# STATUS AND PERSPECTIVES OF THE S-DALINAC POLARIZED-ELECTRON INJECTOR*

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*Abstract*

The S-DALINAC Polarized Injector (SPIn) uses GaAs photocathodes to provide pulsed and/or polarized electron beams for nuclear-structure investigations. Recently, a test facility for Photo-Cathode Activation, Test and Cleaning using atomic-Hydrogen (Photo-CATCH) has been developed. This setup uses an inverted-insulator geometry for the photo-electron gun. Currently, tests and optimizations are conducted at Photo-CATCH in order to implement this new gun design at SPIn. We will present the current status of Photo-CATCH, the planned upgrade of SPIn (aimed at an operational voltage of 200 kV) and future measurements.

## INTRODUCTION

The superconducting Darmstadt linear accelerator S-DALINAC is a recirculating electron accelerator which provides beams with energies up to 130 MeV with a beam current of up to 20 µA [1] for various nuclear physics experiments. The S-DALINAC Polarized Injector SPIn [2] has been installed in order to include polarization degrees of freedom into the physics program at the accelerator [3]. This source can provide both polarized and unpolarized electron beams up to 125 keV by means of photoemission from negative electron affinity (NEA) GaAs-based photocathodes. To generate unpolarized high current beams, bulk-GaAs cathodes are irradiated with blue laserlight at 405 nm. For polarized beams, strained-layer superlattice-GaAs cathodes are irradiated with circularly polarized laser light at an optimum wavelength of 780 nm [4]. The cavities of the S-DALINAC operate in continuous wave (cw) mode with a fundamental frequency of 3 GHz. For optimal acceleration of the electron beam, suitable bunch structure and length have to be provided by the injector.

In order to conduct research on preparation methods for improving the performance of the photocathodes used at SPIn as well as to test an inverted-insulator geometry gun (IIGG) design, a test stand for Photo-Cathode Activation, Test and Cleaning using atomic-Hydrogen Photo-CATCH has been developed and put into operation [5] which is capable of providing polarized or unpolarized electron beams with energies up to 60 keV. This apparatus will also allow the cleaning of GaAs cathodes used at SPIn. Results from the tests of IGGS prototypes at Photo-CATCH will play a crucial role in the planned upgrade of SPIn which presently has an external insulator design thereby requiring a corona shield. In addition, an energy upgrade of SPIn to 200 keV is also foreseen to match a new capture section of the S-DALINAC injector [6].

The status and perspectives of SPIn and Photo-CATCH are presented in this contribution. First, the test stand Photo-CATCH and current developments are introduced. The following section discusses the planned upgrades of SPIn at S-DALINAC. Finally, investigations at Photo-CATCH will be presented.

## Photo-CATCH TEST STAND

Research at Photo-CATCH focuses on preparation of and beam extraction from semiconductor photocathodes used at SPIn. Additionally, it functions as a test facility for inverted-insulator geometry gun (IIGG) as well as future electron source designs, and as a stand alone source of spin-polarized electron beams of energies up to 60 keV. The present layout of this facility can be seen in Fig. 1. In order to enable a transfer of results obtained at Photo-CATCH to SPIn, the test setup has been designed to meet the requirements for electron beams at the S-DALINAC, and it uses the same GaAs cathode holders as SPIn. Studies are also oriented towards both improving the vacuum conditions and the preparation process to achieve better lifetime of NEA photocathodes during storage as well as operational conditions. The first prototype of an IIGG has been simulated using CST Studio Suite® and beam parameters optimized [7].

Normalized transverse emittance variation from 0.01 mm mrad to 0.13 mm mrad are expected for laser beam radii ranging from 50 µm to 750 µm, as shown in Fig. 2. In comparison, transverse emittances $\epsilon_{n,x}$=0.15(3) mm mrad and $\epsilon_{n,y}$=0.10(2) mm mrad have been measured at SPIn [2] which has an electrode modeled using similar techniques.

Differently from SPIn, atomic-hydrogen cleaning (AHC) and multi-alkali NEA activation are available at Photo-CATCH [5]. As opposed to the conventional cleaning technique of annealing above 600 °C practised at SPIn, AHC offers a quicker and safer way to produce atomically clean surfaces at a low-temperature (~400 °C), which is highly desirable in the case of strained-layer superlattice photocathodes susceptible to permanent physical damage at higher annealing temperatures. Recent studies at Photo-CATCH on multi-alkali NEA activation incorporating lithium (Li) into traditional caesium (Cs) and oxygen ($O_2$) layer through a two-stage activation method have shown to improve vacuum lifetime of the activated lifetime by more than three times [8, 9]. A dedicated

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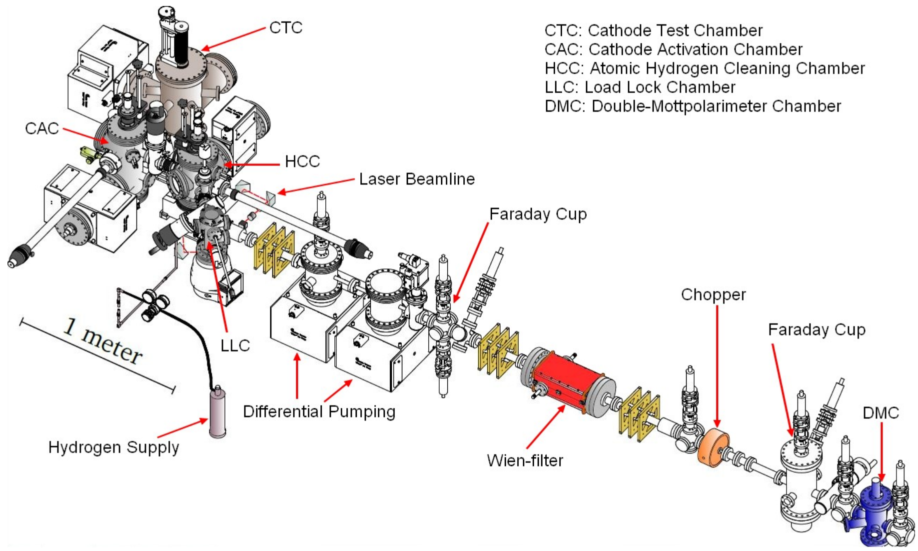


Figure 1: Beamline of the test setup Photo-CATCH.

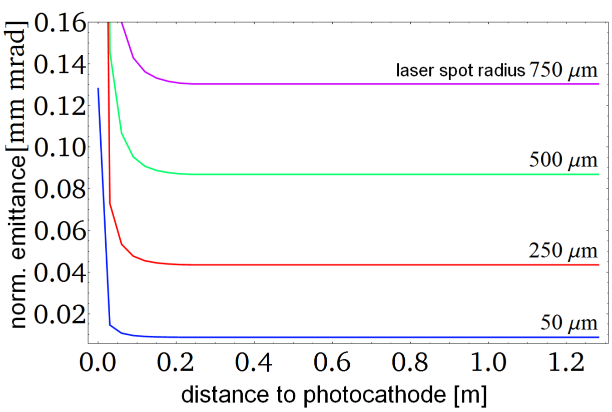


Figure 2: Laser spot radii dependence of normalized transversal emittance from the Photo-CATCH IIGG, resulting from CST simulations for a beam current of 100 µA [7].

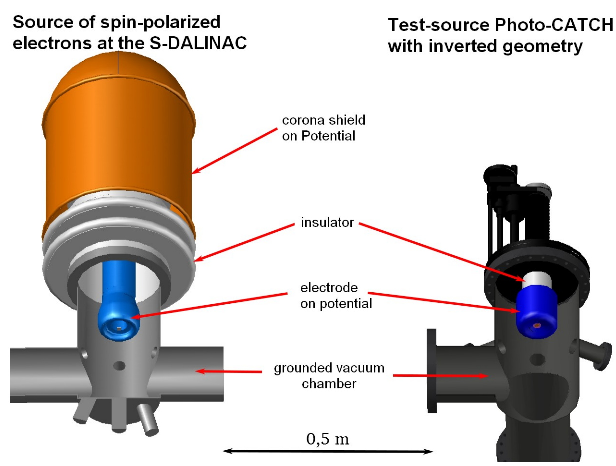


Figure 3: Comparison between gun designs used at SPIn (left) and Photo-CATCH (right) [7].

ultra-high vacuum (UHV) cathode transfer vessel exists to provide SPIn with atomic-hydrogen cleaned cathodes. Measurement and optimization of the beam parameters are to take place as soon as the IIGG design is finalized. An expansion of Photo-CATCH test stand with the addition of a cryogenic gun is envisaged [10] to investigate high-current operation of the GaAs-based spin-polarized electron source for applications at, e.g., energy-recovery linacs [11] for positron production [12].

## UPGRADE OF SPIn

A new capture cavity structure for the injector of the S-DALINAC is currently under development [6]. To match this development, the electron-gun of SPIn will be converted from the present 125 kV external insulator geometry with a corona shield to a 200 kV IIGG. A comparison of these two geometries is given in Fig. 3. In addition to being much more compact than the external insulator design, IIGG will provide improved personal as well as machine safety. The experience gained from designing and operating the IIGG at Photo-CATCH will play a crucial role in this upgrade. The beam transport of SPIn will also be adapted to this upgrade with a re-calibration of the $\alpha$-magnet that transfers the beam to the horizontal beamline and the Wien-filter that rotates the electron-spin. Other beamline components and diagnostics, such as steerer and quadrupole magnets and Mottpolarimeter, are foreseen to be overhauled.

## PROPOSED EXPERIMENTS AT Photo-CATCH

A precise knowledge of electron bunch properties is essential for providing high quality spin-polarized electron beams for physics experiments at the accelerator. The test stand Photo-CATCH allows to carry out a multitude of measurements regarding beam quality and properties of photoemission from GaAs, independent of the SPIn




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availability. One possible line of experiments focuses to study the emission of electron bunches along the lines of Ref. [13]. Preliminary studies at SPIn have shown that at low QE Spicer's [14] description of the emission process may be insufficient [4].

Polarization and QE are also crucial characteristics when producing electron beams with a photogun. Further measurements at Photo-CATCH aim to study those parameters in dependence of wavelength and intensity of the incident laser beam on the cathode. It is planned to conduct these investigations for both bulk-GaAs and superlattice-GaAs photocathodes.

## CONCLUSION

The test facility Photo-CATCH provides an environment for development and testing of photoelectron gun and beamline components for future upgrades of SPIn at the S-DALINAC, and also functions as an independent source of up to 60 keV spin-polarized electrons. A first prototype of an inverted gun has been recently developed and tested at Photo-CATCH, and a second prototype is currently being developed. Experience gained and results obtained from these IIGG development phases will be applied during the planned upgrade of SPIn to a 200 keV IIGG.

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