FORMATION OF BUNCHED ELECTRON BEAM AT THE ELECTRON COOLER OF CSRm*

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Abstract

The motivation for formation of bunched electron beam at the electron cooler of CSRm is based on the three requirements. Firstly, the high energy electron cooling, especially, the ion beam with TeV energy, the bunched electron beam for cooling would be easier than the DC operating mode. Secondly, the electric field induced by the intensity modulated electron beam will be used for the suppression of instability developed in the high intensity ion beam after accumulation with the help of electron cooling, Thirdly, the electron beam was required to turn on and off in the different period of the atomic physics experiments. Some initial design and consideration were presented in this paper. And also the current situation and condition of CSRm electron cooler were described here. An off-line testbench will be established in the laboratory, and the test and the optimization will be explored in this experimentation. The validity of this system will be verified in the near future. The procedure of the modulation on the voltage of control electrode in the electron gun of the CSRm cooler was discussed. The scheme of off-line measurement was devised according to the progress.

INTRODUCTION

The electron coolers of HIRFL-CSR have operated for ten years from 2005. The performance and upgrade was reported in the paper [1]. The latest experiments and results can be found in the report [2]. During the routine operation, especially in the case of higher accumulated ion beam intensity, the instability of ion beam was observed [3, 4], some information can be found in the references [5]. It is an essential problem to find the way to suppress the instability in order to obtain the higher accumulated and stored ion beam in HIRFL-CSR.

As the described in reference [6], the conventional way to suppress the instability was adopting the feedback system. From the report [7] the feedback system was helpful to increase the accumulated ion beam intensity, the action on the instability was not clear. Another solution was proposed in the paper [8], in order to avoid the overcooling, additional heating on the electron beam was used to suppress the instability. The results were presented in the reference [9].

A more efficient way [10] to suppress the instability was increasing the energy spread with the help of modulation.

A new method was proposed in this paper, the idea came from the electron beam as 3d kicker for stochastic cooling [11,12]. The intensity of the electron beam was modulated transversely and longitudinally. The distribution of electron became asymmetrical and inhomogenous, as a result, the electron beam becomes the electron bunches. The space charge field between the bunches acts as the kicking on the ion beam. These actions can be used to suppress the instability of ion beam.

The electrostatic field produced by the space charge of electron beam in the cooler by means of modulation on the voltage of control electrode in the electron gun will act as a travelling wave in the cooling section. This action will be attempted to suppress the ion beam instability in the presence of electron cooling device.

Another application of this work can be used to demonstrate the cooling effects of bunched electron beam [13,14].

SOME CONSIDERATIONS

Generally, the bunched electron beam was easily produced by the pulse electron gun. Unfortunately, the electron gun in the CSR coolers was direct current. On the other hand, the limitations come from the normal routine operation and heavy load beamtime in CSR.

From the technical point of view, the cathode of electron gun of the electron cooler was thermic cathode. It was continuously heated during the operation. The configuration of electrodes in the electron gun presents capacitive feature. The charge and discharge rate of the electron gun should be taken into account. Due to lack of the diagnostic instruments in the electron cooler, the measurement of the bunch should be solved offline.

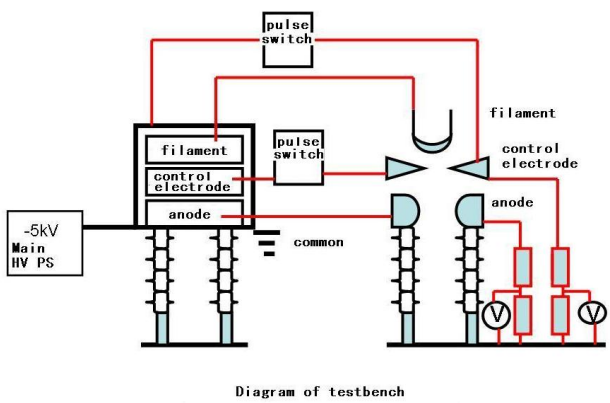

Figure 1: Layout of offline testbench.

A simplified solution was derived in this plan. The DC voltage of control electrode in the gun which was used to extraction of electron from the surface of cathode will be replaced by a new bipolar pulse power supply, in additional, a fast switch among the positive, negative and

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ground outputs will adopt to charge and discharge for the control electrode as illustrated in the Fig. 1. In this case, the electron pulse beam will formed in the electron cooler.

In the past year, a model of electron gun was designed and fabricated. The waveform of voltage at the control electrode was roughly explored. The scenario of the test bench was carefully considered.

The real waveform of voltage at the control electrode, the response times of gun and power supply will be measured offline in the test bench this year. The feasibility, reliability and stability of this system will be tested and validated.

A new power supply for control electrode will be installed into the electron cooler system, the output of this PS will be connected the computer. The voltage output parameters such as shape of wave, frequency, and the interval of pulses will be controlled by this computer. The cooling force and cooling time, accumulation process, the instability suppression will be investigated in the different bunched electron beam. Demonstration of electron cooling by the bunched electron beam will be performed in the near future.

The electron beam will be turn on and off optionally in the different period according to the requirement of atomic physics experiment situation.

Limitation

The cathode of CSR electron cooler [15,16] was thermal dispenser cathode, it was heated continuously, there are electron cloud existing in the surface of the cathode, once an enough strong electric field was established, the electron will be extracted from the surface of the cathode, forming the electron beam. On the other hand, when the extracting electric field disappeared, namely extracting was suppression, the electron beam was vanished, the electron beam was turn off. When the voltage on the control electrode of the gun was less than a proper value, maybe negative value, the electron beam will be turn off. In this case, if the voltage of the control electrode changes from positive one to negative one, the electron beam will be switched off as demonstrated in the Fig. 2.

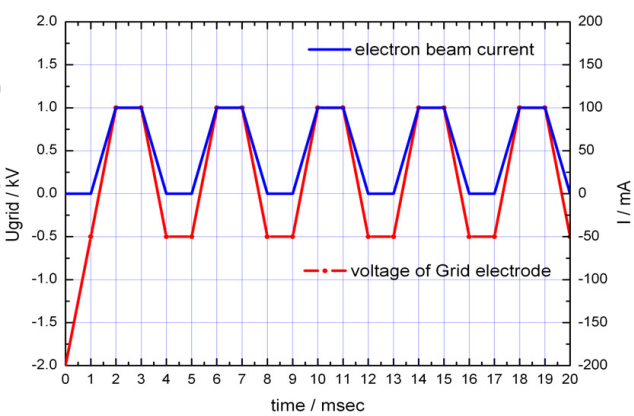

Figure 2: Waveform of electron beam current and the voltage on the control electrode of the gun.

Plan and Procedure

The scheme for the DC operation mode converts into pulse mode in the existing facility, specially the waveform of voltage on the control electrode of the electron gun varying with time was studied carefully. From the point of technical view, one possible solution was adopted directly the pulse HV power supply for the control electrode. The other alterative optional way was described as the following way. Add a pulse switch between the control electrode and the common terminal. A special twigger for switch on and off the electron beam was adopted during atomic experiments as shown in the Fig. 3. The modulation frequency will be an important parameter, it will be set as the time dimension such as the injection interval of ion beam, or the revolution period of the ion beam in the ring, or the expected cooling time.

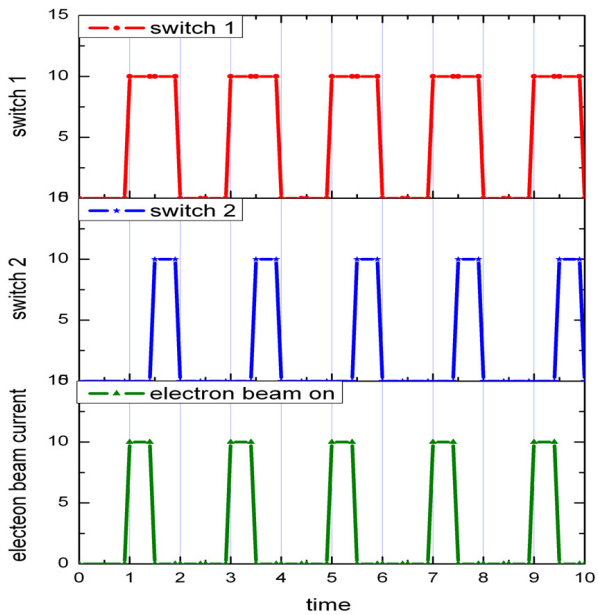

Figure 3: Two switches alternately act on the control electrode as chopper to get the different pulse length and interval.

The parameters of the pulse electron beam such as pulse width, interval of pulses, and the longitudinal and transverse distribution of pulse are the essential one. The offline measurement of these parameters will be performed in the existing electron cooler.

Due to the different electron kinetic energy, the longitudinal velocity of electron beam will be different in the experiments, in the other hand, in order to cool different ion beam, the parameters of the electron pulse should vary according to the essential situation. By the way, the length of the cooling section was fixed, the relation between the kinetic energy of electron beam and the modulation frequency should be explored clearly.

Toroid

The electron pulse propagates through the toroid in the cooler. Because of the electron beam transverse dimension and different path length in the toroid, the linear ve-

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locity, namely the kinetic energy of electron beam are the same before entre the toroid. But the path lengths are different in the toroid, the electron pulse will slightly incline, as a result, the space between the pulses will become smaller. Another point was the precession motion of the whole electron beam due to the transverse electric field and the longitudinal magnetic field, the electron beam was rotated slowly around the beam axis, the whole electron beam has a same angular velocity, this effect will influence on the spatial distribution of the pulse electron beam. The influence of the different modulation frequency on the length of the electron pulse and interval in the case of fixed electron energy and the influence of the same modulation frequency on the length of the electron pulse and interval in the case of fixed electron energy should be taken into account.

Diagnostics

The most important point was that the judgement criterion should be found to realize the situation of the electron beam after modulation, the electron beam becomes the separated pulse, or it becomes fluctuation on the base of the DC flow as shown in the Fig. 4.

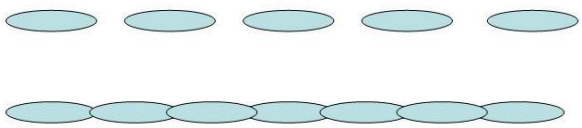

Figure 4: Schematic diagram of the electron beam distribution.

Offline Test

A set of test system was established in the laboratory. A prototype of the electron gun was fabricated. And a new HV power supplies were contrived. The modulation system was conceived. The measurement system of voltage on the control electrode was planned and prepared. The control and trigger system were taken into account. Due to the control electron power supply was placed on the main 35kV HV power supply, and the signals from this part should be insulated and transferred by the optical fibre. The data acquisition system was programmed.

CONCLUSION

Based on the offline experiments results, the proper modulation system of control electrode in the gun will be discovered to satisfy the requirements for produce the pulsed bunch electron beam. The proved modulation system will be migrated to the electron cooler system of CSRm. The real bunched electron beam will be formed in the cooler. The parameters such as length of bunch, interval of the bunches and the distribution of bunch will be measured with the help of diagnostic instruments in the cooler. The action and effect of this system will be tested in the presence of ion beam. The function of this system will be applied in the following aspects:

- suppress the instability of ion beam,
- increase the maximum accumulated ion beam intensity,
- improve the beam stability after accumulation,
- decrease the cooling time,
- verify the results of bunched electron beam cooling ability in the lower energy range.

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