047 nm wavelength, 8.3 ps (FWHM) pulse with 10 Hz repeat rate. Through the second and fourth harmonic generation crystals, 262 nm UV laser is gained. The performance of the laser system was measured and the optical transport line for oblique incidence at the cathode was also designed[1].

The high precise phase synchronization system is also a critical requirement for the normal operation of the injector. A timing stabilizer is used to synchronize the 102 MHz laser oscillator signal and the rf signal, the precision is achieved about 100 fs . 2856 MHz signal is acquired by the 28th frequency multiplier and sent to the high power RF system.

HIGH POWER TESTING OF THE GUN

To get the gun into normal operation, conditioning work was done. After hundred hours continuous conditioning, almost 10 MW RF power at the exit of the klystron was achieved. Fig.2 showed the RF power at different high voltage settings of the power supply of the klystron.

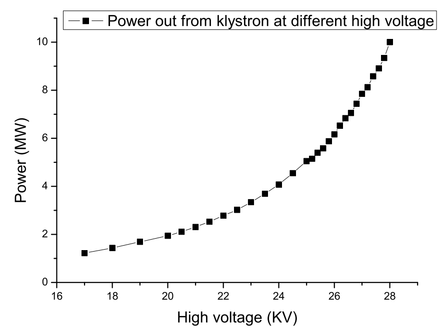

Figure 2: RF power at different high voltage settings

Whereafter, the dark current was also measured, as shown in Fig.3. To collect all of the electron current, the magnetic field strength of the solenoid should be tuned with the changing of the RF power.

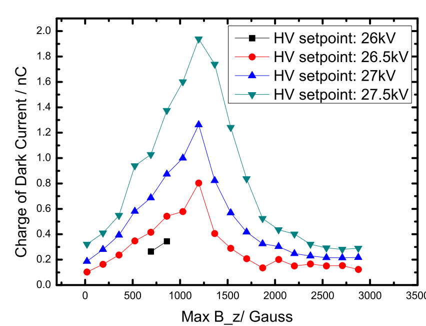

Figure 3: Dark current Vs magnetic field strength of the solenoid at different RF power

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QUANTUM EFFICIENCY

The quantum efficiency (QE) of the photocathode is the amount of electrons emitted from the cathode illuminated by one photon. To acquire high charge electron beam, quantum efficiency is crucial. The QE of the copper cathode was measured at the beginning and also after few days experiment, which was shown in Fig.4. At the beginning,

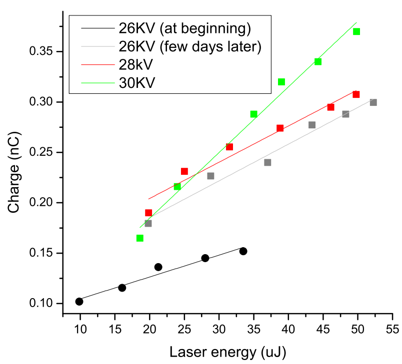

Figure 4: Beam charge as function of laser energy

the measured QE was 1.0×10^{-5}. From the theory and experiment results of reference[2], the QE should reach 1.0×10^{-4} for the copper cathode illuminated by 262 nm laser. Furthermore, it would be increased when high gradient acceleration field appearance on the surface of the cathode. Because of the oblique incidence at the cathode by using p-polarization laser, the QE should be further increased by several times[3]. The poor QE of the cathode must be induced by contamination of the surface. The reasons should be: the gun exposed to the atmosphere, and the low degree of the vacuum in the gun (3.0×10^{-6} Pa).

After few days experiment, the QE under the same RF power was increased to 1.73×10^{-5}. When the high voltage setting of the klystron were 28 KV and 30 KV, the QE were 2.1×10^{-5} and 3.08×10^{-5} respectively. During the experiment processing, the laser illuminate on the cathode. That partly played a role as laser cleaning[4] process, which is effective to improve the QE. So, a particular laser cleaning process should be arranged.

BAEM QUALITY

Transverse Emittance and Beam Profile

The transverse emittance is the most critical parameter of beam quality, multi-slits based emittance measurement[5] was applied in the photoinjector. The multislit parameters, such as slit width, slit separation, slit thickness and drift length, are crucial for emittance measurement[6]. Besides, the incidence position of the drive laser on the cathode is also critical for figuration of beamlet profile. If the position isn't accurate, the beam should deviate the collimated beam line and the emittance couldn't be measured. The 90 um width multi-slits spaced by 1 mm distance was inserted in the pipe at the distance of 55 cm downstream from the cathode, and the beamlet profile was measured at the distance of 105 cm downstream from the cathode. Due to the 90 um width of the slits (two wild), the slits in the beam image could not be resolved for a small beam to passing through them. It means that the beam with a small transverse emittance couldn't be measured. Fig.5 showed the false color image and its intensity graph of a beam passing through the vertical slits. A set of geometrical transverse

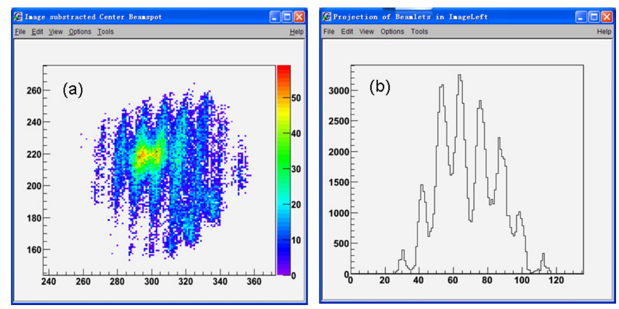

Figure 5: False color image and its intensity graph of a beam passing through the vertical slits

emittances, as function of relative acceleration phase, was measured at a low energy (around 1.4 MeV), which was shown in Fig.6. The difference between the two direction emittance was caused by the oblique incidence of the drive laser.

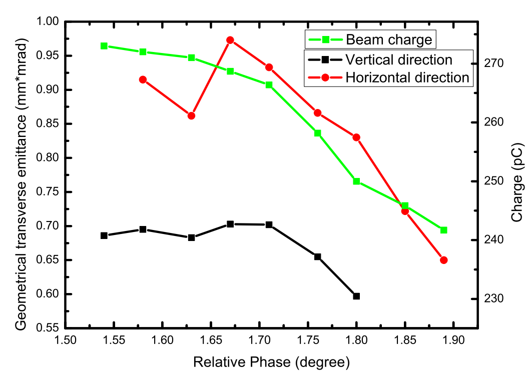

Figure 6: geometrical transverse emittance and beam charge as function of relative acceleration phase

The beam profile was imaged by YAG screen at the distance of 55 cm downstream from the cathode and collected by a camera. Fig.7 showed the measured and simulated rms vertical beam size at different field strength of the solenoid, which two were consistent. The beam profile could be focused to small size, which was about 0.6 mm.

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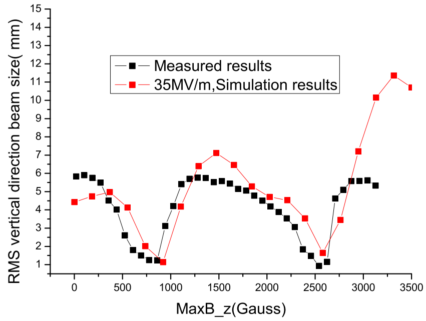

Figure 7: Measured and simulated rms beam size at vertical direction as function of field strength of the solenoid

Beam Charge

The charge of beam was measured by the Integrating Current Transformer (ICT). When the beam was first emitted, the temporal duration of ICT output pulse was stretched to 70 ns, which could be easily observed by oscilloscope. The charge could be calculated by integrating the signal, the interface was shown in Fig.8. Because of the poor QE and the low energy of the drive laser, the charge was not so high (as shown in Fig.6). Recently, the energy of the drive laser was improved, 1 nC charge beam have been obtained.

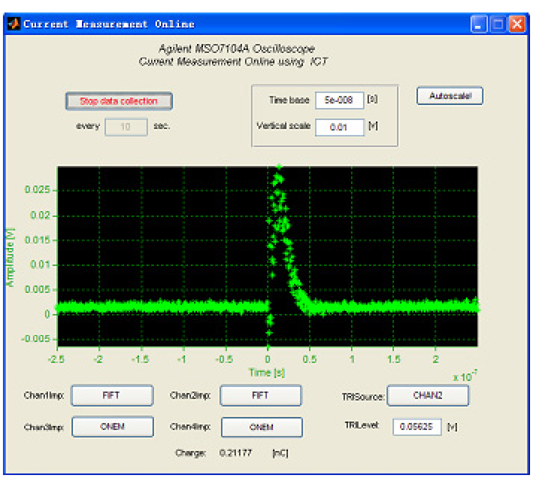

Figure 8: Interface of the beam charge measurement

Average Energy of the Beam

Recently, the energy analysis system installed into the beam line. $3.4MeV$ average energy was measured when the RF power was $7MW$. Because of the limited screen size of the YAG screen in the energy analysis system, the energy spread wasn't measured yet.

SUMMARY

A photoinjector has been installed in HLS, and the performance of the system was tested. The electron beam was acquired from the injector, the beam quality was measured. However, There performance of the beam diagnostic system need further improvement, Such as the transverse emittance measurement and the energy spread measurement. To measure the temporal distribution of the beam, scheme might be considered. Work should be planned to improve the vacuum of the system. Laser cleaning work also should be arranged to advance the QE of the cathode.

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