

INVERTED GEOMETRY PHOTO-ELECTRON GUN RESEARCH AND DEVELOPMENT AT TU DARMSTADT*

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Abstract

The Institute for nuclear physics at TU Darmstadt houses the Superconducting Darmstadt Linear Accelerator S-DALINAC. A photo-electron gun using GaAs photocathodes to provide pulsed and/or polarized electron beams, the S-DALINAC Polarized Injector SPIN, has been installed for future nuclear-structure investigations. In order to conduct research and development for this source, a test facility for Photo-Cathode Activation, Test and Cleaning using atomic-Hydrogen (Photo-CATCH) has been constructed. This setup provides several chambers for photocathode handling and a 60 keV beamline for photo-gun design studies. Currently, an upgraded inverted insulator geometry is under investigation for Photo-CATCH that is supposed to be implemented at SPIN after successful operation. We will present the current developments at Photo-CATCH and future measurements.

INTRODUCTION

The superconducting Darmstadt linear accelerator S-DALINAC [1] is operated by the Institut für Kernphysik (IKP) at Technische Universität Darmstadt. It is a linear electron accelerator with a thrice-recirculating lattice design and provides beams with energies up to 130 MeV with a beam current of up to 20 μA [2] for various nuclear physics experiments. Two guns are available for beam production: a thermionic electron gun and a DC photocathode electron gun. The latter has been added to the accelerator with the installation of the S-DALINAC Polarized Injector SPIN [3]. It can provide both polarized and unpolarized electron beams up to 125 keV, using photoemission from two types of negative-electron-affinity (NEA) GaAs-based photocathodes. Irradiating Bulk-GaAs cathodes with blue laserlight at 405 nm generates unpolarized high-current beams, while irradiating strained-layer superlattice-GaAs cathodes with circularly polarized laser light at an optimum wavelength of 780 nm [4] yields polarized beams.

Planned nuclear-structure studies including polarization degrees of freedom within the S-DALINAC energy range using the SPIN source [5] require a precise knowledge of photocathode parameters such as quantum efficiency (QE), cathode lifetime and degree of polarization. In order to conduct research on those parameters independent from available beamtime at the S-DALINAC, a separate test stand for Photo-Cathode Activation, Test and Cleaning using atomic-Hydrogen Photo-CATCH has been developed

and built [6]. Producing polarized and unpolarized electron beams with energies up to 60 keV is tested using an inverted-insulator geometry gun (IIGG) design. An additional photo-gun with a cryogenic design is currently under development [7]. The results from the tests of IIGG prototypes at Photo-CATCH are foreseen to be implemented at SPIN. The current external insulator design will be replaced with an IIGG design with an energy of 200 keV to match a new capture section under development for the S-DALINAC injector [8].

Current IIGG and photocathode research at SPIN and Photo-CATCH are presented in this contribution. Current developments at the test stand Photo-CATCH are introduced in the first section. The second section discusses the planned upgrade of SPIN and the current status. Future investigations at Photo-CATCH will be presented in the final section.

Photo-CATCH TEST STAND

Photo-gun and photocathode research is not efficiently possible at SPIN due to the operation of the S-DALINAC. A dedicated test facility with adjacent beamline was set up to conduct research and development of photo-gun prototypes and to study photocathode preparation and handling. For this purpose, the layout of Photo-CATCH is equipped with separate chambers for cathode activation, atomic hydrogen cleaning (AHC), and photo-gun testing, as well as a short beamline, as shown in fig. 1. Photocathodes are transferred between chambers with a cathode holder, called puck, as used in SPIN. This allows to transfer IIGG designs tested at Photo-CATCH to SPIN. Cathodes are loaded into the system of chambers using the Load-Lock Chamber (LLC), which also allows to apply a preliminary heat cleaning. In the adjacent Atomic Hydrogen Cleaning Chamber (AHCC), the sample surface can be atomically cleaned at temperatures of about 400 °C [6], compared to conventional annealing above 600 °C available at SPIN. In order to provide AHC for cathodes used at SPIN, a dedicated ultra-high vacuum (UHV) transport chamber for cathode transfer between SPIN and Photo-CATCH has been developed. NEA cathode activation is applied in the Cathode Activation Chamber (CAC) before the sample is transferred to the Cathode Test Chamber (CTC), where it is placed in the IIGG for beam production.

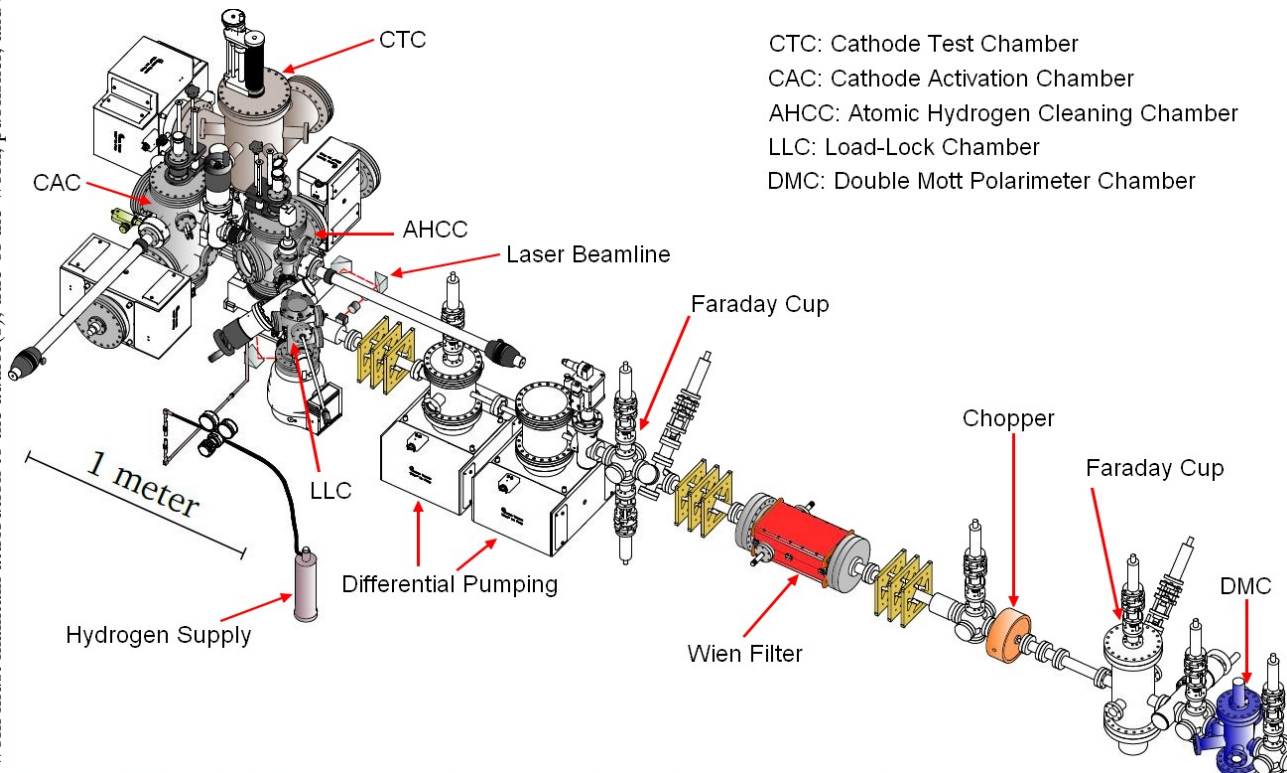
Cathode Activation Studies

Recently, studies on NEA activation using caesium (Cs) and oxygen (O₂) have been conducted at Photo-CATCH. Preliminary studies on three different procedures have been carried out: Co-deposition (Co-De), YoYo-type Nagoya-

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CTC: Cathode Test Chamber
 CAC: Cathode Activation Chamber
 AHCC: Atomic Hydrogen Cleaning Chamber
 LLC: Load-Lock Chamber
 DMC: Double Mott Polarimeter Chamber

Figure 1: Beamline of the test setup Photo-CATCH. Cathode samples are loaded to LLC and pass through AHCC and CAC before being transferred to CTC for beam extraction.

Table 1: QEs Obtained at Photo-CATCH Using Different Activation Methods [9]

Activation method	QE in %
Co-deposition	19.1 ± 1.0
Nagoya	22.0 ± 1.2
Two-step	25.4 ± 1.3

Activation (Na-Ac) and two-stage (TS) activation. During a TS procedure, the photocathode is activated to its maximum photoresponse, then annealed and cooled down before being activated again. At Photo-CATCH, a *Co-De – annealing – Na-Ac* procedure was used. First results for an excitation wavelength of 405 nm are shown in tab. 1. Na-Ac yields a slightly higher QE compared to Co-De, while TS activation showed an even higher improvement of QE, exceeding 25% [9]. In addition to conventional NEA activation methods available at SPIN, multi-alkali NEA activation is possible at Photo-CATCH [6]. Adding lithium (Li) during an activation process is expected to increase resistance of the active cathode surface against reactive residual gases [10]. First studies on QE and cathode lifetime obtained with different Li-enhanced multi-alkali activation methods have been conducted and are currently under evaluation [11].

IIGG Development

The photo-electron gun at Photo-CATCH uses an IIGG design featuring an electrode with a lift. The puck holding

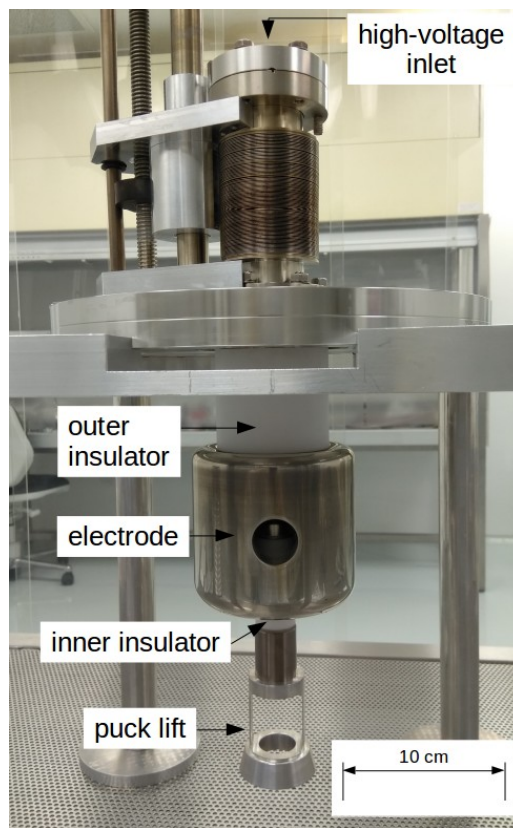


Figure 2: Current IIGG design prototype with puck lift extended. A hole has been cut into the side of the electrode to enable pumping of its interior when the lift is retracted.

the photocathode is inserted into the extended lift and then retracted into the electrode. High voltage is connected to the lift and transferred to the electrode. The current prototype can be seen in fig. 2. Electrode and lift have been manufactured out of aluminum EN AW-2007 and mechanically polished obtaining a mirror-like finish. This prototype is currently used to conduct mechanical and electrical tests in order to optimize the design. The final design is planned to be manufactured from stainless steel (SS316L), but adaption of other materials such as titanium (TiAl 6V4) is also foreseen.

In addition, a cryogenic gun is currently under development [7]. This expansion of the Photo-CATCH test stand is aimed at conducting investigations on high-current operation of the GaAs-based spin-polarized electron source for applications at, e.g., energy-recovery linacs [12] for positron production [13].

UPGRADE OF SPIN

The S-DALINAC features a capture section consisting of a dedicated two-cell capture cavity for operation of SPIN and a five-cell capture cavity for regular operation. A reduced-beta design is currently in development as replacement for this capture section [8]. In order to match this development, the present 125 keV external-insulator geometry electron-gun of SPIN will be converted to a 200 keV IIGG. The adaptability of the design used at Photo-CATCH is currently under investigation. First results for a stainless steel electrode using CST Studio Suite[®] suggest that modifications of the electrode shape and/or material are necessary [14]. First steps for the adaption of the beam transport of SPIN to this upgrade have already been undertaken. The α -magnet that transfers the beam to the horizontal beamline has been designed for a beam energy of 100 keV. However, beam trajectory simulations and temperature measurements have shown that the magnet is capable to transfer 200 keV electron beams without additional cooling [15]. The existing 100 keV Mott-Polarimeter will yield sufficient count rates for operation at 200 keV [16].

PROPOSED EXPERIMENTS AT Photo-CATCH

With construction of the test stand Photo-CATCH, a beamtime-independent facility for studies concerning photo-electron gun design, GaAs photocathode handling and photoemission properties has been established at TU Darmstadt. Further investigations of multi-alkali NEA activation procedures with focus on QE and cathode lifetime are foreseen. Parameters of Li-enhanced cathodes such as QE, degree of polarization, beam emittance and bunch structure will be studied in the course of the first IIGG and beamline commissioning of Photo-CATCH that is currently in preparation. Systematic investigations along the lines of Ref. [17] concerning the emission process of electron bunches as described by Spicer [18] have been proposed to review prelim-

inary studies at SPIN which have shown that at low QE this description may be insufficient [4].

CONCLUSION AND OUTLOOK

A 200 keV IIGG is foreseen to replace the SPIN photo-electron gun as an upgrade matching the S-DALINAC injector's new capture cavity structure. Research and development on photo-electron guns as well as investigations of photocathode properties and handling can be conducted at the recently constructed dedicated test facility Photo-CATCH. The highest values for QE were obtained using two-step photocathode activation during first studies on different NEA activation methods. Additional investigations on Li-enhanced multi-alkali NEA activation are in progress. An IIGG prototype is currently prepared for tests at Photo-CATCH, aiming to further optimize the design. Operational experience during IIGG tests and commissioning, photocathode preparation and handling, photoemission properties and beam parameters will be adopted for future upgrades and operation of SPIN.

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