CATHODE PUCK INSERTION SYSTEM DESIGN FOR THE LEReC PHOTOEMISSION DC ELECTRON GUN

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Abstract

The operation of LEReC is to provide an electron cooling to improve the luminosity of the RHIC heavy ion beam at lower energies in a range of 2.5-25 GeV/nucleon. The electron beam is generated in a DC Electron Gun (DC gun) designed and built by the Cornell High Energy Synchrotron Source Group. This DC gun will operate around the clock for at least two weeks without maintenance. This paper presents the design of a reliable cathode puck insertion system, which includes a multi-pucks storage device, a transfer mechanism, a puck insertion device, a vacuum/control system, and a transport scheme.

INTRODUCTION

The operation of Low Energy RHIC Electron Cooling (LEReC) at Brookhaven National laboratory (BNL) is to provide an electron cooling to improve the luminosity of the RHIC heavy ion beam at low energies in a range of 2.5 -25 GeV/nucleon. The design goals [1] of the electron beam generator are (1) to generate a high average current (up to 50 mA) and low emittance electron beam and (2) to operate the generator around the clock, through a 6 months RHIC run, with 8 hours maintenance periods every two weeks. A DC photoemission gun (DC gun) is currently under construction at BNL, which adopted the successful DC gun technology for the new ERL X-Ray facility at Cornell [2, 3] and was developed to generate an average beam current up to 100 mA.

The high current operation of a DC gun will cause ion back-bombardment, which had been shown as the main reason for the degradation of the performance of a photocathode [3]. To obtain good operational lifetimes, in addition to keep the vacuum level in the gun as low as possible, the spent high average current photocathode will need to be cleaned and replaced regularly. In the past, the reported lifetime of a photocathode varied from 200 hours [4] (with a 1 μA average beam current) to a couple minutes [5] (with a 10 mA average beam current). Recently the gun development result at Cornell [6] showed that the lifetime of their CsK_2Sb photocathode could generate up to 60 mA beam current with 30 hours 1/e lifetime. Development for a much higher average beam current still continues. This short lifetime necessitates the design and construction of a rapid Cathode Puck Insertion System (CPIS) for the LEReC's operation. We are building a system which can store, transfer, exchange and insert 12 cathode pucks, one at a time, into the gun reliably without breaking the vacuum. In this paper, a CPIS design is presented, which includes a Multi-Pucks Storage Device (MPSD), a transfer mechanism, a Puck Insertion Device, a vacuum/control system, and a system transporting scheme.

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CATHODE PUCK INSERTION SYSTEM DESIGN

A 3-D model of the developed CPIS design is shown in Fig. 1, which includes a mobile and a stationary portion.

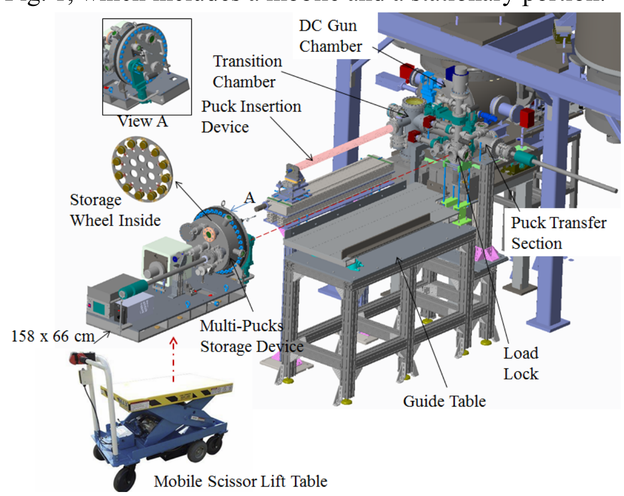

Figure. 1: Model of the cathode puck insertion system.

The former, which is used to transport the cathode pucks to the DC gun, inside the RHIC tunnel, includes a MPSD, a puck manipulating mechanism, a mobile scissor lift table, and the associated vacuum equipment. The latter, which is attached to the rear of the gun, includes a Load Lock, a Puck Transfer Section (including a puck transfer mechanism), a Puck Insertion Device, a Guide Table (for the alignment with the mobile portion), and the associated vacuum equipment. Designs of four major system components are described below:

Multi-Pucks Storage Device

The cathode puck, which will be used in the BNL's DC gun, is made of arc cast molybdenum with a size of 51 mm in diameter and 45 mm in length. (See Fig. 2.)

Figure. 2: The molybdenum cathode puck.

A rotatable stainless steel Storage Wheel (419 mm Dia. x 14 mm thick) with 12 elongated openings, inside the MPSD, is used to store the 12 cathode pucks. Four spring detents are provided on the sides of each smaller diameter opening to secure the pucks in place. (See Fig. 1 and Fig. 4(b).) By rotating the wheel, with the puck being secured by a manipulator, one can lock (centering the puck to the smaller diameter opening), release (centering the puck to the larger diameter opening) or select any puck (positioning the manipulator to the puck) on the wheel. The wheel is oriented vertically so that the space for the vacuum chamber is minimized and the required transport distances for all the pucks are identical. The Storage Wheel is enclosed by a 457 mm Dia. x 108 mm long 304L stainless steel tube, which is vacuum sealed by a pair of 22.13” (562 mm) diameter wire seal flanges to provide a UHV enclosure for the pucks. A high torque rotary feedthrough (made by Pfeiffer Vacuum), which is driven by a hand wheel, is used to rotate the Storage Wheel inside the chamber. A set of vacuum pumps are provided, near to the chamber, to maintain it the vacuum quality constantly. (See *Vacuum System Design* for details.) A normally closed manual gate valve (VAT DN63) is provided to maintain the chamber in vacuum all the time and to serve as the connection to the load lock on the stationary portion. To provide a capability to check the performance of each photocathode inside the MPSD before the insertion, a Quantum Efficiency (QE) measurement device is provided on the MPSD, which includes a stainless steel ring (being installed in between a vacuum window and a cathode puck), four ceramic standoffs, a BNC feedthrough and a signal cable. To allow using a high power laser to remove the spent photocathode material on the cathode pucks inside the MPSD without breaking the vacuum, a fused silica vacuum window is also provided on the device.

Puck Locking and Transfer Mechanism

Figure. 3 shows the transfer mechanism to insert a cathode puck from MPSD into the gun chamber. The insertion procedures are (1) to use Manipulator #1 to select a puck in MPSD and insert it into Puck Transfer Section, (2) to use Manipulator#2 in Puck Transfer Section to pick up the puck, which is inserted from MPSD, and transfer it to Transition Chamber, (3) to use Manipulator #3 to take the puck at Transition Chamber and insert it into the Cathode Electrode Assembly, inside the DC Gun chamber, and (4) to retract Manipulator #3 from the gun chamber when the puck is already secured inside the gun. (See Fig. 4(d).) Three Port Aligners and three vertical supports are provided in the system (see Fig. 3) to prevent the puck from sagging due to the defection of the long manipulator arm during the transfer. To extract the puck from the gun to MPSD, the procedures are reversed.

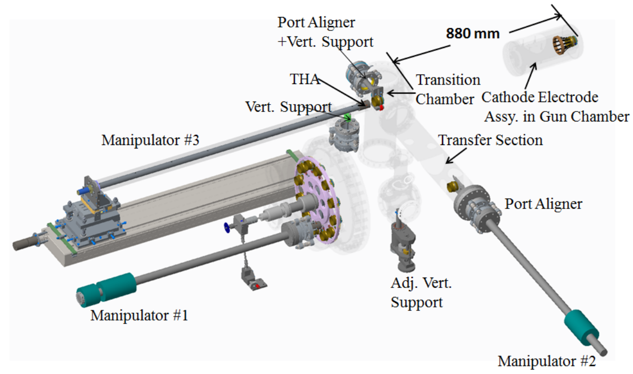

Figure 3: Model of cathode puck transfer mechanism.

Manipulator #1 is a custom made double linear/ rotary magnetic manipulator, which is made by UHV Transfer Engineering and has a 762 mm and a 19 mm travel and a 360° rotation capabilities. The 762 mm travel is for the puck transferring and the 19 mm travel is for the control of the puck locking mechanism inside a Transporter Head Assembly (THA), which is attached at the end of the manipulator. A cone shaped spring tensioner in the THA is attached to the 19 mm travel actuator. By sliding the tensioner and pushing the 6 locking springs outward, the puck can be locked to THA on its inner grooved surface (See Fig. 4(c).)

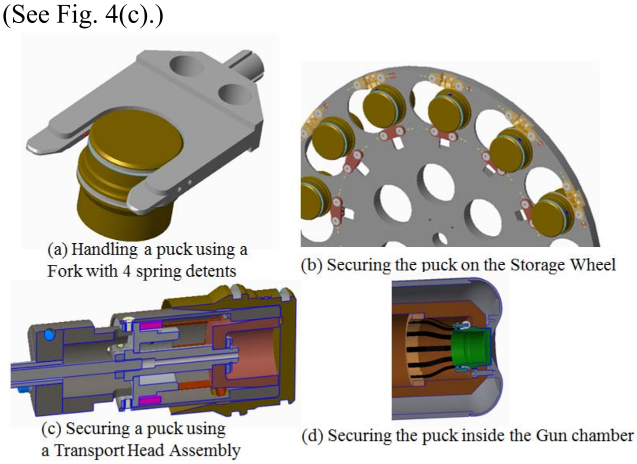

Figure 4: Models of cathode puck locking mechanisms.

Manipulator #2 is another custom made linear/ rotary magnetic manipulator, which is made by UHV Transfer Engineering, has an 813 mm travel and a 360° rotation capabilities. A Fork Assembly, which is attached to the end of this manipulator, is equipped with four spring loaded detents on its forks to lock the puck on its exterior groove. (See Fig. 4(a).) Manipulator #3 is a mechanical device, which has two linear slides, two vacuum bellows, two long SST tubes (the manipulators) and a THA, which is attached to the end of the manipulator to lock or to release the puck. (See Fig. 4(c).) The motor controlled linear slide (LES 5, by ISEL USA), which has a travel of 1010 mm, allows a quick transfer of the puck to the location near the final insertion destination. The manual controlled linear slide (A4006P10-S4, by Unislide), which has a travel of 50 mm, will allow to move the puck slowly and make sure that the puck is secured properly at the final insertion destination. The longer stainless steel bellow (Metal Flex 24915AA-42), with a travel of 1016 mm, is required for the insertion and the extraction of the puck into and from the gun chamber. The shorter stainless steel bellow (Standard bellows Co. 64-34-5), with a travel of 50 mm, is provided to allow the puck locking mechanism to work.

Transporting Multi-Pucks Storage Device

The overall weight, including the MPSD, the supporting plates and the associated vacuum equipment, is about 390 kg. To transport the MPSD, a total of 23 Ball Transfers are installed underneath and on the sides of the MPSD supporting plate to help moving and guiding the device onto the Guide Table or from a mobile platform. A self-propelled Mobile Scissor Lift Table (with a load capacity of 910 kg and a lifting travel of 91 cm), which is made by Lift Products Inc., will be used to transport the MPSD to the gun location inside the RHIC tunnel. The Guide Table will be used to direct the MPSD to the final destination, where the 4-1/2” (114 mm) CF flange on the Load Lock will mate with that on the gate valve of the MPSD. An elastic bumper is also provided on the Guide Table to damp out the huge momentum caused by the moving heavy mass.

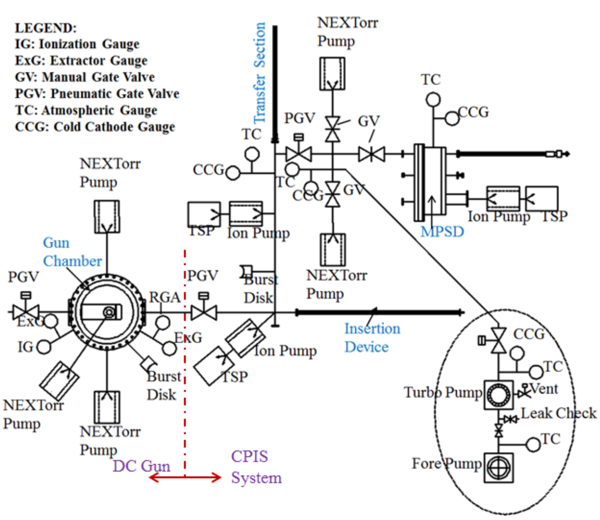

Figure 5: P& ID diagram of the CPIS vacuum system.

CPIS Vacuum System Design

A P& ID diagram of the CPIS vacuum system is shown in Fig. 5. To maintain the cathode pucks inside the MPSD under a UHV condition (<10^{-10} Pa) all the time, an ion pump (360190, by Gamma Vacuum) and a Titanium Sublimation Pump (TSP) (150TV-6D, by Gamma Vacuum) are provided, which are powered by a portable power supply constantly. A cold cathode gauge, an atmospheric gauge, and a roughing port are also provided on the MPSD. Load Lock is a 4-1/2” (114 mm) CF six-way cross between the mobile and the stationary portion. A fore pump, a turbo molecular pump, two 200L NexTorr pumps (by SAES), two cold cathode gauges, and three atmospheric gauges are provided on the Load Lock to achieve a UHV system efficiently. Puck Transfer Section includes a Puck Transfer Chamber and a Transition Chamber, which has a total volume of ~ 20 liters. Two ion pumps (Gamma 360044), two TSP’s (Gamma 200-L-CV-8D), one burst disk (to protect the system from being pressurized by a leaking High voltage insulation gas, such as: SF6 gas), one cold cathode gauge, one atmospheric gauge, three manual gate valves and three pneumatically controlled gate valves are installed on the Puck Transfer Section. The pneumatically controlled gate valves are connected to the Machine Interlock System in RHIC to protect the gun system from being contaminated. The Puck Insertion Device shares the same vacuum equipment as those in this Puck Transfer Section.

CONCLUSIONS AND CURRENT STATUS

Fabrication of the Cathode Puck Insertion System is near completion. Initial tests on the puck locking mechanisms demonstrated that the system would work properly. With the design presented above, the estimated time to exchange a cathode puck between the Gun Chamber and the MPSD could be done within an hour. An 8 hours downtime is also reasonable to exchange a MPDS, which includes the time for the transportation between the cathode production facility and the gun site and for the vacuum pumping down and baking out the Load Lock. The CPIS will be used for the DC gun commissioning in October 2016 and will be fully operational in early 2017. We are confident that the system will meet the design requirements as described above.

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