STATUS OF THE POLARIZED–ELECTRON GUN AT THE S–DALINAC*

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Abstract

Aiming at an extension of the experimenting capabilities for nuclear structure physics at low momentum transfer at the superconducting Darmstadt electron linear accelerator S–DALINAC, a polarized electron gun is being constructed. The new injector will be able to supply the S–DALINAC with 100 keV polarized electrons and should complement the present, unpolarized thermionic source. The design requirements are a degree of polarization of at least 80%, a mean current intensity of 60 μA and a 3 GHz cw time structure. We report on the status of the polarized source with its laser and vacuum system, the preparation setup and a test beam line as well as the present status of preparations for implementing the source at the S–DALINAC.

INTRODUCTION

The superconducting Darmstadt electron linear accelerator S–DALINAC [1] provides electron beams of energies ranging from a few MeV up to 130 MeV with intensities up to 60 μA for various nuclear physics experiments. The activities are combined within a collaborative research center ("Sonderforschungsbereich 634") of the Deutsche Forschungsgemeinschaft. The electron beams are produced by a 250-kV thermionic, unpolarized DC electron source whose beam is chopped and bunched to a continuous-wave beam of 3 GHz repetition frequency to be further accelerated in the superconducting 10-MeV injector linac.

To complement the existing experimental capabilities and to enlarge the experimental program to polarization degrees of freedom, a source of polarized electrons is being developed for the S–DALINAC. This "S–DALINAC Polarized Injector" (SPIN) should provide electron beams with a degree of polarization of up to 80% with intensities of up to 60 μA. Simulations have shown that for the superconducting part of the S–DALINAC injector an electron energy of 100 keV is sufficient for further acceleration. The basic design of SPIN has been adapted from the established source of polarized electrons installed at the Mainz Microtrons MAMI [2]. However, due to geometrical restrictions for installing such a source at the S–DALINAC, it was necessary to build a smaller source, thus requiring design and development efforts.

Various experiments utilizing the polarized electron beam are in preparation, ranging from nuclear structure studies with polarized photons produced from bremsstrahlung of the longitudinally polarized electrons to measuring the fifth structure function of light nuclei in electron scattering experiments at low momentum transfer. Moreover, polarized beams may be used for studies of symmetries such as parity violation effects.

In this contribution, we present the current status of SPIN, show recent developments and discuss the progress of setting up a test stand for the polarized source separate from the S–DALINAC. Upon successful completion and test of the source, SPIN is planned to be installed at the S–DALINAC.

TEST STAND SETUP

Cathode Chamber

A schematic overview over the layout of the central elements of SPIN is shown in Fig. 1. Polarized electrons are

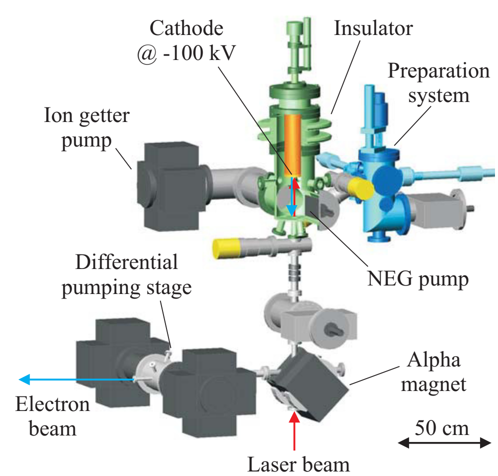

Figure 1: Technical drawing of the core part of the source of polarized electrons. The central UHV chamber contains a highly polished electrode holding the sensitive semiconductor photocathode. The laser beam is incident from the bottom. After a short vertical beam line with a compact quadrupole triplet, the electrons are deflected by an alpha magnet.

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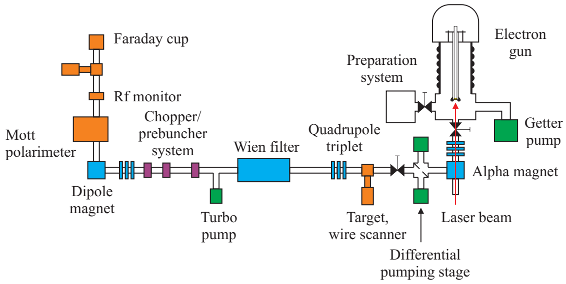

Figure 2: Schematic drawing of the SPIN test setup.

produced following the excitation of electrons in a strained-layer GaAs/GaAsP lattice or InAlGaAs/GaAs superlattice from the valence band into the conduction band. One spin direction is selected by using circularly polarized light from a diode laser system focused onto the photocathode crystal. The cathode is installed at the front end of a highly polished stainless steel (1.4429/316LN) electrode which has been designed following numerical simulations [3]. Prior to installation in the cathode chamber, the strained-layer cathode is brought into the system by way of a load-lock chamber and is cleansed and activated by applying a thin CsO layer in a separate preparation chamber. This CsO layer is needed to extract the electrons from the conduction band to the vacuum through negative electron affinity. Cathode chamber and preparation system have been assembled and are presently undergoing vacuum (bake-out) and high-voltage testing.

Beam Optics

Following the emission, the beam is deflected by an alpha magnet onto the horizontal direction. The schematic setup of the test beam line is depicted in Fig. 2.

Transverse focusing is achieved using triplets of very compact quadrupole magnets which can be as short as 72 mm for the entire triplet. At the same time, the quadrupoles have a large aperture of 51 mm that allows the quadrupoles to be installed on a standard UHV CF 35 beam pipe after welding of the knife edges for the seals. Figure 3 shows a readily assembled compact quadrupole triplet on a common mount. The electron-optical properties, field distributions, and resulting effects on the beam transport have been studied numerically [4] using the software V-code [5] after extending the capabilities of the program to handling overlapping electromagnetic fields [6].

Chopper and Prebuncher

Because of the short pulses provided by the diode laser system (see below), the electron source produces electron bunches. As the electron bunch lenght may vary depending on the laser intensity and cathode properties, a chopper cavity is under construction. The final setup of SPIN at the S–DALINAC will also allow one to use the existing thermionic gun that usually delivers a dc electron beam

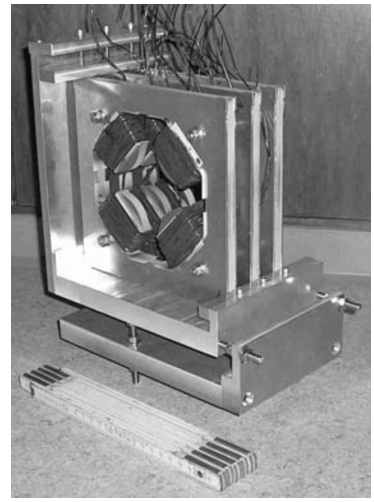

Figure 3: Photograph of a compact triplet of quadrupoles with a total length of only 72 mm and 51 mm aperture.

that needs to be chopped. It is foreseen to use one common chopper setup. Numerical design studies, based on the existing 2.45-GHz chopper cavity at MAMI [7] is presented elsewhere [8]. Similarly, the Mainz prebuncher system [9] consisting of two cavities operated on the fundamental frequency and the first harmonic, respectively, is being adapted for SPIN, see [8]. The prebuncher system will compress the chopped electron bunches from about 50 ps down to 5 ps which will suffice for further acceleration.

Polarization Manipulation and Measurement

In order to measure the degree of polarization, a Mott polarimeter is installed in the 100-kV beam line [10]. The operation of the polarimeter requires the electron spin to be oriented perpendicularly to the beam direction. This is achieved by installing a Wien filter in the beam line. This device is also needed for adjusting the electron spin orientation during future experiments. The Wien filter was adapted from a design developed at SLAC that will also be used for electron spin manipulation at MAMI C [11]. The magnetic field of the Wien filter is being mapped. The Mott polarimeter is equipped with four silicon surface barrier detectors to detect the electrons scattered elastically from thin gold foils.

Diode Laser System

The laser system of the new photo injector consists of a Sanyo diode (model DL-8032-001) emitting light at a mean wavelength of about 830 nm. For pulsing the laser, it is connected using a "bias-tee" to a radio-frequency source driven with an operating frequency of 3 GHz of the S–DALINAC. Pulses as short as 80 ps have been observed using an ultrafast photodetector (New Focus 1004) and a sampling oscilloscope (Tektronix 7T11, 7S11, S-4). However, this method reaches its limit at the investigated

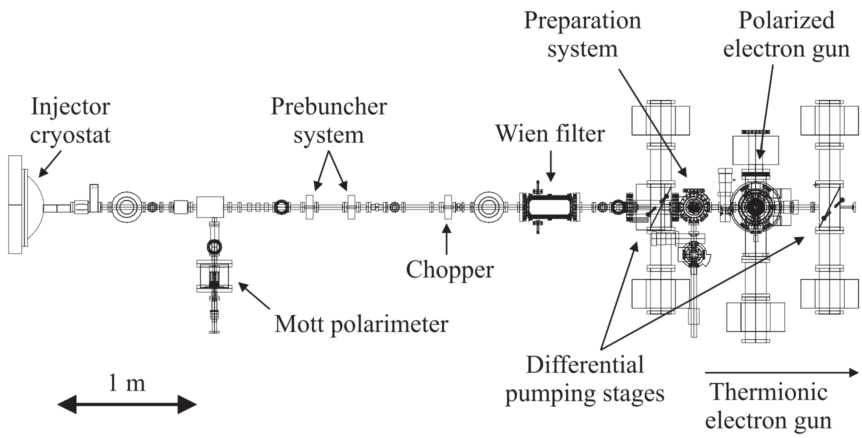

Figure 4: Technical drawing of the planned installation of SPIN at the S–DALINAC. The existing unpolarized thermionic gun is located outside the right edge of the figure; on the far left, the beginning of the cryostat of the superconducting 10-MeV injector linac is shown. The preparation system is placed above the beam line.

time scale. Therefore, measurements of the actual electron bunch length emitted from the photocathode are foreseen as soon as the test stand comes online.

IMPLEMENTATION OF THE POLARIZED SOURCE AT THE S–DALINAC

Due to the spatial constraints for the implementation of SPIN at the S–DALINAC, detailed plans are already being made. Figure 4 displays a schematic drawing showing the future site of SPIN in the accelerator hall. The thermionic unpolarized gun is located towards the right-hand side, and the superconducting capture section of the S–DALINAC is shown on the left-hand side. In order to keep the setup as compact as possible and to allow for additional space for transporting heavy equipment into the accelerator hall, some modifications with respect to the test stand are foreseen. The preparation system will be located directly above the beam line, and the Mott polarimeter will be rotated out of the way. A comprehensive analysis of the beam dynamics both for polarized and unpolarized beams are underway; preliminary results are presented by [4].

SUMMARY AND OUTLOOK

A test stand for a source of polarized electrons to be installed at the superconducting Darmstadt electron accelerator S–DALINAC is underway. The main components are being assembled and tested. First measurements with beam are planned for 2006, followed by a characterization of the beam properties, such as emittance, electron bunch length, and degree of polarization. The installation of the source at the S–DALINAC is scheduled for 2007.

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