POLARIMETRY OF 0.1 - 130 MeV ELECTRON BEAMS AT THE S-DALINAC*

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Abstract

Polarimetry is a key field of interest if an experimental program with polarized electron and photon beams is planned. The new photo injector recently installed at the superconducting 130 MeV Darmstadt electron linac S-DALINAC provides polarized electrons from a GaAs cathode for nuclear structure studies at low momentum transfers. The degree of polarization needs to be measured at different positions close to the experimental sites and at different energies ranging from 100 keV up to 130 MeV. A 100 keV Mott polarimeter had been set up and commissioned at a test stand of the polarized source prior to implementation, while a 5-10 MeV Mott polarimeter is currently under construction and simulations for a 50-130 MeV Møller polarimeter are going on. Compton transmission polarimeters are foreseen to monitor polarization during experiments.

S-DALINAC

The recirculating superconducting electron linear accelerator S-DALINAC [1] is able to produce electron beams at beam energies from 2.5 MeV up to typically 80-90 MeV, with a design value of 130 MeV. Nuclear structure physics, nuclear astrophysics and fundamental studies on the structure of the nucleus and few-body systems are carried out at the S-DALINAC. The experimental program and the continuous upgrade of the accelerator are the research topics within a collaborative research center of excellence established by the German Research Foundation (DFG) about eight years ago. An overview over the facility is shown in Fig. 1.

Behind the superconducting injector linac, 3-10 MeV electrons with currents of up to 60 μA are delivered for experiments. The bremsstrahlung setup [3] is used for photon scattering (see, e.g. Ref. [2]), photo-activation (e.g. Ref. [4]), and recently also photofission [6].

The main linac may be passed thrice so that a maximum energy of 130 MeV is possible. Two electron spectrometers – a high-resolution energy-loss system [7] and a large-acceptance QClam spectrometer – are available. At the former mainly form-factor measurements are carried out [8], the latter is used for coincidence experiments [9] or single-arm scattering at 180°, recently performed on very light nuclei [10]. Two setups provide photons behind the main linac: (i) a bremsstrahlung site for about 50 – 100 MeV electron beams [11] which is prepared for an experiment on the proton polarizability and (ii) a high-resolution photon tagger [12] for photodisintegration and photon scattering studies between 5 MeV and 20 MeV.

The addition of a laser-driven strained-layer superlattice GaAs electron source along the lines of Ref. [13] enhances the experimental capabilities by providing polarized electrons and photons in the entrance channel for novel nuclear structure studies at very low momentum transfers. An overview over the first experiments to be performed is given in Ref. [14].

TESTSTAND PERFORMANCE

An offline test stand of the source of polarized electrons for the S-DALINAC [15] has been used to investigate all components and the functionality of the overall system prior to installation. 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. Furthermore, the pulsed operation of the source was demonstrated as well as the operation of the Wien filter for spin rotation. A maximum degree of polarization of about 86(3)% was detetermined using a 100 keV Mott polarimeter (see below).

PHOTO INJECTOR

The teststand has been decommissioned 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 completed in 2010.

Injecting the electron beam from the new source required a new chopper-prebuncher system which has been set up and tested. A two-cell capture cavity [16, 17] has been 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). Tuning of the polarized beam up to the superconducting part of the accelerator was completed successfully.

At the S-DALINAC, two laser systems are available driving the source: a diode laser system (as used at the teststand) and a Ti:Sapphire laser. While the diode laser system

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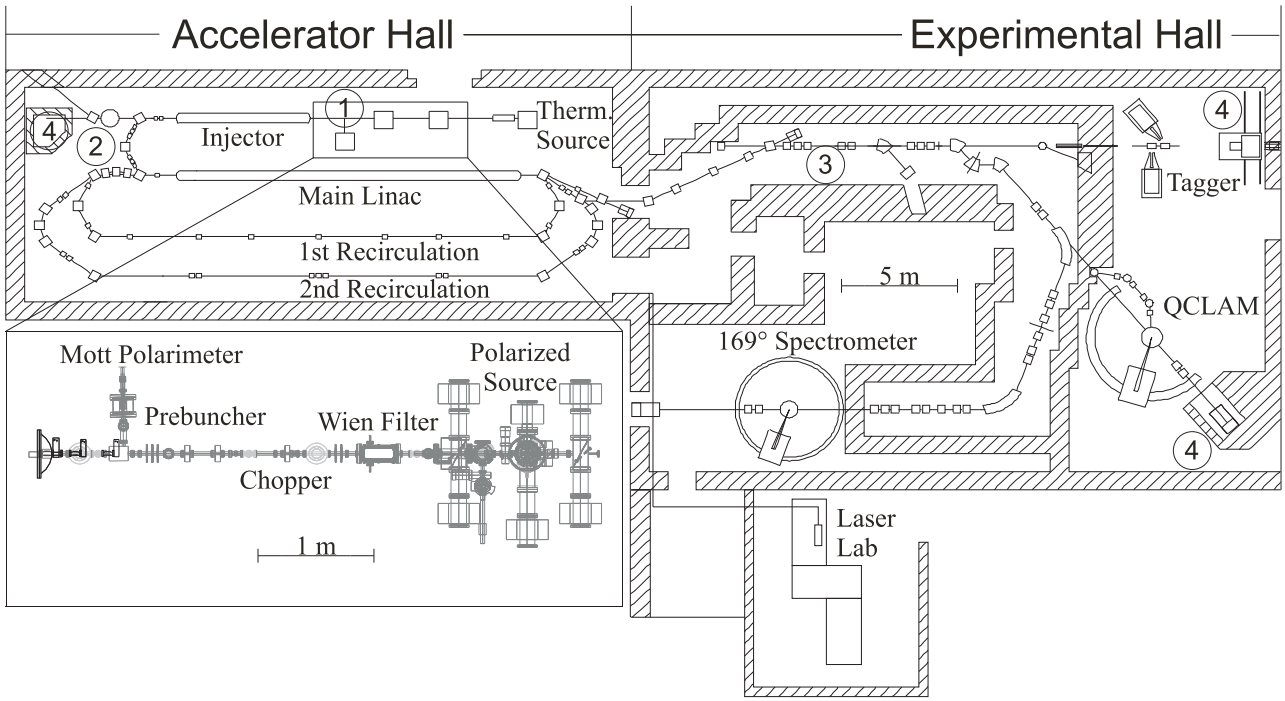

Figure 1: Layout of the S-DALINAC. The 100-keV polarized source seen in the inset on the lower left is installed between the 250-keV thermionic source and the superconducting injector linac. The laser beam is transported through an optical fiber (diode laser) or an actively stabilized laser beam transport 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 polarimeters.

will provide laser light for the 3-GHz continuous-wave operation of the S-DALINAC ($\leq$ 1 ps), the Ti:Sapphire laser is aimed at short laser pulses with repetition frequencies of 75 MHz. The laser beams are transported about 40 m using an optical fibre in case of the diode laser and an evacuated transfer line for the intense Ti:Sapphire beam. Various components have been developed, such as a spectrometer for laser diagnostics, an autocorrelator for laser pulse length measurements, a Stokes polarimeter monitoring the degree of polarization, and an active stabilization of the laser-beam pointing and centering.

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 from 100 keV up to 130 MeV.

100 keV Mott Polarimeter

A 100-keV Mott polarimeter is installed in front of the injector linac. This device was already used at the test stand beam line. It is described in an earlier publication [18]. This device allows one to study the performance of the source, and it is foreseen to serve experiments, e.g. studying polarization correlations in bremsstrahlung production [19].

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. Partly due to the limited space, a fixed scattering angle of 165° was chosen. This is relatively close to the optimal angles between 173° and 176,5° for the maximal values of the analyzing strength. This Mott polarimeter will provide an absolute determination of the electron beam polarization with an accuracy of a few per cent.

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 (Fig. 2). To accomodate the large scattering angles associated with the energy range which is rather low if compared to similar existing devices, a large-acceptance compact magnet set up has been developed to momentum analyze the scattered Møller electrons and separate them from the beam. Research and development work is going on for the integration of the Møller spectrometer in the beam line. Further investigations on the Møller-electron trajectories are being carried out in order to finalize the detector

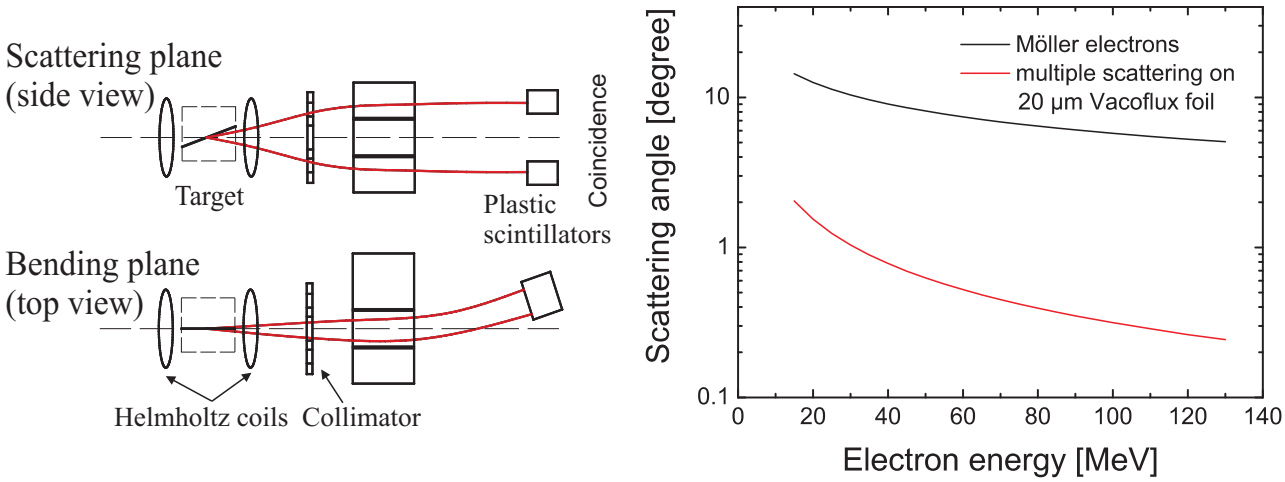

Figure 2: Schematic layout of the Møller polarimeter. The magnetic field of the two Helmholtz coils polarizes a Vacoflux foil. Scattered electrons are separated by a collimator and bent out of the beam path by a dipole magnet. On the right, the energy dependence of the scattering angle for Møller electrons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

design of the system in due course. Plastic scintillator arrays are foreseen to detect the recoiling and scattered electrons in coincidence. Further information can be found in Ref. [18]. We aim at an accuracy of a few per cent in the absolute degree of polarization.

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 polarimeters, respectively. A prototype of the Compton transmission polarimeter to be used at the 10 MeV injector linac experimental site has been set up consisting of two CsI(Tl) detectors. An electromagnet with VACOFLUX core serves as scatterer of circularly polarized photons. The device was successfully tested at the injector of the MAMI accelerator [20] in Mainz at 3.5 MeV electron energy. First results on this system are described elsewhere [21]. The Compton polarimeter will be installed at the bremsstrahlung site at the S-DALINAC during the commissioning of the polarized source in summer. Adapted designs are foreseen for the site at the tagger system NEPTUN and behind the QClam spectrometer. We refer the reader also to a similar polarimeter that has been developed for the A4 experimental setup at Mainz [22].

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