A Prototype of RF Photogun with GaAs Photocathode for Injector of VEPP-5

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Abstract

A prototype of RF photogun with GaAs photocathode is designed and produced for injector of VEPP-5 complex at Novosibirsk. The nominal parameters of a prototype are: operation frequency - 2797 MHz, bunch energy around 500 keV, laser pulse duration - 50 ps (FWHM), peak current up to 160 A. The design of this source is made in order to use all possible advantages of RF photogun. At first, a production of originally short and intensive electron bunch, it helps to avoid a subharmonic buncher system and make an electron source very compact. Second, an operation of photogun at the linac frequency using a small part of power of existing RF source for linac. Third, the possibility to produce an electron bunch with high degree of spin polarization. The GaAs photocathode is chosen as a most effective emitter of polarized electrons. The main goal of this prototype is to demonstrate a possibility of a long time operation for GaAs photocathode in a strong RF field of accelerating cavity. The results of the GaAs photocathode tests in the DC gun at high current density level and short bunch duration are also presented.

1 INTRODUCTION

The injector for VEPP-5 complex at Novosibirsk, presently under construction, contains two linacs. The first is 300 MeV electron linac for positron production, the second rises up the energy of electrons and positrons to the level of dumping ring (510 MeV). In order to avoid a significant distortion of operating regime for 510 MeV linac, while it accelerates electrons, one should use an additional electron source. This source should produce a short intensive electron bunch at the average energy of positrons after convertor. From such a source 10^{11} electrons per bunch at the energy of 3 MeV, with 20 ps (FWHM) bunch duration and 1 Hz repetition rate are required. It corresponds to 480 A/cm^2 peak current density for 1 cm cathode diameter.

A source, based on a DC gun, requires a subharmonic buncher system, which takes a lot of space and can't be fit in resent accelerator hall. A laser driven RF gun was chosen as a compact solution for electron source with parameters specified above .

Nowadays GaAs polarized electron source is best available, because it has many intrinsic advantages in performance of intensity, quantum efficiency, degree of polarization and resolution time compared with other types of polarized electron sources. Combining all these advantages with a significant interest to polarized electron beams, which comes from a high energy physics, we have chosen a GaAs photocathode as a most attractive emitter for our RF gun project. Unfortunately up to now there is no any experimental confirmation of a long time GaAs photocathode operation in high gradient accelerating cavity. And now this fact is the main obstacle on the way of using GaAs photocathode in RF photogun.

2 THE GOAL OF A PROTOTYPE.

It is possible to fix at least three problems connected with GaAs photocathode inside the high gradient accelerating cavity.

1) Suitable vacuum conditions for activated photocathode surface inside accelerating cavity.

2) The possibility to operate with the GaAs photocathode at high peak current density corresponding to RF gun.

3) The possibility to have a short response time of the photocathode compared with RF period. It helps to avoid the back electron bombardment of the cathode surface and maintain a good original quality of electron bunch.

In order to investigate two last problems a specially GaAs electron source for a short intensive electron bunch production is made by our group [1]. This source is based on high gradient DC electron gun with a photocathode irradiated by short Nd:YLF (524 nm) laser pulse. The installation is supplied by the special electron bunch length measurement system [2]. We use in our experiment commercially available

450 μm thick GaAs crystal, p-doped by Zn $10^{19}\ cm^{-3}$, with surface orientation (100), produced by "MCP Wafer Technology Limited". The GaAs photocathode is prepared in Negative Electron Affinity (NEA) condition by depositing Cs and O_2 on its surface, following the standard procedure [3]. The result of our experiment is 3.5 hours photocathode lifetime in the DC gun with 80 kV/cm accelerating gradient, $3 \cdot 10^{-10}$ torr vacuum pressure, for following electron bunch parameters: 50 A/cm^2 - peak current density, 200 ps (FWHM) electron bunch duration and 1 Hz repetition rate. The value of electric field on the cathode in our gun is very close to the practical limit for DC guns. As a result a further increasing of peak current density is possible only in full scale RF gun experiment.

There are two reasons for short time response operation of GaAs photocathode in RF gun. The first is an elimination of returned electrons bombardment of the cathode surface. This bombardment can destroy an activating layer and decrease the cathode lifetime. In addition returned electrons initiate the uncontrolled secondary electron emission from GaAs. The second reason is the bunch energy spread and emittance minimizing. The response time τ of GaAs photocathode with NEA is determined by the diffusion time of photoelectrons thermolized at the bottom of conduction band and can be easily estimated by the formula:

$$\tau = \frac{d^2}{D}, \quad (1)$$

where d is the minimum of two values: absorption length of photons and crystal thickness, D is a diffusion coefficient for photoelectrons in conduction band. For thick GaAs photocathode (the photon absorption length is smaller then the thickness of the crystal) with NEA surface the response time is usually in the range of few hundred ps. This time is comparable to S-band RF period. There are at least two ways to diminish the response time. The first is connected, according to (1), with decreasing of photocathode thickness. Second one corresponds to a photocathode operation at small Positive Electron Affinity (PEA), when mainly nonthermolized photoelectrons can be emitted from the cathode. In this case the response time is determined by the photoelectrons thermolizing time and lies in the range of few ps. The results of our bunch length measurements [3] also can be explained in such a way. We found [3] that the electron bunch lengthening in comparison with the laser pulse duration approximately 10 times less, then (1) predicts. The operation of GaAs photocathode at a slightly positive electron affinity probably will have some advantages, especially for RF gun application:

- originally short response time,
- suppression of secondary electron emission,
- better spin polarization of nonthermolized electrons, forming the main part of emitting current.

The cost of these advantages is the small Quantum Efficiency (QE) $10^{-3} \div 10^{-4}$, but it it's still reasonable and comparable to QE of a thing strained GaAs photocathode designed for high degree of spin polarization [4, 5].

3 THE DESCRIPTION OF THE PROTOTYPE

All mentioned above inspired us to design and construct the prototype of RF photogun with GaAs photocathode. At first step we use the same cathode type like in our previous experiments. Fig. 1 shows the scheme of the prototype, which consists of working and activation chambers. It helps to avoid Cs covering of accelerating cavity and vacuum perturbation in activation chamber during RF processing of the cavity. The cathode assembly is fixed on the manipulator and can be moved from the cavity to the activation position. The cathode part also includes the thermo-couple and heater for cathode surface regeneration. We use the cesium and oxygen dispensers for photocathode activation. It helps to make the complete computer control of activation process.

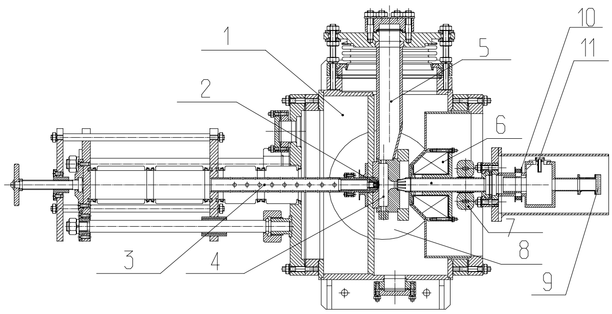

Figure 1: The scheme of RF gun prototype. 1 - activation chamber, 2 - photocathode assembly, 3 - manipulator, 4 - accelerating cavity, 5 - waveguide, 6 - focusing lens, 7 - transverse corrector, 8 - working chamber, 9 - vacuum window for laser beam, 10 - ceramic insulator, 11 - the cavity for bunch length measurement.

The electron bunch diagnostic system contains a passive cavity for bunch length measurements. This cavity simultaneously acts as a Faraday Cup to measure the bunch charge. The basic parameters of prototype are presented in the following table:

The main frequency	2797 MHz
Quality factor	11000
Shunt impedance	920 $k\Omega$
Overvoltage coefficient	1,23
Photocathode diameter	8 mm

The accelerating cavity is placed inside the working chamber and can be easily changed to another one with different shape.

Now the prototype is passing through the vacuum, technological and RF tests. The vacuum in prototype is $6 \cdot 10^{-12}$

torr. We plan to start the first experiments this year.

4 REFERENCES

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