THE S-DALINAC POLARIZED INJECTOR SPIN - PERFORMANCE AND RESULTS*

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Abstract

At the superconducting 130 MeV Darmstadt electron linac S-DALINAC the new source of polarized electrons uses a GaAs cathode illuminated with pulsed Ti:Sapphire and diode laser light. The electron source had been set up and commissioned at a test stand with a beam line where a Wien filter for spin manipulation, a Mott polarimeter for polarization measurement and a chopper-prebuncher system were part of the system. Upon completion of the tests, test stand and beam line were dismantled and re-installed at the S-DALINAC. The new photo injector opens up the potential for experiments with polarized electron and photon beams for nuclear structure studies at low momentum transfers. Various polarimeters will be installed at all experimental sites to monitor the beam polarization. We report on the S-DALINAC, the results from the teststand performance, 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 capable of producing electron beams at beam energies from 2.5 MeV up to typically 80-90 Mev, with a design value of up to 130 MeV. Around the S-DALINAC, a multifacetted nuclear-physics program is realized in Darmstadt. Research topics are nuclear structure, nuclear astrophysics, fundamental studies and the continuous upgrade of the accelerator, all being the focus of a center of excellence funded by the German Research Foundation (DFG) about eight 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 [3]. The same experimental site is used for (γ,n)-photoactivation experiments [4, 5]. Recent fission studies [6] add to the injector linac experimental program.

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 [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 astrophysically relevant photodisintegration and photon scattering studies between 5 MeV and 20 MeV.

This research programm will be extended by implementing a laser-driven strained-layer superlattice GaAs electron source along the lines of Ref. [13]. 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. [14].

TESTSTAND PERFORMANCE

Before installing the source of polarized electrons at the S-DALINAC, an offline test stand [15] has been set up. All components and the functionality of the overall system have been 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. 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).

IMPLEMENTATION

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.

For injecting the electron beam from the future source, a new chopper-prebuncher system has been set up and tested

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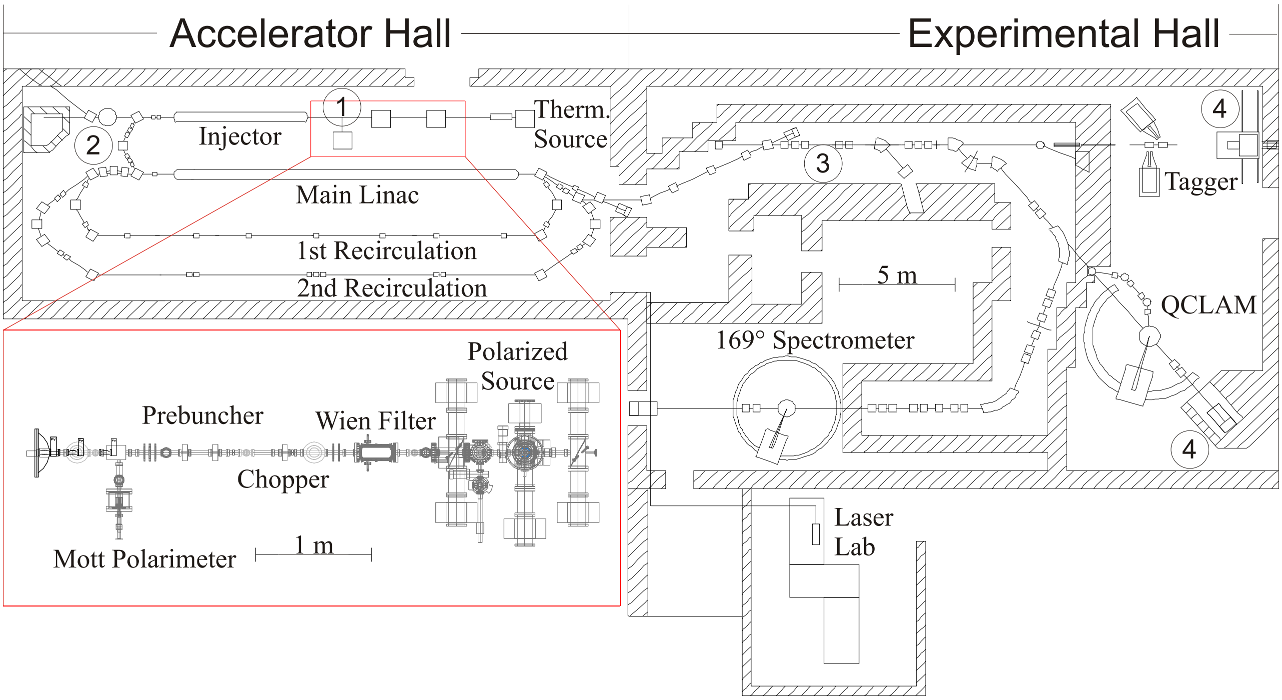

Figure 1: Layout of the S-DALINAC. The polarized source seen in the inset on the lower left is installed between the thermionic source and the superconducting injector linac. The laser beam is transported through an optical fiber (diode laser) or an evacuated laser beam transport line (Ti:Sapphire laser).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

to match the 3 GHz time structure of the S-DALINAC. 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). Currently, beam tuning 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 test-stand) and a Ti:Sapphire laser. While the diode laser system will provide laser light for the 3-GHz continuous-wave operation of the S-DALINAC – optionally pulsed with this frequency and tyical laser pulse lengths of 50 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 through the beam transport line.

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 kV 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].

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.

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 (cf. Fig. 2). To accomodate the large scattering angles associated with the energy range (Fig. 2), a large-acceptance compact magnet set up has been developed to

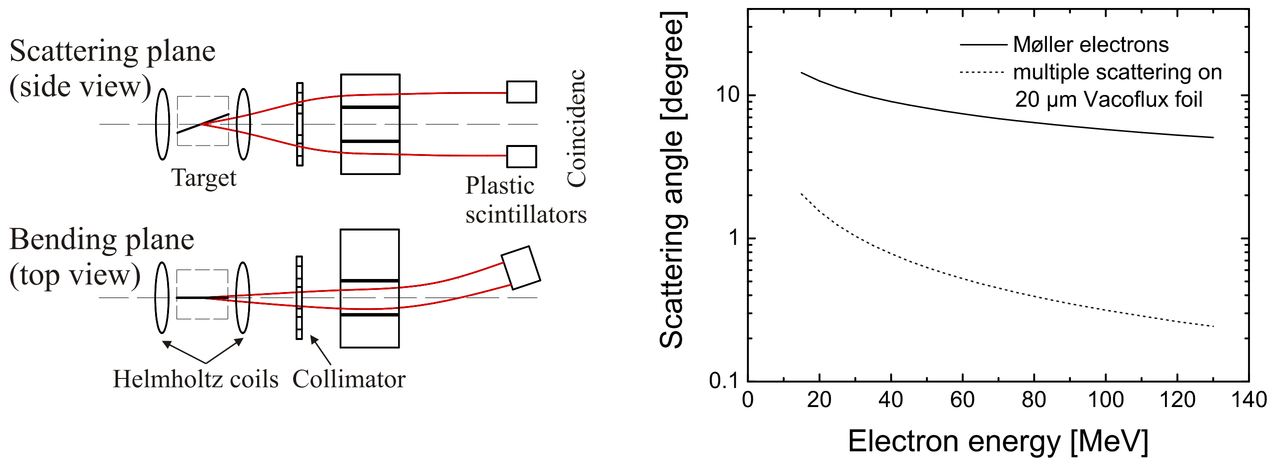

Figure 2: Schematic layout of the Møller polarimeter. The magnetic field of the two Helmholtz coils polarizes a Vacoflux foil. Scattered electrons are separated by a collimator and bent out of the beam path by a dipole magnet. On the right, the energy dependence of the scattering angle for Møller electrons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

momentum analyze the scattered Møller electrons and separate them from the beam. Research and development work is going on for the integration of the Moeller spectrometer in the beam line. Further investigations on the Moeller-electron trajectories are being carried out in order to finalize the detector 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].

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. 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. A VACOFLUX magnet serves as scatterer of circularly polarized photons. The device was successfully tested at the injector of the MAMI accelerator [19] in Mainz at 3.5 MeV electron energy. First results on this system are described elsewhere [20]. 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 [21].

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