COMMISSIONING OF THE OFFLINE-TESTSTAND FOR THE S-DALINAC POLARIZED INJECTOR SPIN*

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Abstract

At the superconducting Darmstadt linear accelerator S-DALINAC a new injector for polarized electrons (SPIN) is under development. For this purpose an offline-teststand has been constructed. It consists of the source of polarized electrons and a test beamline including a Wien filter for spin manipulation, a Mott polarimeter for polarization measurement and various beam steering and diagnostic elements. The polarized electron beam is produced by photoemission from a strained GaAs cathode. We report on the status of this project and present first results of the measurements of the beam properties. We also give an outlook on the upcoming installation of SPIN at the S-DALINAC.

INTRODUCTION

The superconducting Darmstadt linear accelerator S–DALINAC [1] is a recirculating electron accelerator dedicated to nuclear physics experiments. It provides an energy range of a few MeV up to 130 MeV with an average beam current up to 60 µA. Due to the usage of superconducting accelerating structures, a 3 GHz continuous-wave (cw) time structure of the electron beam is possible. It is generated by chopping and bunching a DC electron beam currently produced at a thermionic gun.

To complement the present experimental program with polarized electron and photon scattering experiments a new injector for polarized electrons, the S–DALINAC Polarized INjector SPIN, has been developed [2]. Therewith experiments are planned e.g. studying parity violation in nuclei or measuring the fifth structure function in electron scattering. With these experiments results obtained at other accelerator laboratories can be extended to lower momentum transfer values.

The new injector consists of a polarized electron source, a chopper and prebuncher system, a Wien filter and a Mott polarimeter for spin manipulation and polarization measurement and of several beam steering and diagnostic elements. To test the electron source independently of the operation of the S–DALINAC, an offline-teststand has been developed. In this contribution, we describe the commissioning of this teststand and present the results of the measurements of various beam properties. Furthermore, an outlook on the planned installation of SPIN at the S–DALINAC is given.

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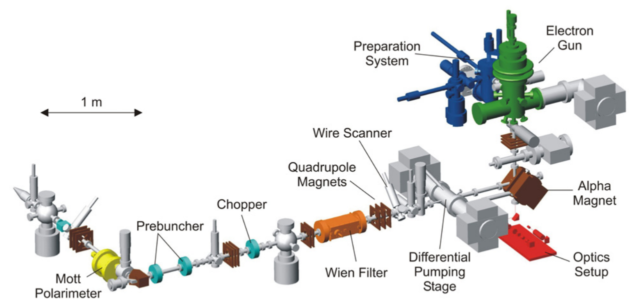

Figure 1: Schematic drawing of the teststand. A laser beam focused onto the cathode produces a polarized electron beam by photoemission. After pre-acceleration to 100 keV it is injected into the horizontal test beamline where its properties can be studied. The chopper and prebuncher system is not yet installed.

TESTSTAND

Figure 1 shows an overview of the teststand. The electrons are produced in the ultra-high vacuum vessel of the electron gun at a GaAs cathode by photoemission. The detailed operating principle is described e.g. in Ref. [3]. For the first tests bulk GaAs cathodes are used, whereas strained-superlattice cathodes [4] are foreseen for regular operation to achive high degrees of polarization of more than 80%.

A laser beam with the 3 GHz time-structure of the S–DALINAC is focused from an optics setup below the electron source onto the photocathode and produces the electrons. These are accelerated inside the source electrostatically to an energy of 100 keV and injected by an alpha magnet into the horizontal beamline. Beam properties can be measured with various diagnostic elements. Prior to usage the photocathodes have to be activated in a preparation system. While the design of the polarized electron source is based on the gun used at the MAMI accelerator [5], a more compact source had to be constructed (Fig. 2), due to limited space in the accelerator hall.

Figure 2: Photograph of the electron source (center) and the preparation system (left).

BEAM PROPERTIES MEASUREMENTS

Transverse Beam Quality

The transverse beam properties can be investigated qualitatively by several fluorescent screens and quantitatively by a wire scanner [6]. A typical beam profile measured with the wire scanner is shown in Fig. 3. It has approximately Gaussian shape. If the beam radius is measured in this way for different focussing strengths of a solenoid preceding the wire scanner, the transverse emittance can be determined. Thus the normalized transverse emittance has been determined to $\varepsilon_{n,x} = (0.146 \pm 0.037)$ mm mrad and $\varepsilon_{n,y} = (0.197 \pm 0.089)$ mm mrad respectively. The values are higher than those expected from simulations [7], but in the same order as the emittance of other polarized electron sources [8].

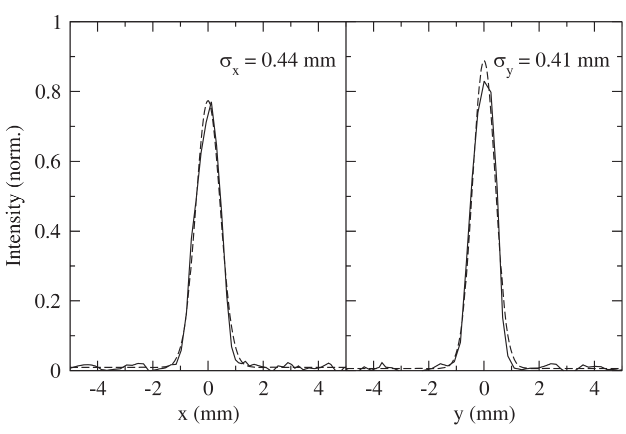

Figure 3: Measurement (solid line) of a typical beam profile. Its shape is nearly Gaussian (dashed line).

Time Structure

The electron beam needs to be modulated with the frequency of the S–DALINAC's superconducting cavities of 3 GHz for cw operation. This is achieved by using a modulated laser diode as light source [9]. To verify the time structure, the electron beam current was measured with an ultra-fast coaxial Faraday cup [9] and a sampling oscilloscope. The weak signal had to be amplified. The result depicted in Fig. 4 shows an oscillation with the correct period. Due to the limited bandwidth of the amplifier of 2-4 GHz, the shape of the curve looks like a sine function rather than a train of narrow peaks which is the time structure of the laser beam.

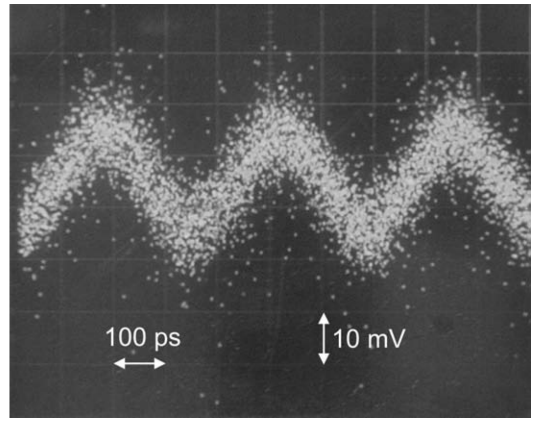

Figure 4: Measurement of the time structure. The period of approx. 330 ps matches with the 3 GHz S–DALINAC time structure.

For the capturing process of the beam into the superconducting accelerating structures the electron-bunch length is important. This has been estimated to be less than 80 ps by measuring the laser-pulse length with a fast photodiode and sampling oscilloscope [2]. To subtract background between the electron bunches and to match the bunch length to the superconducting capture cavity, a new chopper and prebuncher system has been developed [10], based on a similar setup at MAMI [11].

Polarization

The degree of polarization is the most important parameter to characterize a polarized electron beam. Its measurement for 100 keV electrons is typically based on Mott scattering. Thereby one utilizes the effect that the Coulomb potential has a term which is proportional to the scalar product of the angular momentum and the spin of the incident electron. This results in a right-left asymmetry A of the angular distribution of the scattered electrons which is proportional to the polarization P of the electron beam:

$$A = \frac{N_r - N_l}{N_r + N_l} = S \cdot P$$

The variables N_r and N_l are the number of scattered electrons to the right and left, respectively. The asymmetry function S is the so-called Sherman function and can be calculated theoretically for infinitesimal thin targets. By

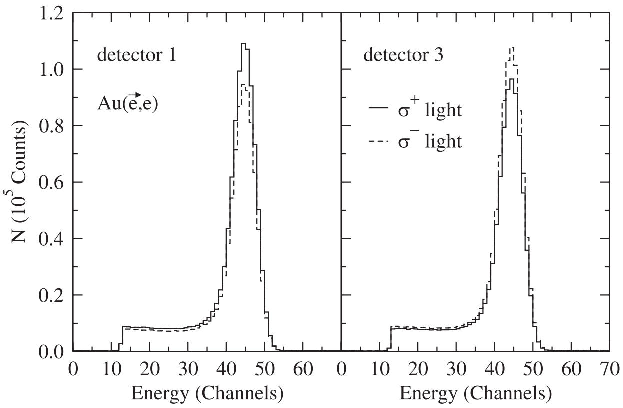

Figure 5: Measurement of Mott spectra with the two detectors of a scattering plane for reversing electron helcities. The helicity can be switched by reversing the polarization of the laser light.

measuring the number of scattered electrons for a scattering angle of $\pm 120°$ where the Sherman function has a maximum at a kinetic energy of 100 keV, one can determine the beam polarization.

Since in this way only transverse polarization components can be determined, the initially longitudinal orientated spin must be rotated by 90° into the transverse direction. This is done by a Wien filter [12].

The used Mott polarimeter [13] houses four silicon surface barrier detectors which are oriented in two perpendicular scattering planes to measure both transverse polarization components simultanously. As targets self-supporting gold foils of the thickness in the range from 42.5 nm to 500 nm are utilized.

To be independent from instrumental asymmetries, two measurements with opposite beam helicities must be performed. The helicity of the electron beam can be switched by reversing the polarization of the laser light. This can be done with a Pockels cell. Typically measured spectra are shown in Fig. 5. From this data a degree of polarization was determined to be (33.4 ± 1.6)% which agrees very well with published values for bulk GaAs cathodes [8]. Thereby the finite target thickness was taken into account by performing an extrapolation to zero target thickness. The detailed procedure is described in Ref. [14].

A strained-superlattice cathode from Ioffe Institute in St. Petersburg, Russia which is foreseen for regular beam operation of SPIN has been tested at MAMI. Thereby, a degree of polarization of (84 ± 5)% was measured which is in good agreement with the data provided by the manufacturer.

SUMMARY AND OUTLOOK

In this paper we showed that the offline teststand for the S-DALINAC Polarized Injector has been set up and put into operation successfully. The measured transverse beam quality is comparable to that of other polarized electron sources. Furthermore, the degree of polarization of the electron beam produced with a bulk GaAs cathode is in good agreement with the literature. The time structure of the S–DALINAC is matched by the polarized beam of the new injector.

The next steps are the completion of the test stand with the chopper and prebuncher system and the further investigation of source parameters. Then, at the end of 2008 the installation of the electron source and its subsystems at the S–DALINAC is planned. For that purpose, the beamline of the teststand requires only slight modifications and will replace the existing beamline between the thermionic gun and the cryostat of the S–DALINAC injector, including the present chopper and prebuncher system. Details of the planned layout of SPIN have been presented in Ref. [2]. After that polarized electrons will be available at the S–DALINAC for experiments.

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