The 50 keV Source of Polarized Electrons at ELSA: Past and Future

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Abstract. Since 2000, an inverted source for polarized electrons is in operation at the electron stretcher accelerator ELSA of Bonn university. Within several years of operation for the GDH experiment, the gun provided a pulsed beam with high polarization and intensity using a single strained-layer superlattice photocathode. The generation of rectangularly shaped pulses with 100 nC charge is achieved by optical pumping with a flashlamp-pumped titanium sapphire laser and space charge limited emission at 50 keV. Continuous degradation of the photocathode due to oxygen deposition on the surface which could not be removed completely by heat cleaning at moderate temperatures had been observed. In order to enhance the reliability and uptime of the source, a new load-lock system with crystal storage and atomic hydrogen cleaning will be installed in the near future.

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INTRODUCTION

Starting in 2006, a new experimental set-up of CB@ ELSA at Bonn university will come into operation [1], requiring circularly polarized photons, produced by Bremsstrahlung of longitudinally polarized electrons. In order to fulfill the demands of this as well as the already completed GDH experiment an inverted source of polarized electrons is in operation since 2000 [2]. In this paper, we will report about measurements and operational experience with the source. In addition we will present the new load-lock, which is presently under construction.

MODE OF OPERATION

A picture of the inverted gun of polarized electrons and the load-lock at Bonn university is shown in fig. 1. It operates with a pulsed injector linac which requires an injection energy of 48 keV, rectangular pulses with a pulse length of 1 μs, and a repetition rate of 50 Hz. Special care was taken in construction and setup of the gun and the transfer line to the linac in order to reach a low base pressure of 10^{-11} mbar and extremely low partial pressures of poisoning gas species (H_2O, CO_2) of less than 10^{-13} mbar (see fig. 2) by application of differential pumping [3].
Since the equivalent cw beam current density of the gun is only 0.1 μA/mm^2 due to the fact, that the gun operates in a pulse/pause mode and uses a relatively large cathode of 8 mm diameter, the overall lifetime of the photocathode is mainly limited by the dark

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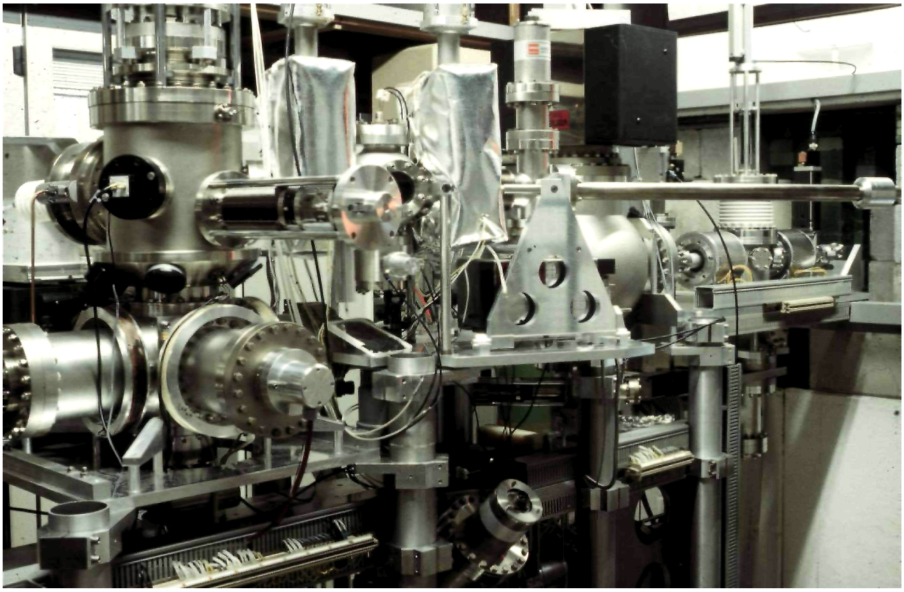

FIGURE 1. Picture of the 50 keV source at Bonn university.

lifetime and therefore by the partial pressures of poisoning gas species.
In order to maintain the gun vacuum and consequently the lifetime of the photocathodes, heat cleaning and activation of the photocathodes are carried out in a seperate preparation chamber, which is connected to the gun chamber with a manipulator. These build the existing load-lock of the source. This setup allows to change crystals without breaking the vacuum of the gun chamber. Photocathode lifetimes of more than 3000 h have been achieved regularly.
To obtain a rectangular pulse structure the emission is limited by space charge. The distance between anode and cathode can be varied from 45 mm to 75 mm, which permits to change the perveance of the gun and allows a space charge limited operation over a wide range of currents. Electron emissions from 85 mA up to a maximum current of 190 mA were measured with an 8 mm diameter photocathode, see [2]. The range of operation can be enlarged using photocathodes with different diameters.

LASER SYSTEM

The light source is based on a free running flashlamp-pumped 50 Hz titanium sapphire laser, which is tuneable between 700 nm and 900 nm by the means of three prisms in the resonator, see fig. 3. The laser delivers pulses of up to 400 mJ, at a wavelength of 830 nm up to 310 mJ, respectively. The laser-pulses originally have a pulselength of 10 μs, are chopped down to 1μs by a $\lambda/2$-Pockels cell placed between two polarizing beam splitters and transferred through an 80 m optic fibre cable to the room in which

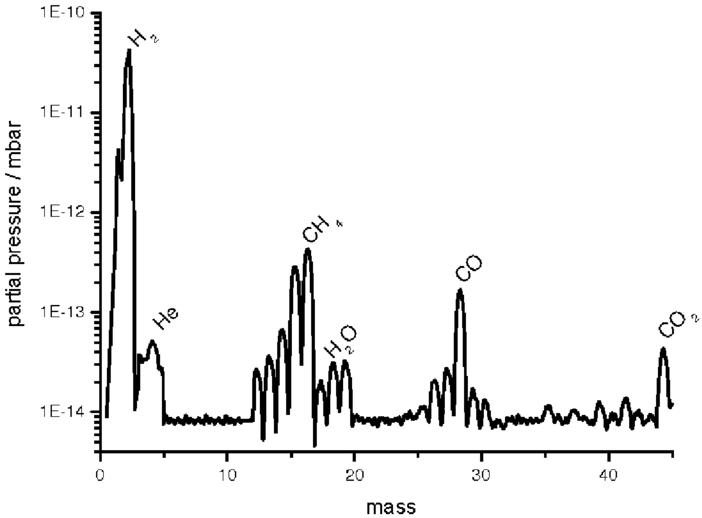

FIGURE 2. Partial pressures of various gas species in the gun chamber.

the gun is located. The pulses then become circularly polarized after passing a linear polarizer and a Pockels cell and are guided through a quarz window into the vacuum of the gun chamber and focussed onto the photocathode at a distance of 1235 mm.

In order to measure the quantum efficiency and polarization in dependence on the wavelength a cw titanium sapphire laser was set up. It is pumped by an argon ion laser and can be tuned by a Birefringent filter. A helium neon laser with a wavelength of 633 nm and a diode laser with a wavelength of 830 nm are also implemented for easier measuring of the quantum efficiency. Various methods to measure wavelength, polarization and time variance of the laser are set up on the laser tables.

OPERATIONAL EXPERIENCE

The 50 keV source was in operation from 2000 to 2003 for machine studies and the GDH experiment. During this time, a Be-InGaAs/Be-AlGaAs strained-layer superlattice photocathode [5] was used and maximum currents of up to 190 mA were obtained. With this photocathode, a polarization of 80 % and a corresponding quantum efficiency up to 0.4 % at a wavelength of 830 nm were measured [2]. During the three years of operation, the crystal was activated twelve times, which is shown in fig. 4. Before every activation, yhe crystal was heat cleaned fot 1 h at 400 °C for the first seven cycles and at 450 °C afterwards.

The degradation of the photocathode was determined by measuring the time dependent decrease of the quantum efficiency using the diode laser and the helium neon laser. Continuous degradation of the photocathode has been observed, as the quantum efficiencies

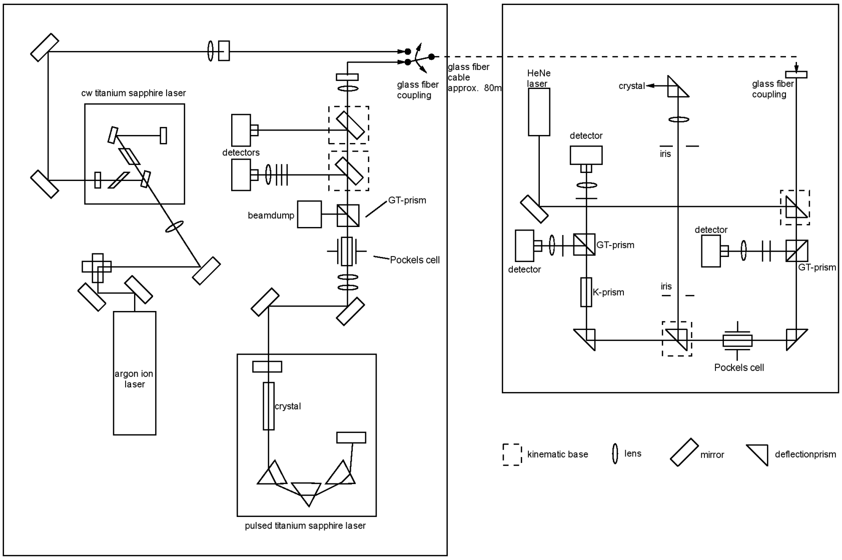

FIGURE 3. Optical tables in the laser room (left) and under the 50 keV source (right).

right after a heatcleaning are slowly declining with the number of activations. This is adressed to oxygen deposition on the surface which could not be removed completely by heat cleaning at moderate temperatures.

FUTURE PROJECT: NEW LOAD-LOCK

In order to enhance reliability and uptime of the source, a new load-lock is under construction, see fig 5. Next to the gun chamber a new preparation chamber for heat-cleaning and activation of the photocathodes will be installed. During the heat-cleaning of the photocathode, a turbo vacuum pump (TVP) with only magnetic bearings will be in operation. It will be possible to separate the TVP from the preparation chamber with a vacuum valve. In addition to the preparation chamber and the manipulator two non-evaporable getter (NEG) pumps with throughputs of 2000 l/s for H_2 and an ion getter pump (IGP) with a throughput of 65 l/s will be installed.
Next to the preparation chamber, a new crystal storage chamber will give the possibility to test different crystals with varied diameters and emission properties in parallel to accelerator operation. Up to five crystals can be stored. Four NEG-modules with throughputs of 330 l/s for H_2 and an IGP with a throughput of 65 l/s will be installed in the storage chamber. It will be possible to separate the storage chamber from the preparation chamber and the loading chamber with vacuum valves. Pressure gauges will be installed in the preparation chamber (Penning) and in the storage chamber (Bayard Alpert extractor). The new load-lock also includes atomic hydrogen cleaning, which will be installed in the loading chamber above the crystal storage chamber, interconnected by

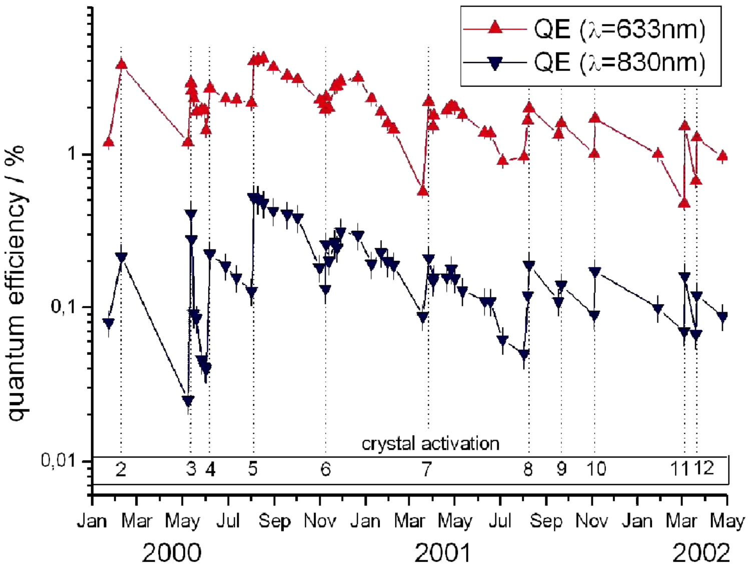

FIGURE 4. Overall degradation of the quantum efficiency.

an elevator. A TVP with a throughput of 70 l/s will be installed in the loading chamber. Atomic hydrogen cleaning is effective in the removal of oxide layers on GaAs surfaces and consequently expands the overall working time of a crystal. In the planned setup atomic hydrogen is dissociated to a high degree in a tungsten capillary, which is heated by electron bombardment up to 1850 K [6]. To prevent overheating of the photocathode by IR-radiation from the capillary the crystal is shielded by a shutter which will only be opened for the short time of the aplication of the atomic hydrogen.

CONCLUSION

In the last years, the 50 keV source of polarized electrons was in operation for the GDH experiment and machine studies. During this period, lifetimes for a Be-InGaAs/Be-AlGaAs strained-layer superlattice photocathode of more than 3000 h have been obtained. The uptime of the gun was close to 100% and did not effect the GDH program at all.

The variation of the distance between anode and cathode permits to change the perveance of the gun and allows a space charge limited operation over a wide range of currents. Maximum currents of up to 190 mA were obtained from an 8 mm diameter

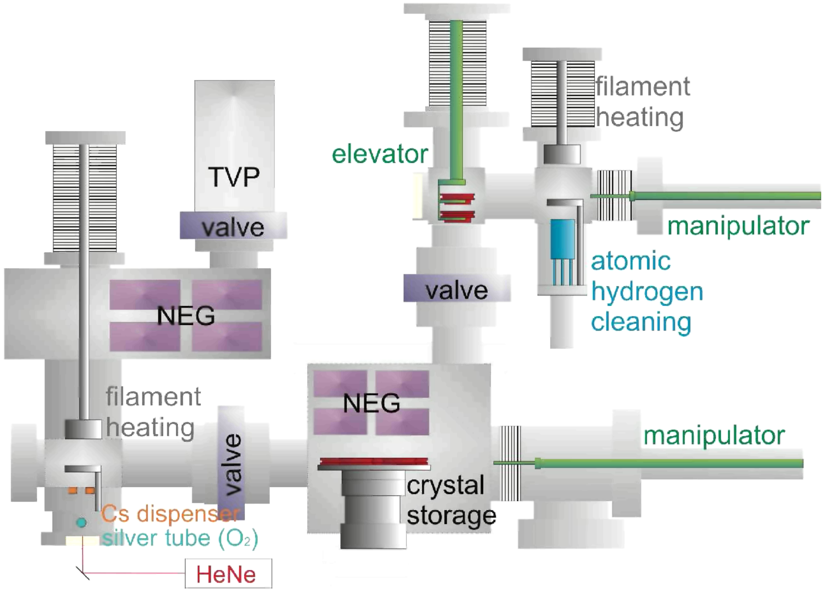

FIGURE 5. New load-lock with crystal storage and atomic hydrogen cleaning.

photocathode which corresponds to a maximum intensity of 4 mA/mm^2. A polarization of 80 % with a corresponding quantum efficiency of 0.2 % at a wavelength of 830 nm were measured. The transfer line to the linear accelerator provides for high vacuum isolation and was optimized for high transfer efficiencies.

Continuous degradation of the photocathode due to oxygen deposition on the surface has been observed. At present, an extended load-lock with crystal storage and atomic hydrogen cleaning is under construction in order to enhance reliability and uptime of the source.

ACKNOWLEDGMENTS

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