JAERI 200kV ELECTRON GUN WITH AN NEA-GaAs PHOTOCATHODE

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Abstract

The photocathode DC-gun with high average current, low beam emittance and long operational lifetime is considered to be indispensable for ERL-FEL. We have started the developmental program of a 200keV electron gun with the NEA-GaAs photocathode for the first time in JAERI. In order to long an NEA surface lifetime, JAERI 200kV electron gun system consists of a 200kV DC-gun chamber on extreme high vacuum condition and an NEA activation chamber with load-lock system. We report the goal of photocathode DC-gun R&D and the schedule of a developmental program.

INTRODUCTION

ERL-FEL and 4th generation ERL-LS with higher output and higher luminosity than the existing technology can be realized by the extraordinary high injector performance. Especially, electron source with higher current and lower beam emittance than existing is indispensable in order to improve the injector performance.

As such an electron source, it is thought that the GaAs type semiconductor photocathode with negative electron affinity surface (NEA-GaAs) is a strong candidate.

It is because maximum quantum efficiency of NEA-GaAs photocathode is 10% or more of quantum efficiency and NEA-GaAs photocathode has the advantage that initial emittance can be made small by choosing the wavelength near a band gap for excitation laser [1].

We started development of the NEA-GaAs photocathode electron gun which generates the electron beam with the structure of 1.3GHz of repetitions and 77pC/bunch (the average current of 100mA).

NEA SURFACE

Since the surface of NEA-GaAs photocathode forms a NEA state by Cs and O2 of angstrom order of thickness (or NF3), the surface before NEA activation must be pure and NEA surface is also very weak.

Therefore, the countermeasure to clean-surface before NEA activation and long life time of NEA surface is indispensable to the design of an NEA photocathode electron gun.

The surface of the photocathode exposed into the atmosphere before the introduction to a vacuum chamber is being worn with impurities, such as an oxide and carbide.

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When the photocathode electron gun introduces photocathode out of the atmosphere, it needs surface cleaning such as annealing, atomic hydrogen cleaning [2] in order to remove impurities in the surface.

The following cause can be considered for degradation of NEA surface; the adsorption phenomenon to the surface of remains gas in vacuum chamber, and ion back bombardment due to field emission dark current between anode- and cathode-electrode.

The former degradation phenomenon can be suppressed by extra high vacuum chamber in order to suppression of the adsorption phenomenon.

It is thought that the field emission dark current is dependent not only on the fall of electrode work function due to the adsorption of caesium, but also the characteristic of the electrode material.

The following conditions are needed for good NEA surface.

- The photocathode surface before NEA surface activation is clean.
- The vacuum of chamber should be extra high vacuum in order to suppress the remains gas in chamber.
- In order to suppress of field dark current, it is choosing the electrode with the sufficient characteristic, and prevent caesium adsorption to the electrode.

DESIGN AND COMPONENTS OF JAERI PHOTOCATHODE GUN

As an electron gun which realizes the NEA surface of a long lifetime, development of the electron gun which combined MBE apparatus with NEA activation system and 200kV electron gun chamber under extreme high vacuum by the load-lock system was started.

JAERI photocathode gun has the performance of fabrication of photocathode in vacuum chamber by using MBE apparatus. That is, it means that surface cleaning process (such as anneal and atomic hydrogen cleaning) and the exchange of photocathode become unnecessary. It is the first photocathode gun which has the photocathode production system in the world.

Figure 1 show the design of JAERI photocathode gun which consists of three components (MBE chamber, gun chamber and mode-lock laser system).

The following describes a design and parts about each component.

MBE apparatus with NEA activation system

JAERI photocathode gun use MBE apparatus (EV-10: eiko-engineering co.) as an NEA activation chamber.

This main chamber can realize ultra high vacuum of a 10^{-8}Pa order by using an ion pump (500 l/s) and titanium sublimation pump (400 l/s) after 200 degree baking of 100 hours by a rotary pump and a turbo pump. This degree of vacuum fulfils the necessary condition for NEA surface formation. In the main chamber, it has the liquid nitrogen shroud, and a still better vacuum can be expected by introducing liquid nitrogen.

The semiconductor substrate on which is carried out photocathode growth is inserted from gate-bulb-A in Figure 1, and it introduces to a main chamber after a preliminary pump. In a main chamber, photocathode growth and NEA surface activation by vacuum evaporation of caesium and oxygen is carried out.

The photocathode with NEA-activated surface is transported to gun chamber with a transfer rod, and it equips with it from behind cathode electrode.

The design of gun chamber

In order to realize extreme high vacuum, it is necessary to make gun chamber capacity small. For this reason, cathode- and anode- electrode are designed small, a size of photocathode is made into the sufficiently larger diameter of 5mm than the excitation laser diameter of 2mm, and the gap between cathode- and anode- electrode is 30-50mm, and anode hole-size is 20mm.

About the vacuum of gun chamber, after baking of 200 degrees, the combination of an nonevaporating type getter pump and an ion pump aims at realization of a extra high vacuum (10^{-10}Pa order).

Anode- and cathode-electrode are under design using beam simulation codes, such as EGUN, PARMERA. As the material of electrode, Ti and Mo are used. It is thought that these materials have the advantage which suppresses the field emission dark current from SUS or Cu in recent years [3].

A high-voltage power supply uses 200kV power supply (PK200N18: GLASSMAN HIGH VOLTAGE INC.) with the maximum voltage of 200kV and the maximum current of 18mA.

Mode-lock laser

As excitation laser for photocathode, the mode lock Ti: Sapphire laser (TSUNAMI: Spectra Physics) of 83MHz of repetitions is used. Laser is irradiated from anode back to photocathode through an anode hole.

TSUNAMI has a maximum of 500mW output on the wavelength of 790nm. When it is 10% of quantum efficiency of photocathode, a maximum current of 16mA will be obtained by laser excitation with a wavelength of 790nm.

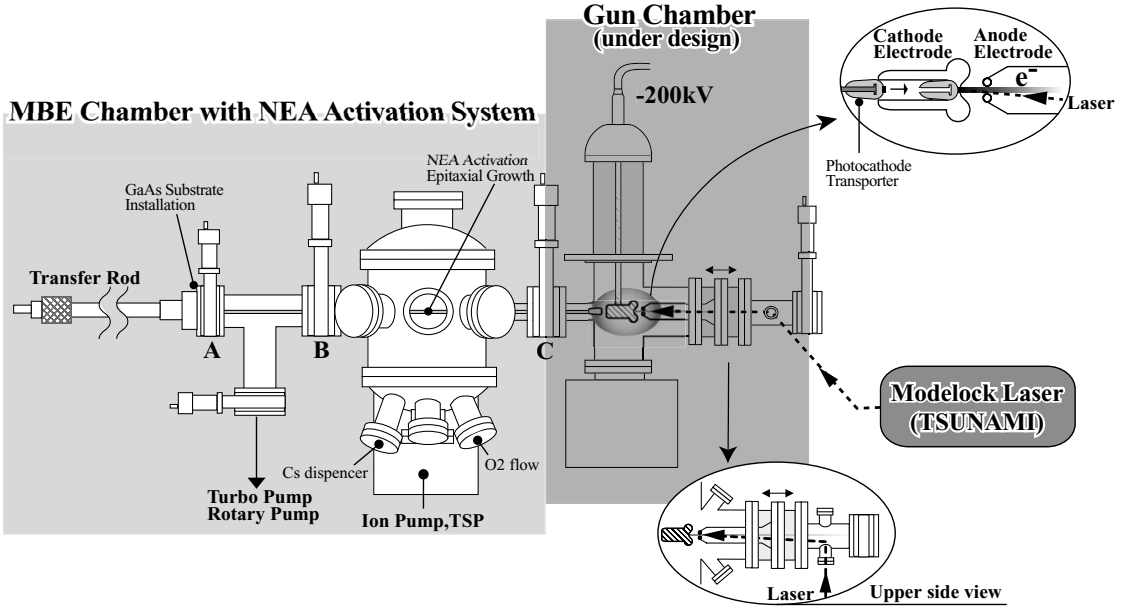

Figure 1: The design of JAERI photocathode gun.

The present condition and a work schedule

We consider the present target of JAERI photocathode gun as 200keV electron beam generation of 77 pC/bunch (average current of 6.2mA) and 83MHz repetition, and show the schedule of a developmental program in Table 1.

We are performing the design of photocathode holder, electrode (anode and cathode) and gun chamber, and the vacuum examination of MBE apparatus.

We are considering development of the beam evaluation system such as measurement of the bunch width and emittance as a next subject. Furthermore, by using MBE apparatus, development of the new type photocathode which has high quantum efficiency and the strong NEA surface compared with the conventional NEA photocathode is also planned.

REFERENCES

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Table 1: The schedule of a developmental program