STATUS OF HIGH INTENSITY POLARIZED ELECTRON GUN PROJECT AT MIT-BATES

E. TSENTALOVICH

MIT-Bates Linear Accelerator Center, 21 Manning Rd, Middleton, MA, USA

eRHIC ring-linac version requires a polarized electron gun with extremely high intensity. MIT-Bates investigates the possibility to build such a gun. The design implements separate preparation chamber, load lock, ring-shaped beam and active cathode cooling. Currently, the gun chamber has been built and undergoes vacuum and High Voltage tests. The design of the preparation chamber is completed. The conceptual design of the beam line is completed as well. The beam line includes two dipole magnets, several focusing solenoids, several sets of steering coils and a beam dump. For the high intensity beam, a biased beam dump will be used to minimize outgasing.

1. Introduction

The need for a high-energy, high-luminosity electron-ion collider (IOC) has been discussed intensively over the past few years. The most promising and advanced proposals use the RHIC complex ion ring in combination with an electron accelerator. The most attractive version (linac-ring) requires polarized electron gun with extremely high intensity (average current of about 50 mA).

Existing state-of-the-art guns produce average current of several hundreds μA. Groups at JLAB [1] and Mainz [2] achieved average current of several mA, but with rather poor lifetime. The most obvious reason for the short lifetime is the overheating of the cathode. A laser beam with a very significant laser power has to be used for the photo injection, and all existing guns have very poor thermal connection to the cathode.

However the most challenging problem for the lifetime is produced by ion back bombardment. Electron beam ionizes the molecules of the residuum gases in the cathode-anode gap, ions accelerate toward the cathode and damage it on the impact. Tremendous efforts have been applied to improve the vacuum inside the guns, but the ion bombardment remains the main limiting factor in gun intensity.

It was shown that the ion damage depends on the size of the active area of the photocathode. With large photocathodes the damage is spread over a large area and allows for the longer lifetime. It was also demonstrated [3, 4] that the ions tend to damage the central area of the cathodes mostly due to the focusing properties of the anode.

MIT-Bates investigates the possibility to build a polarized electron gun with very high intensity [4]. A large area cathode will be used in the gun. The new feature of the installation will be annular shape of the beam. A ring-shaped laser beam will be formed with an axicon lens. The central area of the cathode, where most of the damage is concentrated will not be used at all. The active cathode cooling will be implemented.

2. Gun Chamber

The gun implements so-called "inverse geometry". There is no outside ceramics, the gun chamber is manufactured from a stainless steel (Figure 1). The cathode assembly is suspended on three long ceramic tubes. Two of these tubes serve as pipes to deliver cooling agent to and from the cathode. A Fluorinert is used as a cooling agent. This liquid has virtually zero conductivity and very good electrical strength. The third tube serves as a conduit for HV cable. The working voltage of the cathode is 120 kV.

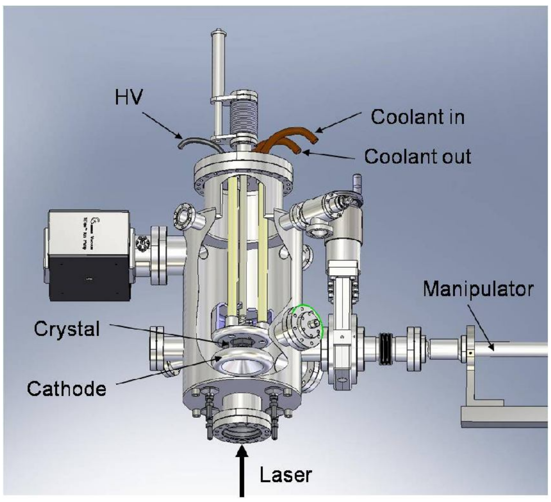

Figure 1. Gun chamber.

Proc. 14th International Workshop on Polarized Sources, Targets and Polarimetry (PSTP 2011) 12-16 September 2011, St.Petersburg, Russia
eds. K. Grigoryev, P. Kravtsov and A. Vasilyev, ISBN 978-5-86763-282-3

The GaAs crystal is mounted on a Molybdenum puck with a Tantalum cup pressing it to the puck. An indium foil is inserted between the puck and the crystal. During the first activation the foil melts and solders the crystal to the puck providing very good thermal connection. An additional ceramic rod attached to a Linear Transfer Mechanism (LTM) at the top of the chambers moves the cathode in vertical direction allowing to open a gap between the cathode and the heat exchanger and insert the puck with a crystal through the side port using a magnetic-coupled manipulator. Conical shape of the interface between the puck and heat exchanger insures self-centering and good thermal connection (see Figure 2).

The quality of the thermal connections were tested by attaching a thermocouple to the Molybdenum puck and applying laser power to the crystal. Varying the temperature of the cooling agent, we were able to maintain the puck temperature at the room level with as much as 34 W of laser power reaching the crystal.

The gun chamber is pumped by a 100 l/s ion pump and five 400 l/s NEGs. The chamber walls are made from thin (3 mm) stainless steel to reduce the wall outgasing. The main body and all large metal parts were prebaked at 400 °C. After that the chamber was fully assembled and baked at 200 °C. The resulting vacuum is in low 11th scale, dominated by hydrogen.

The cathode assembly is surrounded by a polished field shield to prevent a field emission. The gun was processed to 150 kV. After the processing there is no any signs of the activity (measurable dark current or vacuum excursions) at the working voltage of 120 kV.

The anode is disconnected from the ground potential and will be biased to 1 kV in order to reflect the ions produced outside the cathode-anode gap and trapped in the electron beam.

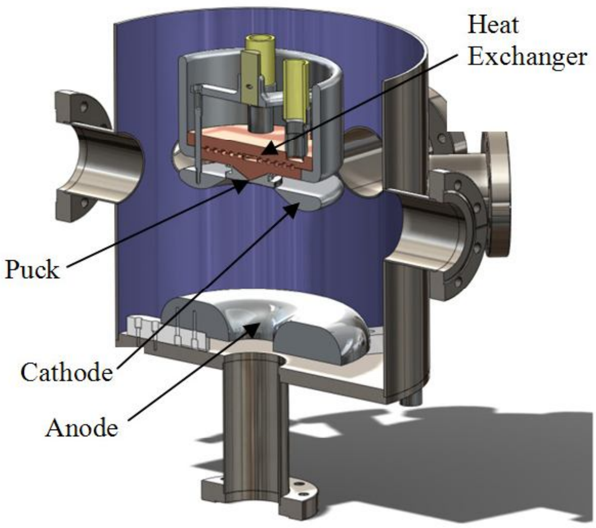

Figure 2. Anode and cathode assembly.

3. Preparation Chamber and Load Lock

The design of the preparation chamber and the load lock has been completed. The pucks equipped with crystals will be placed into the load lock. The load lock rack can hold up to four pucks. After a good vacuum conditions are achieved in the load lock, the pucks could be moved into the preparation chamber with a magnetic-coupled manipulator. The preparation chamber carousel can hold up to four pucks. The preparation chamber has two heat-cleaning stations and two activation stations. Each heat cleaning station is equipped with a PBN heater, thermocouple for the reference measurements and a view port for the pyrometer. The activation station are equipped with cooling rods, Cesium dispensers, NF3 leak valve and windows for laser light. The cooling rods could be biased to apply negative voltage to the crystals.

Activated crystals will be moved into the gun chamber using a similar manipulator.

Load lock, preparation chamber and the gun chamber are all equipped with view ports to control the vacuum manipulation and halogen bulbs inside for illumination.

4. Beam Line

The beam line consists of the two 90° dipole magnets, several focusing solenoids, steering coils and a beam dump. The beam propagation in the beam line was carefully modeled. It is extremely important to minimize the beam losses near the gun. At such high intensity even 10^{-6} losses could be fatal for the crystal. The simulations indicated that our losses will be much smaller than 10^{-6} up to the second dipole. A special attention was given to the "extreme" rays - electrons produced at the very edge of the crystal. Although the simulation suggested that even these electrons will not hit the walls, it is unclear how accurately the calculations include the influence of the Tantalum cup which produces a tiny step on the flat surface. In order to minimize the risk produced by the "extreme" electrons, the outer 1 mm of the crystal will be screened during the activation, so Quantum Efficiency of this area will be very low.

Proc. 14th International Workshop on Polarized Sources, Targets and Polarimetry (PSTP 2011) 12-16 September 2011, St.Petersburg, Russia
eds. K. Grigoryev, P. Kravtsov and A. Vasilyev, ISBN 978-5-86763-282-3

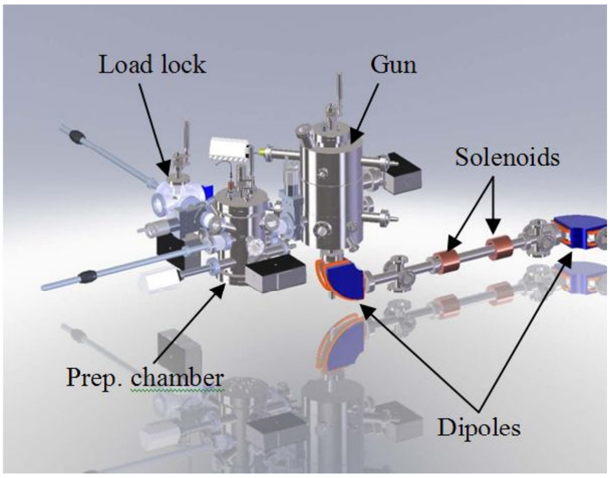

Figure 3. General view of the installation.

The most demanding part of the beam line is the beam dump. The 50 mA electron beam with the energy of 120 kV produces 6 kW of heating power. It is technically challenging (but not impossible) to remove this amount of heat in the water-cooled beam dump. However, when the beam of such intensity hits the dump, the outgasing will be so great, that it will ruin the UHV conditions in the gun itself. Large apertures of the beam line, designed to reduce the beam scrape off in the gun vicinity, provide too high conductance between the gun and the beam dump. These conditions are specific for these tests, they will not affect the gun performance in the accelerator where the gun is separated from the beam dump by a very long beam line. Still, it needs to be addressed.

We plan to use the biased beam dump. With the dump biased to 119 kV the beam energy drops to 1 kV in the dump, and deposited power drops by 2 orders of magnitude. Instead of using a second 120 kV power supply, the "CW energy recovery" scheme could be used. In this scheme an additional isolated 1 kV power supply is inserted between the gun cathode and the beam dump. Such scheme reduces significantly the current requirements to the main power supply since most of the current circulates in the circuit powered by small power supply.

Biased beam dump solves the problem of the outgasing in the dump, but it is a complicated and cumbersome device. The dump should be supported in vacuum by ceramic stands long enough to hold 120 kV voltage. The design of the dump should be smooth enough to prevent the electrical breakdowns. Several tens of Watts deposited in the dump by the electron beam need to be removed, and with High Voltage involved, the Fluorinert cooling agent has to be used again. Additionally, it is virtually impossible to combine the biased beam dump with beam diagnostic.

We plan to build two beam dumps. The first one is unbiased and it will be used in the tuning phase of the tests. It will be equipped with a flip target and current monitor, and it will be used with low beam current only. Once the beam is established, the biased dump will be installed.

References

1. M. Poulker *et al*. Proc. of 12th Intern. PST Workshop, Upton, AIP Conf. Proc. **1149**. 2007. P. 73.
2. R. Barday and K. Aulenbacher. Proc. of 17th Spin Ph. Symp., Kyoto, AIP Conf. Proc. **915**. 2006. P. 1019.
3. J. Grames *et al*. Proc. of 12th Intern. PST Workshop, Upton, AIP Conf. Proc. **980**. 2007. P. 110.
4. E. Tsentalovich. Proc. of 18th Spin Ph. Symp., Charlottesville, AIP Conf. Proc. **1149**. 2009. P. 997.

Proc. 14th International Workshop on Polarized Sources, Targets and Polarimetry (PSTP 2011) 12-16 September 2011, St.Petersburg, Russia
eds. K. Grigoryev, P. Kravtsov and A. Vasilyev, ISBN 978-5-86763-282-3