A NEW LOAD LOCK SYSTEM FOR THE SOURCE OF POLARIZED ELECTRONS AT ELSA*

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Abstract

The inverted source of polarized electrons at the electron stretcher accelerator ELSA routinely provides a pulsed beam with a current of 100 mA and a polarization degree of about 80 %. One micro-second long pulses with 100 nC charge are produced by irradiating a GaAs strained-layer superlattice photocathode (8 mm in diameter) with laser light.

Future accelerator operation requires a significantly higher beam intensity, which can be achieved by using photocathodes with sufficiently high quantum efficiency. Therefore, and in order to enhance the reliability and uptime of the source, a new extreme high-vacuum (XHV) load lock system was installed and commissioned. It consists of a loading chamber in which an atomic hydrogen source is used to remove any remaining surface oxidation, an activation chamber for heat cleaning of the photocathodes and activation with cesium and oxygen and a storage chamber in which up to five different types of photocathodes with various diameters of the emitting surface can be stored under XHV conditions. Additionally, tests of the photocathodes' properties can be performed during accelerator operation.

INTRODUCTION

Since 2006, experiments on baryon spectroscopy are performed at the University of Bonn, requiring circularly polarized photons which are generated by bremsstrahlung of longitudinally polarized electrons [1]. The polarized electrons cannot be produced via self-polarization according to the Sokolov-Ternov mechanism [2] due to a considerably long polarization time. Thus, in Bonn, polarized electrons are generated in a dedicated source [3] and are transported to the experiment while aiming at the highest possible conservation of polarization.

The main parameters of the source are determined by the properties of the injector chain of the ELSA stretcher ring. A beam energy of 48 keV is required for the buncher section of the pulsed injector linac and leads to a strongly space charge dominated beam transport to the linear accelerator. A pulse length of 1 µs and a repetition rate of 50 Hz are determined by the booster synchrotron.

Polarized electrons are generated by irradiating a strained-layer superlattice photocathode with circularly polarized laser light from a flash lamp pumped pulsed Titanium Sapphire laser [4]. The emitted current (by default 100 mA) is controlled by space charge limitation. In order to vary the beam intensity, the perveance[1] can be adjusted by changing the distance between the anode and the cathode.

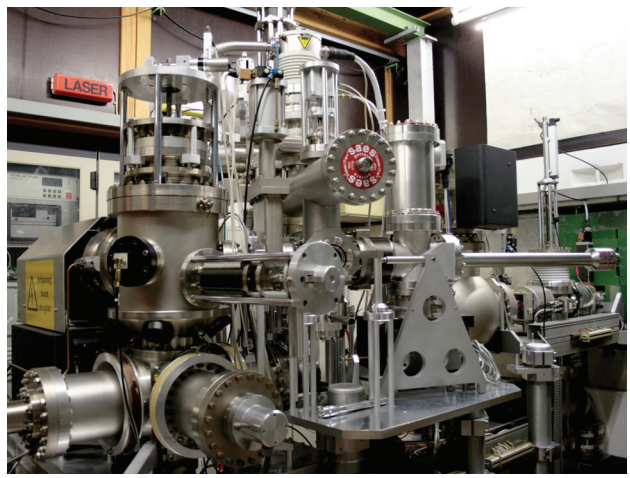

Figure 1: The source of polarized electrons and the new load lock system.

Future accelerator operation requires a significantly higher beam intensity, which can be achieved by using photocathodes with sufficiently high quantum efficiency. Therefore, and in order to enhance the reliability and uptime of the source, a new extreme high vacuum (XHV) load lock system including an atomic hydrogen source for cleaning photocathode was installed and commissioned. In this paper, the new load lock system and the setup for atomic hydrogen cleaning will be detailed.

THE NEW LOAD LOCK SYSTEM AND HYDROGEN CLEANING

Overview

Figure 2 shows a 3D-drawing of the new load lock system. It consists of three chambers: A loading chamber for bringing in new photocathodes and for cleaning with atomic hydrogen. A storage chamber (total pressure $< 1 \times 10^{-12}$ mbar) accessible via an elevator and an activation chamber for heat cleaning and activation with cesium

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[1] The perveance is the constant of proportionality between the emitted current and the applied voltage and is only dependent on the geometry.

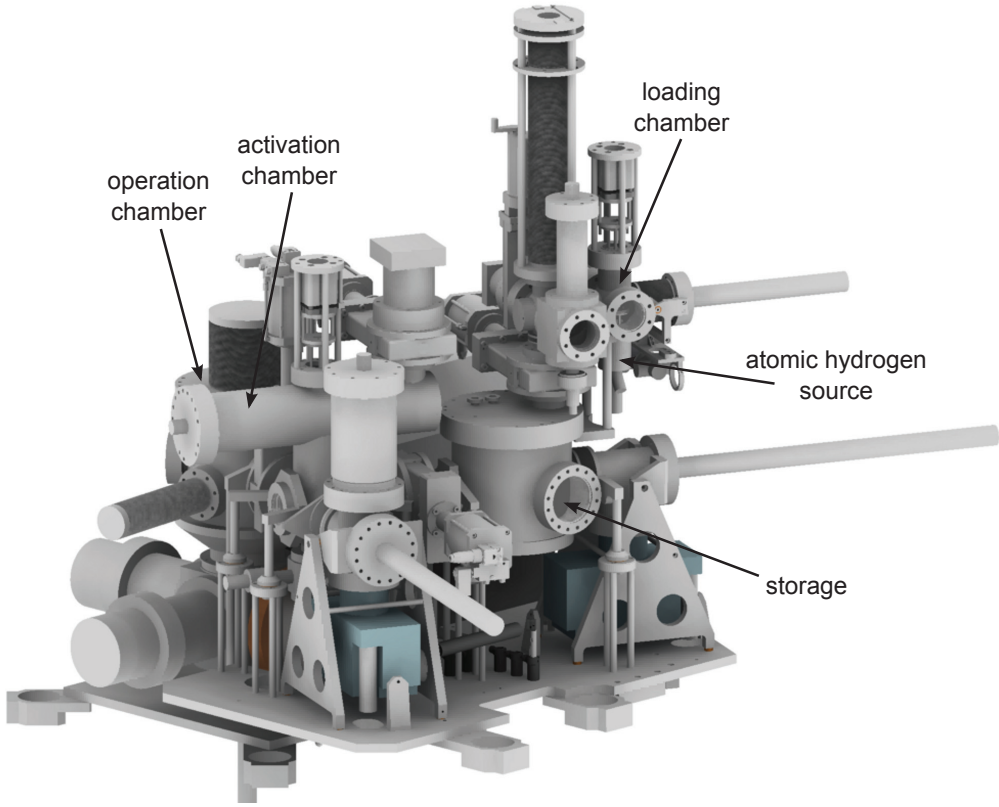

Figure 2: Overview of the new load lock system with its three XHV chambers.

and oxygen. After the activation the photocathode is transported into the gun for operation.

Atomic Hydrogen Cleaning

Atomic hydrogen cleaning will be used for new photocathodes without any protective cap or for multiply activated photocathodes whose quantum efficiency fails to regain its inital value because of remaining surface oxidations after only heat cleaning them. Heat cleaning alone requires temperatures near the damage threshold of the GaAs cathode for a comparable pure surface, but additionally leads to a rough surface with many defects. While applying atomic hydrogen cleaning, strong ligated molecules on the photocathode's surface like Ga_2O_3, Ga_2O and As_2O_x are converted into volatile ones:

$$Ga_2O_3 + 4H \rightarrow Ga_2O + 2H_2O \uparrow . \quad (1)$$

$$Ga_2O + 2H \rightarrow 2Ga + H_2O \uparrow . \quad (2)$$

$$As_2O_x + 2xH \rightarrow As_2 + xH_2O \uparrow . \quad (3)$$

The gallium and arsenic reaction products remain on the surface, the oxidations (ligated as H_2O) are removed by additionally heating the photocathode to moderate temperatures (450 °C). Because of the cracking procedure (see next section), the atomic hydrogen beam does not contain any hydrogen ions, resulting in an atomically clean and flat surface.

Hydroge Filtering and Inlet

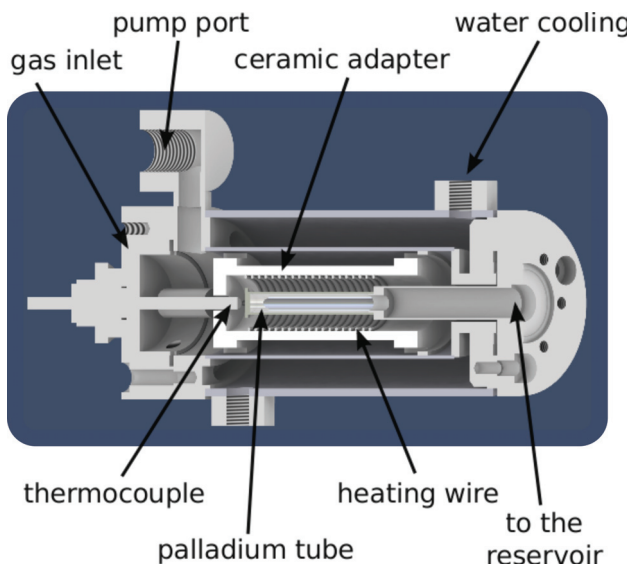

Figure 3: Palladium tube for filtering hydrogen.

In order to avoid any impurities of the hydrogen used for cleaning, highly purified molecular hydrogen (99.9999 %)

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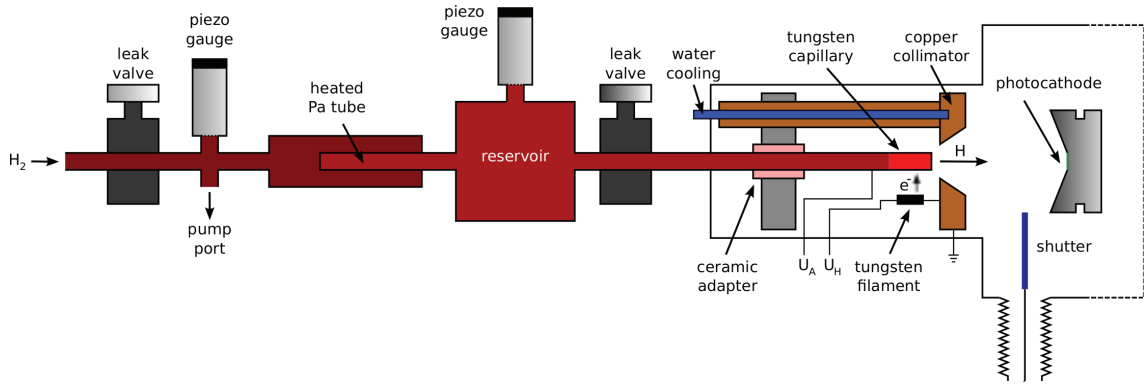

Figure 4: Inlet of hydrogen into the loading chamber for H-cleaning.

from a gas bottle is additionally filtered by a heated palladium tube (see in Figure 3) [5]. For temperatures higher than 200 °C palladium is permable for hydrogen. The tube is 5 cm in length and has an inner and outer diameter of 5 mm and 6 mm. It is heated using a wire with high oxidation resistance. In order to prevent the formation of a hydride phase the tube must not to be cooled below 150 °C in presence of hydrogen. Therefore both sides of the tube are evacuated before and after hydrogen cleaning. The temperature is monitored by a thermocouple.

The palladium tube was evacuated and baked out together with the loading chamber, so the inner side of the tube is clean and evacuated. The palladium tube is heated up to 380 °C under vacuum to minimize contaminations. Therefore the volume between the gas bottle and the palladium tube is evacuated with a piston pump. Afterwards the hydrogen (the pressure is controlled by a leak valve and measured with a piezo gauge) flows to the tube (see Figure 4). Because of convection the temperatures falls and limits the maximum gas pressure around the tube. A pressure of 33 mbar results in a temperature of the tube of about 190 °C, which is clearly over the required temperature of 150 °C. The filtered hydrogen accumulates on the baked-out vacuum side of the tube and in the reservoir. The pressure is measured with a piezo gauge, too. A calibrated leak valve is used to adjust the hydrogen flow through a capillary, which is heated by electron bombardement up to 2000 K [6]. In this capillary the molecular hydrogen is cracked into atomic hydrogen with a high dissociation rate for a particle flux in the range of 10^{16} to 10^{17} hydrogen atoms per second and leaves the capillary with an opening angle of 30 ° towards the photocathode. A NEG-pump and a turbo pump keep the pressure during the hydrogen inlet below 10^{-5} mbar.

After cleaning the photocathode it is transported to the activation chamber, in order to measure the quantum efficiency (QE). The activation is done with cesium and oxygen. A sub-mono atomic layer of Cs,O-dipoles is evaporated on the photocathode's surface by alternately heating cesium dispensers and a silver tube[2]. To measure the emitted current and the quantum efficiency (QE) during the activation process, the photocathode is irradiated with laser light from a helium-neon laser and an accelerating voltage is applied between the photocathode and the ground potential. To avoid backstreaming ions evaporated from the cesium dispensers a countervoltage within the distance of acceleration is applied. In order to provide an ultra high vacuum during the activation process, two NEG-pumps (2000 l/s each), an ion getter pump (75 l/s) and a turbo molecular pump (300 l/s) are installed.

CONCLUSION

Since 2000, the source of polarized electrons reliably provides a beam of 100 mA and a polarization degree of 80 %. With the installation and commissioning of the new load lock system with atomic hydrogen cleaning, an enhancement of the source performance is achieved. The replacement of the photocathode in the operation chamber will take only a few hours. In comparison, the formerly used procedure required a downtime of two weeks. Futhermore, the storing of different types of photocathodes with various diameters of the emitting surface will allow a quick change of the operation parameters like the emitted current and polarization degree. Additionally, tests of the quantum efficiency, polarization degree and the success of atomic hydrogen cleaning of different types of photocathodes can be performed during regular operation.

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[2]Heated silver is permeable for oxygen only.