AN EXPERIMENT TO TEST THE VIABILITY OF A GALLIUM-ARSENIDE CATHODE IN A SRF ELECTRON GUN*

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Abstract

Strained gallium arsenide cathodes are used in electron guns for the production of polarized electrons. In order to have a sufficient quantum efficiency lifetime of the cathode the vacuum in the gun must be 10^{-11} Torr or better, so that the cathode is not destroyed by ion back bombardment or through contamination with residual gases. All successful polarized guns are DC guns, because such vacuum levels can not be obtained in normal conducting RF guns. A superconductive RF gun may provide a sufficient vacuum level due to cryo-pumping of the cavity walls. We report on the progress of our experiment to test such a gun with normal GaAs-Cs crystals.

INTRODUCTION

Cathodes made from GaAs, which allow the production of polarized electron beams, have a limited quantum efficiency and life time. They degrade through three effects: 1) the deposition of residual gas on the surface, which acts as a getter, 2) the bombardment with ions created by the collision of electrons in the generated beam with residual gas and 3) bombardment with electrons originating from dark currents.

DC guns typically have vacuum pressure better than 10^{-11} torr, compared to 10^{-9} torr in a normal conducting RF gun. This minimizes the first two causes of degradation, which are proportional to the vacuum pressure. Because of this all successful existing guns for polarized electrons are DC guns, even though RF guns can produce higher brightness electron beam than DC guns without the technical difficulty of holding off voltages higher than 100 kV. The third reason exists only in RF guns, where electrons emitted from the cavity walls or the cathode itself can be accelerated during the negative RF phase to impact the cathode with high energy.

Experiments at BINP Novosibirsk in the late 1990s demonstrated [1,2] that the quantum efficiency in a pulsed normal-conducting 2.8 GHz RF gun was destroyed in as little as 10 laser pulses. We are now working to repeat this experiment with modifications that we hope will give a positive result. First, instead of a normal-conducting gun we use a superconducting gun. Since the RF fields will not heat up the cavity walls we avoid out-gassing. In fact, the cold walls will act as a cryogenic pump and we expect the vacuum pressure to be better that 10^{-11} Torr. Secondly, we will use a lower frequency half cell gun (1.3 GHz) which will help to avoid electron multipacting involving the cathode

GaAs cathodes must be prepared for use through the following process. First, the GaAs wafer is first heated to up to 550° C for cleaning. Then layers of Cesium and oxygen are deposited on the surface to achieve coverage of 0.6 monolayer of Cesium resulting in a negative electron affinity (NEA) emission surface. The measure for this is the quantum efficiency of the cathode, which is monitored during the deposition process. This is done in a preparation chamber separate from the gun. The cathode is then moved into the gun for use.

The partial pressure requirement for elements other than Cesiums and Oxygen is 10^{-11} Torr or better. In DC guns the preparation chamber and gun are integrated, so that the vacuum is not breached during the transfer.

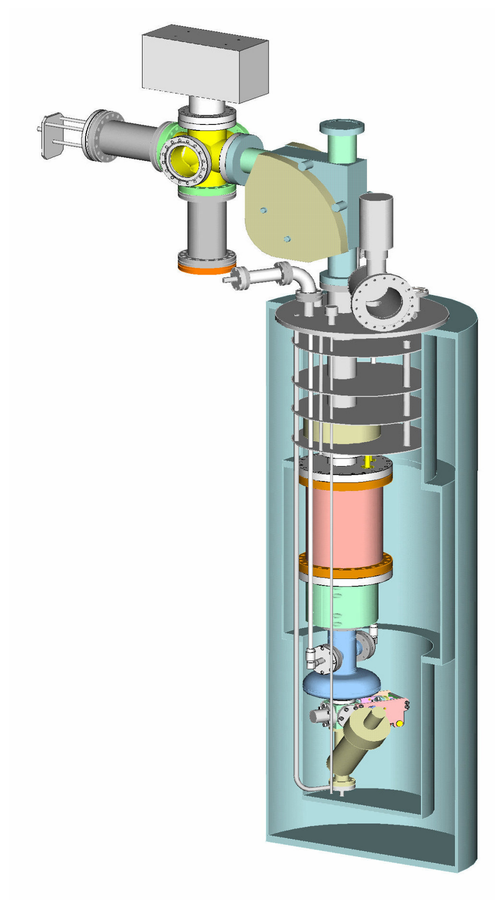

Figure 1: Layout of the accelerator.

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THE ELECTRON GUN

For a superconducting gun this approach is not practical. Our experimental setup therefore has two parts. The first is the electron accelerator, where the gun is placed in a 100 litre cryostat. The layout is shown in figure 1. The gun points upwards, so that the beam exits the cryostat on the top and is bent by a 90 degree dipole (shown in figure 2) into a Faraday cup. A window on top of the dipole is used to introduce the laser. The polarization of the beam is not measured, since we are only interested in the decay of the quantum efficiency in the RF gun. In order to measure the beam current the gun is electrically isolated from the rest of the apparatus with a ceramic break, which is protected from mechanical stress by a G10 sleeve. In order to maintain 10^{-11} Torr vacuum while at room temperature, a NEG pump is positioned close to the gun as shown in orange in figure 1.

Figure 2: Gun assembly as used in the first cool down test. The gun is mounted upside down to prevent particulate from falling into the gun.

Another NEG pump and an ion pump are placed next to the Faraday cup, to minimize the vacuum degradation due to the impact of the beam in the Faraday cup. A set of four aluminium baffles insulates the liquid helium from the top plate and a high temperature superconducting focusing solenoid is placed between the lowest baffles, where a temperature of 17 K was measured.

THE PREPARATION CHAMBER

The preparation chamber consists of a spherical vacuum chamber attached to a 16000 L/min ion pump with TSP, with an effective pumping speed of 1000 L/min.

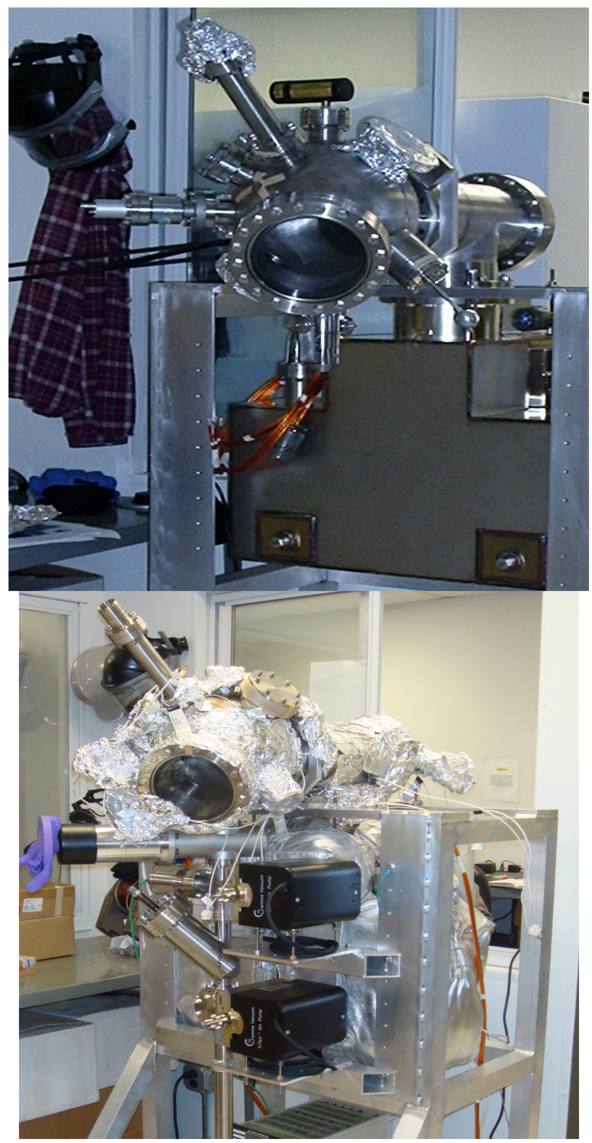

Figure 3: The preparation system on the top with attached TSP and on the bottom wrapped for baking with attached cathode transporter. The two ion pumps are part of the transporter.

The chamber has ports for the laser window, a residual gas analyzer; electrical feed-through for the Cesium source, a leak valve for introducing oxidizer, a temperature probe, an anode and a transporter system, which allows moving the cathode into the gun. The cathode is attached to a niobium plug, which is inserted into the cathode holder using a bayonet connector. The transporter system (figure 5) has a magnetically coupled actuator, which allows removing the cathode plug from the cathode holder and retracting it through two vacuum valves into the transporter. The valves are closed and transporter can be removed from the preparation chamber without breaking the vacuum inside the chamber or the transporter. The transporter is then connected to a valve at the back of the gun and after establishing sufficient vacuum the valves are opened and the cathode plug is pushed into a hole in the back of the gun. The valves are closed, the transporter disconnected and the gun assembly is placed into the cryostat for cool down. After the measurement the cathode is returned into the preparation chamber for regeneration.

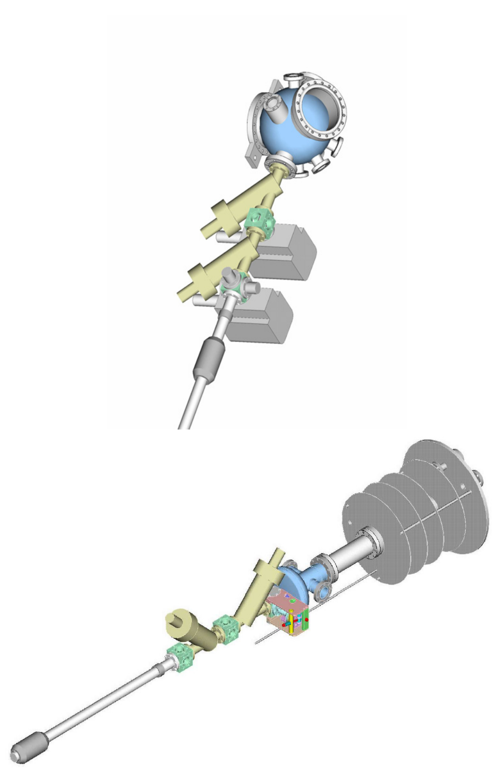

Figure 4: The transporter attached to the preparation chamber and to the gun assembly.

PROJECT STATUS

The preparation chamber is assembled except for the last minute addition of a movable shield to protect the Cesium source from radiated heat from the cathode heater. Operation is planned in the beginning of May 2009.

All parts of the gun assembly have been built or purchased. The vacuum components are being baked, final assembly will follow soon.

Since the electron beam will create a significant amount of radiation a concrete enclosure has been built. We are awaiting the installation of the radiation safety interlock system and a safety review.

In addition theoretical studies of the ion and electron bombardment were performed. It showed that for vacuum pressure comparable to DC gun, the damage from ion bombardment is less severe [5] and that the bombardment of the cathode from electron multipactoring will not occur.

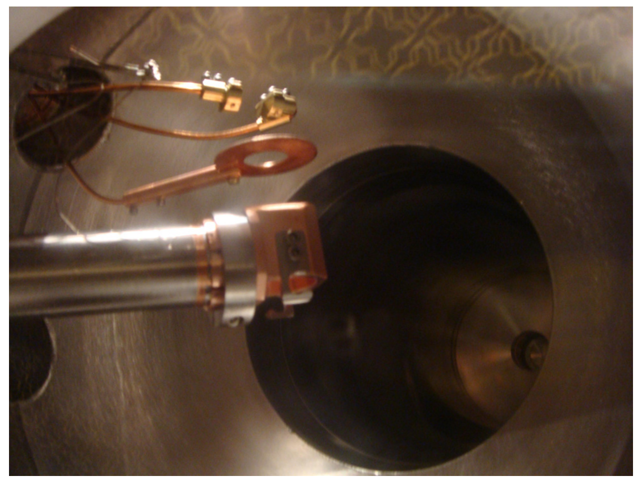

Figure 5: The cathode holder inside the preparation chamber is mounted on a heater stalk. The ring shaped anode is used to measure the quantum efficiency during preparation. Above the anode is the holder for the Cesium evaporation source. Not shown is a movable shield that can be inserted between the heater block and Cesium source to protect the source from radiated heat.

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