# WIRE SCANNERS FOR EMITTANCE MEASUREMENTS AT THE 100 keV SPIN POLARIZED ELECTRON BEAM LINE AT THE S-DALINAC*

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*Abstract*

A source of 100 keV spin polarized electrons has been installed at the 130 MeV superconducting Darmstadt linear accelerator S-DALINAC. Circularly polarized laser light excites a GaAs cathode, producing spin polarized electrons in bunches with pulse lengths in the region of 50 ps and smaller at a repetition frequency of 3 GHz. A Wien-filter for spin manipulation and a Mott polarimeter for polarization measurements are installed in the low-energy beam line. Polarizations up to 86% have been shown with strained superlattice GaAs cathodes. Installed wire scanners in the beam line measure beam radius and position and in conjunction with a solenoid with variable focal length a parameter set of beam sizes depending on the focal length can be obtained, allowing for an emittance calculation. The scanning unit, two perpendicular 50 $\mu$m tungsten wires for x and y measurements mounted on an insulated frame, is installed at an angle of 45° in a plane perpendicular to the beam. Pneumatic as well as electric translation is used while the data read-out is done by a 24-bit ADC with variable reading speed. Measurements at the S-DALINAC give an indication of the beam quality of the spin polarized electron source, permit a comparison with the already installed thermionic electron source, and allow the measurement of a possible emittance growth from the Wien-filter that is to be excluded. Furthermore, the knowledge of the beam size renders a slit measurement of the beam pulse length possible.

## 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 $\mu$A [3]. The same experimental site is used for ($\gamma$,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 is 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].

## POLARIZED INJECTOR

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 $\mu$A and cathode lifetimes of about 100 hours 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.

The teststand has been decommissioned and the implementation of the new source at the S-DALINAC between the unpolarized thermionic source and the injector linac has been completed in 2010 and the cathode lifetime has been improved by a factor of ten.

For the injection of 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-

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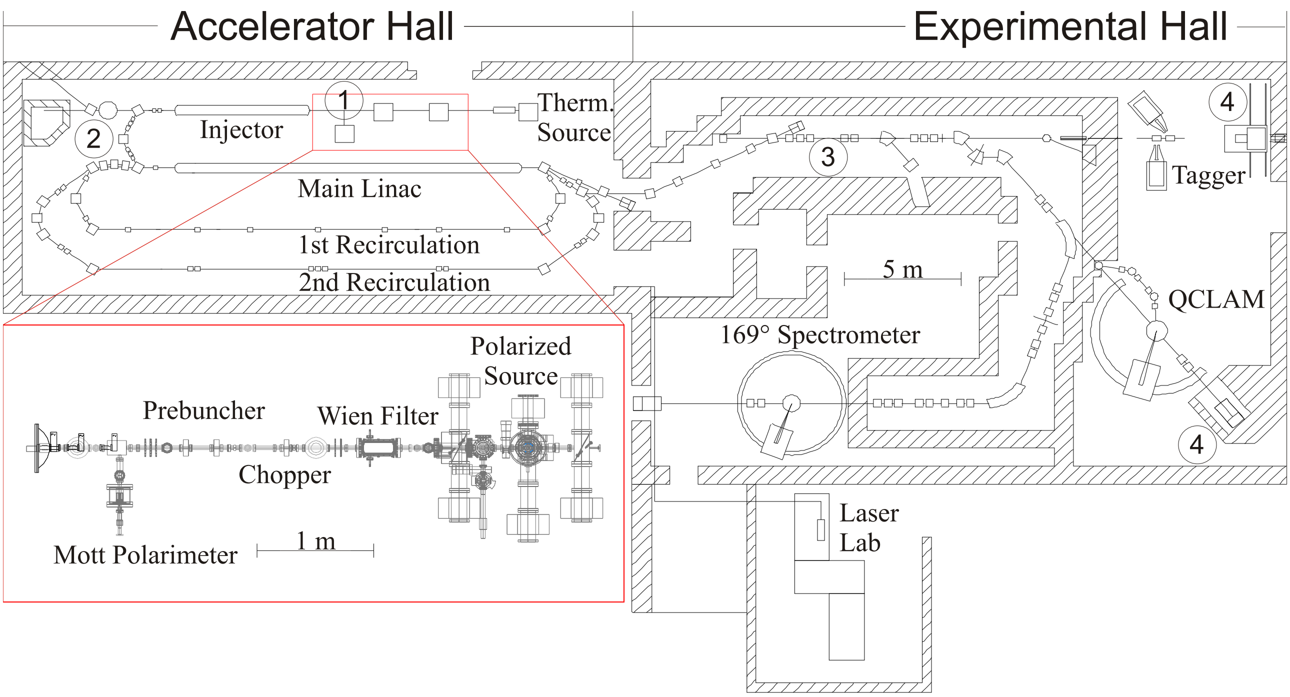


Figure 1: Layout of the S-DALINAC. The polarized source seen in the inset on the lower left is installed between the thermionic source and the superconducting injector linac. The laser beam is transported through an optical fiber (diode laser) or an evacuated laser beam transport line (Ti:Sapphire laser).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

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.

## WIRE SCANNERS

The wire scanners installed at the polarized injector of the S-DALINAC consist of two tungsten wires with a thickness of 50 $\mu$m, perpendicular to each other mounted on an aluminum frame. An electric and pneumatic manipulator are used to move the wire scanner at an angle of 45° in and out of the beam line. Therefore, one wire moves in the vertical, the other one in the horizontal plane, for measurements of the x and y dimensions of the beam. The accumulated charge excess is transported by a coaxial cable, as well as the position information from a potentiometer, to a 24-bit $\Delta\Sigma$-ADC with variable read-out speed for data analysis. Device control is achieved with the software P-CAN explover via Can-bus network. The information is used for beam position identification, beam size measurements and in conjunction with a beam focussing element the emittance can be calculated.

One beam focussing element in the beam line is a short quadrupole made of metal sheets with a geometric length of 8 mm and an apertur of 51 mm. The magnetic field of the quadrupole was measured at GSI at a current of 5.7 A, and the field gradient along the horizontal plane is shown in fig. 2.

Due to the loss in the field gradient strength in the middle of the magnet a double solenoid was choosen for emittance measurements. Using two coils with identical ampere turns but a different sense of rotation chancels out any transversal entanglement and leaves the electron spin unimpaired.

Beam profile measurements at different focal lengths of the solenoid with a sampling rate of 440 Hz yield data sets depending on the focussing power k. Fitting a parabolic function as seen in fig. 3 to the data sets of $\sigma_{11}(k)$ for the

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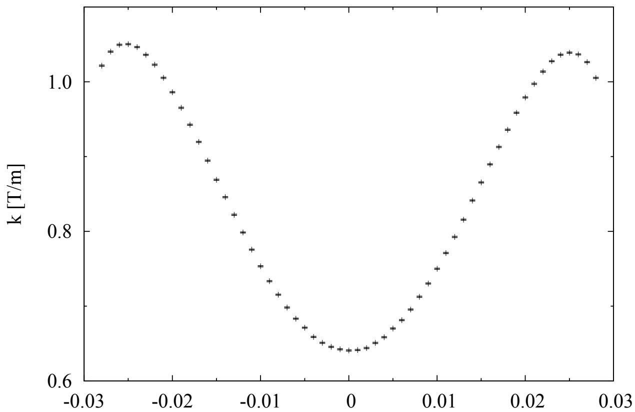


Figure 2: Quadrupol field gradient on the x-axis

x-dimension yields all elements of the $\sigma$-matrix.

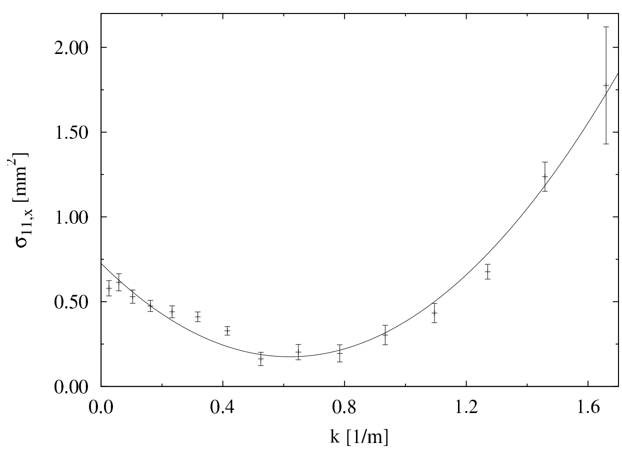


Figure 3: $\sigma_{11,x}(k)$-fit function and measured data

The emittance is then given by the square root of the determinant of the $\sigma$-matrix

$$\varepsilon_x = \sqrt{\sigma_{11}\,\sigma_{22} - \sigma_{12}^2} \tag{1}$$

and as acceleration leads to adiabatic dampening the normalized emittance for comparing emittance at different energies is defined as

$$\varepsilon_n = \beta\gamma\varepsilon. \tag{2}$$

Several beam profile measurements at different focal lengths were taken, and a parabolic function was fitted to the data sets to yield the elements of the $\sigma$-matrix and to calculate the emittance. The emittances in the beam line of the polarized source are summarized in table 1.

## OUTLOOK

In the future the emittance up- and downstream of the Wien-filter will be measured to exclude an emittance growth and an automatic beam alignment for the injector beam line will be put into operation. Measurements with pneumatic and electric manipulators will be taken to determine the better option for future beam position measurements. A planned slit measurement to determine the beam pulse length and a characterization of the polarized beam line will be carried out.

Table 1: Emittance of the electron beam in $x, y$-direction

| **emittance** | **values** |
|---|---|
| $\varepsilon_{n,x}$ | (0,208 $\pm$ 0,017) $\pi$ mm mrad |
| $\varepsilon_{th,n,x}$ | 0,0331 $\pi$ mm mrad |
| $\varepsilon_{n,y}$ | (0,239 $\pm$ 0,034) $\pi$ mm mrad |
| $\varepsilon_{th,n,y}$ | 0,0330 $\pi$ mm mrad |

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