IMPLEMENTATION OF A POLARIZED ELECTRON SOURCE AT THE S-DALINAC*

C. Eckardt†, T. Bahlo, P. Bangert, R. Barday, U. Bonnes, M. Brunken, R. Eichhorn, J. Enders, M. Platz, Y. Poltoratska, M. Roth, F. Schneider, M. Wagner, A. Weber, B. Zwicker, Institut für Kernphysik, Technische Universität Darmstadt, Germany,
W. Ackermann, W.F.O. Müller, T. Weiland, Institut für Theorie Elektromagnetischer Felder, Technische Universität Darmstadt, Germany

Abstract

At the superconducting 130 MeV Darmstadt electron linac S-DALINAC a source of polarized electrons is being installed, extending the experimental capabilities with polarized electrons and photons for nuclear structure studies at low momentum transfers. The polarized source generates electrons by irradiating a GaAs cathode with pulsed Ti:Sapphire and diode lasers and has been set up and commissioned at a test stand including electrostatic preacceleration to 100 keV, a Wien filter for spin manipulation, a Mott polarimeter for polarization measurement and a chopper-prebuncher system. Various polarimeters will be installed to monitor the beam polarization at all experimental sites. We report on the S-DALINAC, the results from the operation of the source at an offline teststand, the implementation of the polarized source and the polarimeter research and development.

S-DALINAC

The S-DALINAC [1] is a recirculating superconducting electron linear accelerator working at an energy range from 2.5 MeV up to 130 MeV. Around the S-DALINAC a multifaceted nuclear-physics program is tailored. Research topics in nuclear structure, nuclear astrophysics, and fundamental studies – along with the continuous upgrade of the accelerator – are the core of a center of excellence funded by the German Research Foundation (DFG) about seven years ago.

Since the S-DALINAC's first commissioning around 1990, nuclear resonance fluorescence experiments [2] are regularly performed downstream of the injector at energies between 2.5 MeV and 10 MeV with average beam currents of up to 60 μA. The same experimental site is used for (γ,n)-photoactivation experiments. Such measurements provide information on the photodisintegration near the separation energy relevant for nucleosynthesis in the astrophysical p (or γ) process [3] as well as s-process branch points [4].

A pass through the main linac may increase the beam energy by up to 40 MeV. By recirculating the beam two times a maximum energy of 130 MeV is possible. Two electron spectrometers – a high-resolution energy-loss system [5] and a large-acceptance QClam spectrometer – are available. At the former mainly form-factor measurements are carried out [6], the latter is used for coincidence experiments [7] or single-arm scattering at 180°, recently performed on very light nuclei [8].

Two setups provide photons behind the main linac: (i) a bremsstrahlung site for about 50 – 100 MeV electron beams which is prepared for an experiment on the proton polarizability and (ii) a high-resolution photon tagger [9] for astrophysically relevant photodisintegration and photon scattering studies between 5 MeV and 20 MeV. This research programm will be extended by implementing a complementary laser-driven strained-layer superlattice GaAs electron source [10] with high polarization. While polarized electrons and photons are used at other laboratories at higher energies, polarized electron beams at energies below about 100 MeV have – to our knowledge – not been used before for nuclear-structure studies. An overview over the first experiments to be performed is given in Ref. [11].

TESTSTAND PERFORMANCE

Prior to installation at the S-DALINAC, the source of polarized electrons has been set up and tested at an offline stand [12]. Here all components and the functionality of the overall system was investigated. Beams with intensities of up to 50 μA, cathode lifetimes of about 100 hours, and small normalized emittances of about 0.15 mm mrad have been achieved. Furhtermore, the pulsed operation of the source was demonstrated as was the operation of the Wien filter for spin rotation. A maximum degree of polarization of above 86(3)% was detetermined using a 100 keV Mott polarimeter (see below).

Next to a high-voltage cathode chamber, a UHV preparation chamber fed by a load-lock chamber is located. Here the cathodes are activated prior to operation by applying a CsO monolayer for achieving negative electron affinity. Beam diagnostics was implemented in a short beam line. Most of the test beam line will be re-used at the implementation of the source at the S-DALINAC which is presently underway.

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† eckardt@ikp.tu-darmstadt.de

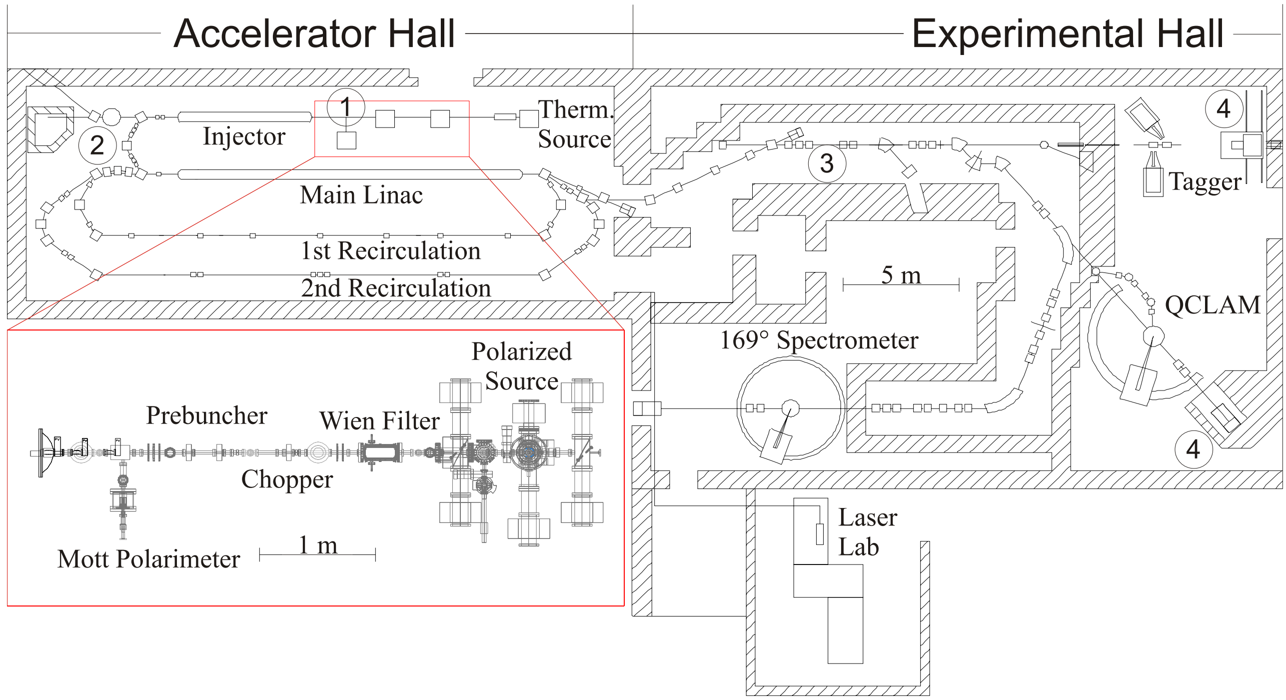

Figure 1: Layout of the S-DALINAC. The polarized source seen in the inset on the lower left will be installed between the thermionic source and the superconducting injector linac. The laser beam is transported through an optical fiber (diode laser) or an evacuated laser beam transport line (Ti:Sapphire laser). The positions of the various polarimeters are as follows: 1. 100 keV Mott polarimeter; 2. 5-10 MeV Mott polarimeter; 3. 50-130 MeV Møller polarimeter; 4. Compton transmission polarimeter

IMPLEMENTATION

The teststand has been decommissioned during January of 2010, and the implementation of the new source at the S-DALINAC between the unpolarized thermionic source (see Fig. 1) and the injector linac has been started. We anticipate the completion of the transfer by June 2010 and the commencement of operation with polarized beams during the summer of this year.

At the S-DALINAC, two laser systems will be available driving the source: a diode laser system (as used at the teststand) and a Titanium:Sapphire laser. While the diode laser system will provide laser light for the 3-GHz continuous-wave operation of the S-DALINAC, the Ti:Sapphire laser can produce short laser pulses with repetition frequencies of 75 MHz that can be used for time-of-flight measurements etc. Both laser systems are located in a dedicated laboratory about 40 m away from the future source location. The laser beams are transported using an optical fibre in case of the diode laser and an evacuated transfer line for the intense Ti:Sapphire beam. For achieving functionality of these systems, various components have being developed such as a spectrometer for laser diagnostics, an autocorrelator for laser pulse length measurements, or an active stabilization of the beam transport line. For injecting the electron beam from the future source, a new chopper-prebuncher system has been set up and tested to match the 3 GHz time structure of the S-DALINAC. A two-cell capture cavity will be re-installed at the S-DALINAC injector to account for the lower (100 keV) injection energy of the polarized electrons with respect to the unpolarized source (250 keV).

Parallel to the source implementation, the S-DALINAC is undergoing further upgrades: The accelerating structures of the injector linac are treated chemically and the accelerator control system including power supplies are installed.

POLARIMETERS

For quantitative analysis of future experiments, the degree of polarization needs to be measured at different positions close to the experimental sites and at different energies ranging up to 130 MeV.

100 keV Mott Polarimeter

A 100 kV Mott polarimeter is installed in front of the injector. Inside the Mott polarimeter four silicon-surface-barrier detectors are placed at 120° backward angle to allow measurements of both transverse beam polarizations with maximum analyzing strength. The target wheel containing several self-supporting gold foils ranging from 42.5 nm to 500 nm is positioned in front of the detectors and allows extrapolation of the measured asymmetries to zero target thickness. This set up was used for polarization measurement at the teststand.

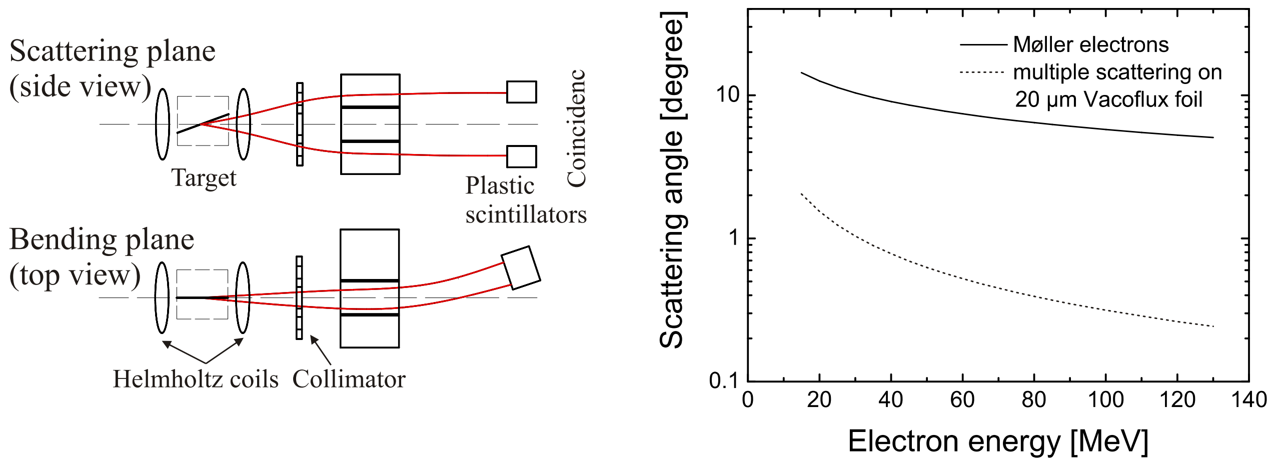

Figure 2: Schematic layout of the Møller polarimeter. The magnetic field of the two Helmholtz coils polarizes a Vacoflux foil. Scattered electrons are separated by a collimator and bent out of the beam path by a dipole magnet. On the right the energy dependence of the scattering angle for Møller electrons and multiple scattered electrons is shown.

5-10 MeV Mott Polarimeter

A 5-10 MeV Mott polarimeter is being set up behind the injector to determine the beam polarization after acceleration to the MeV range. Due to limited space of only 0.5 m the optimal angle for the Sherman function of 173° for 5 MeV or 176.5° for 10 MeV cannot be selected, instead an angle of 165° is chosen to install two scintillators for the detection of the elastically scattered electrons.

50-130 MeV Møller Polarimeter

A 50-130 MeV Møller Polarimeter has been designed for determining absolute polarization in the 50-130 MeV energy region. It will be installed in the extraction section. The longitudinally polarized beam hits a 20 μm vacoflux foil magnetized by the field of two Helmholtz coils. As space is limited to 1 m and the laboratory scattering angle shows a large variation over this energy range, a large-acceptance compact magnet set up has been developed to separate the scattered Møller electrons from the beam and to focus these electrons on a focal plane equiped with a plastic scintillator detector array for coincident detection of the scattered and the recoiling electrons near a center of mass scattering angle of 90°. The schematic layout of the Møller polarimeter and the energy dependence of the scattering angle are shown in Fig. 2. Further information can be found in Ref. [13].

Compton Transmission Polarimeter

For monitoring the degree of polarization during the experiment without beam interruption or destruction, Compton transmission polarimeters are foreseen, measuring relative polarization with respect to the Møller or the Mott polarimeter, respectively. The prototype of the Compton transmission polarimeter will be tested at the bremsstrahlung site at the S-DALINAC during the commissioning of the polarized source in summer. We note that a similar device has been developed for the A4 experimental setup at Mainz [14].

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