THE POWER AND POLARISATION UPGRADE PROJECT AT THE S-DALINAC INJECTOR*

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Abstract

The current upgrade for the injector mainly involves the superconducting rf part. In order to increase the maximum current from 60 µA to 150 or 250 µA the power coupler design had to be modified, resulting in major changes in the whole cryo-module.

Second, an additional polarized electron source (SPIN) has been set-up at an offline test area. There, the polarized electrons are produced by photoemission at a strained GaAs cathode on a 100 kV platform. The test beamline includes a Wien filter for spin manipulation, a Mott polarimeter for polarization measurement and additional diagnostic elements. We will give an overview to the project, report on the status and present first measurement results including the proof of polarisation.

INTRODUCTION

The superconducting Darmstadt electron linear accelerator S-DALINAC [1] is a recirculating linac, using ten superconducting niobium cavities at a frequency of 2.9975 GHz. It was first put into operation in 1987. Running at a temperature of 2 K the main acceleration is done by ten 20 cell elliptical cavities with a design accelerating gradient of 5 MV/m. The first pair of those cavities is used in the injector section of the machine. Behind this section it is possible to use the beam for nuclear physics experiments with a maximum energy of 10 MeV or the beam can be bent into the main linac. With its two recirculations and an energy gain of 40 MeV per pass the maximum design energy of the S-DALINAC is 130 MeV which can be used for several experiments in the adjacent experimental hall. The layout of the machine is shown in Fig. 1.

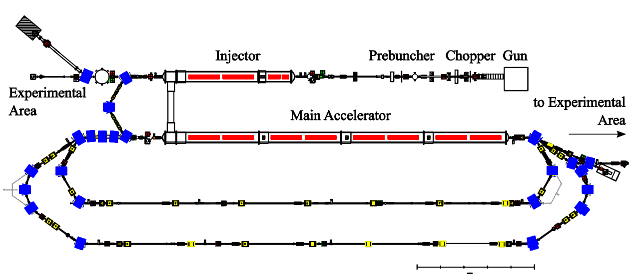

Figure 1: Floor plan of the S-DALINAC.

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POWER UPGRADE

The S-DALINAC uses cryostat-modules with two cavities per module. Each cavity has an rf input coupler, which is capable of a maximum power of 500 W. Assuming a 5 MV/m gradient the beam current is limited to 60 µA for the injector and 20 µA for the main linac, which might be higher for lower beam energies.

For future astrophysical experiments behind the injector, beam currents of 150 µA and above as well as energies of up to 14 MeV are demanded. Therefore, modifications in the injector linac had to be made.

New Power Couplers

The first step was to design and build new power couplers providing the necessary rf power of up to 2 kW to the cavities. While the existing couplers are coax-to-coax couplers [2] and limited to 500 W, the newly designed couplers are of waveguide-to-coax type [3]. One essential design feature of the old coupler was kept, namely the minimized transversal fields being a major concern in the low energy part of the accelerator. This was accomplished by using two diaphragms, reducing the excitations of the transverse electromagnetic fields in the beam pipe below -40 dB.

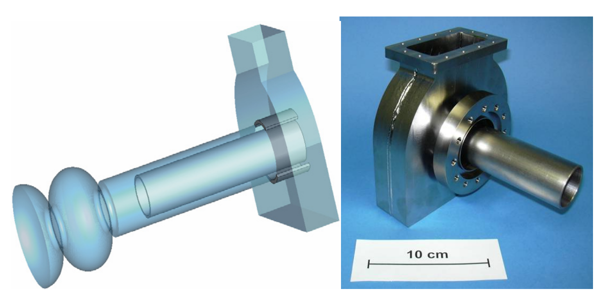

Figure 2: The design and the finally fabricated waveguide-to-coax coupler for the injector upgrade.

Figure 2 gives on the left side an impression, how the coupling from waveguide to coax and to the cavity along its cut-off tube is realized. The external quality factor of $5{\cdot}10^6$ ensures acceleration of beam currents ranging from 150 to 250 µA.

The coupler was made out of bulk niobium. The fabrication including the EB-welding was done by the FZ Juelich. Currently, the chemical cleaning of the couplers is underway.

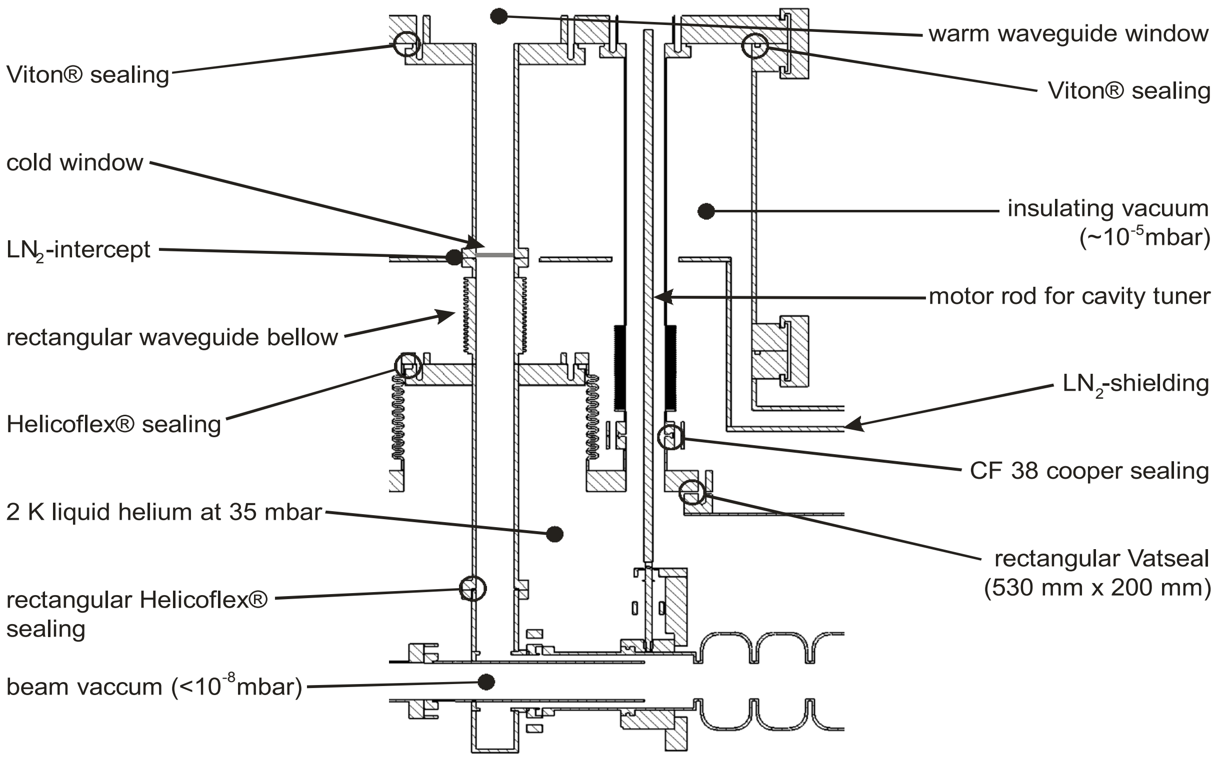

Figure 3: 2-D cut of the cross-section of the waveguide transition line surrounding from the helium vessel through the whole module. The different pressure stages and the position of sealings and other elements are shown.

Design of the New Cryostat

In the current design, the rf transmission line to the power couplers has a diameter of only 21 mm. For the new couplers, a WR-284 waveguide (cross area 72×34 mm^2) has been chosen. Accordingly the existing cryostat-module had to be modified:

The cavities together with their tuners and the couplers are located inside the helium vessel. The vacuum inside the beam-pipe is below 10^{-8} mbar, while the pressure in the liquid helium is at 35 mbar (2 K operation). The thermal shield between the helium vessel and the outer vessel is cooled by liquid nitrogen. Together with the insulation vacuum of 10^{-5} mbar and some 20 layers of super-insulation a minimum heat transfer is ensured (being 4 W per cryo-module currently).

The actual design consists of a complex waveguide which will be flanged to the coupler. Welded to this waveguide is a circular flange sealing the helium vessel. The counter-flange provides a bellow to compensate small vertical and angular displacements while oversized holes are planned to have additional freedom in the horizontal direction. To avoid vacuum forces on the coupler this bellow can be fixed by threaded rods.

To seal between insulating vacuum and atmospheric pressure Viton® gaskets are intended. To keep the static heat losses per transition line below 0.4 W it has a thermal intercept to the nitrogen-shield behind the waveguide bellow. Furthermore, a cold waveguide window could be installed at this position to reduce the heat radiation from the ambient window to be installed outside the cryo-module.

Figure 3 shows the cross-section of the module allowing an insight to the positions of the gaskets, bellows and the different pressure vessels. The big apperture of the helium vessel has to be sealed by a customized VATSEAL® gasket. An additional tube holds a rod for coarse tuning of the cavity. Its motor is placed outside the module at ambient. In addition, the cabling of the magneto-restrictive (fine-) tuner and other electrics like temperature sensors or heaters are located inside that tube.

POLARIZED ELECTRON SOURCE

To complement the present experimental program with polarized electron and photon scattering experiments a new source for polarized electrons, the S–DALINAC Polarized INjector SPIN, is developed [5]. Therewith, experiments are planned studying parity violation in nuclei or measuring the fifth structure function in electron scattering. With these experiments results obtained at other accelerator laboratories can be extended to lower momentum transfer values.

Test-Stand Set-up

The new source consists of a cathode on a HV platform, a chopper and prebuncher system, a Wien filter and a Mott polarimeter for spin manipulation and polarization measurement. To set-up and test the electron source independent from the accelerator operation of the

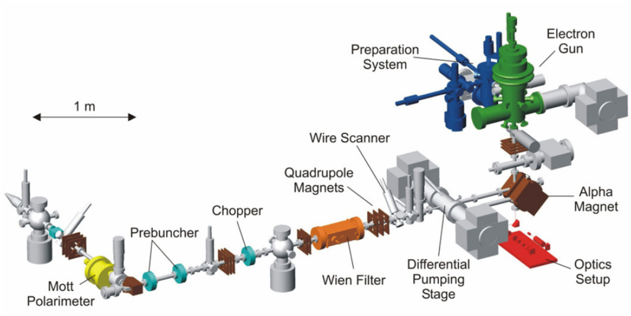

Figure 4: Schematic drawing of the SPIN test-stand. A laser beam focused onto the cathode produces a polarized electron beam by photoemission. After pre-acceleration to 100 keV it is injected into the horizontal beam-line where its properties can be studied. The chopper and prebuncher system is currently installed.

source independent from the accelerator operation of the S–DALINAC, an offline-test-stand has been built.

Figure 4 gives an overview about SPIN. The electrons are produced inside an ultra-high vacuum chamber at a GaAs cathode. For the first tests, bulk GaAs cathodes were used, whereas strained-superlattice cathodes will be used for regular operation. A laser beam is focused from an optics setup below the electron source onto the photocathode and produces the electrons by photoemission. These electrons are accelerated by the platform voltage to 100 keV and bent by an alpha magnet into the horizontal beam-line, where the beam properties can be measured. The whole design is based on the MAMI polarized source [6], but is compared to it more compact due to the limited space in the accelerator hall.

Recent Results

After extracting the first beam, the transverse properties were measured using a wire scanner. The beam profile was determined to have approximately a gaussian shape with an x/y beam radius of .44/.41 mm, respectively. The normalized transversal emittance has been determined to $\varepsilon_{n,x} = (0.146 \pm 0.037)$ mm mrad and $\varepsilon_{n,y} = (0.197 \pm 0.089)$ mm mrad respectively being comparable with the MAMI source. The beam current reached so far was 3 µA.

The polarization of the electron beam was measured by Mott scattering where one uses the effect that the Coulomb potential has a term which is proportional to the scalar product of the angular momentum and the spin of the incident electron (spin-orbit interaction). This results in a right-left asymmetry of the angular distribution of the scattered electrons which is proportional to the polarization P of the electron beam. The Mott polarimeter used houses four silicon surface barrier detectors which are oriented in two perpendicular scattering planes to measure both transverse polarization components simultaneously.

As targets, self-supporting gold foils of the thickness in the range from 42.5 nm to 500 nm are used. From the left/right asymmetry measured, the degree of polarization was determined to be (33.4±1.6)% which agrees very well with common values for bulk GaAs cathodes. For the superlattice photocathode to be used during accelerator operation, the polarization was determined to be (72.1 ± 2.1)%.

SUMMARY AND OUTLOOK

Currently, the design of the cryo-module for the power upgrade is finalized. The chemical treatments for the waveguide couplers are underway and three new cavities have been ordered to complete the module (one cavity spare). Including tests of all components and completion of construction, the timetable aims for a first test in spring 2009.

At that time, the installation of the polarized electron source and its subsystems at the S–DALINAC accelerator vault is planned. Currently, the test stand is completed by adding the chopper and prebuncher system and improvements on the laser system to increase the beam current are pursued.

First results of both upgrade projects, the polarized source and the power upgrade of the injector are expected in late summer 2009.

REFERENCES

[1] A. Richter, "Operational experience at the S-DALINAC", EPAC'96, Sitges (1996) 110.

[2] J. Auerhammer, R. Eichhorn, H. Genz, H.-D. Graef, R. Hahn, T. Hampel, C. Hofmann, J. Horn, C. Luettge, A. Richter, T. Rietdorf, K. Ruehl, P. Schardt, V. Schlott, E. Spamer, A. Stascheck, A. Stiller, F. Thomas, O. Titze, J. Topper, T. Wesp, H. Weise, M. Wiencken, T. Winkler, "Progress and status of the S-DALINAC", SRF'93, Newport News (1993) 1203.

[3] M. Kunze, W.F.O. Müller, T. Weiland, M. Brunken, H.-D. Graef, A. Richter, "Electromagnetic design of new rf power couplers for the S-DALINAC", LINAC '04, Luebeck (2004) 736.

[4] J. Auerhammer, H. Genz, H.-D. Graef, V. Huck, C. Luettge, A. Richter, T. Rietdorf, P. Schardt, E. Spamer, K. Rühl, A. Stascheck, F. Thomas, O. Titze, J. Toepper, H. Weise, "Latest of the Superconducting Darmstadt Electron Accelerator S-DALINAC", SRF'91, Hamburg (1191) 110.

[5] C. Heßler et al., "Status of the Polarized–Electron Gun at the S–DALINAC", EPAC'06, Edinburgh (2006) 3173.

[6] K. Aulenbacher et al., "The MAMI source of polarized electrons", Nucl. Instrum. Methods in Phys. Research A 391 (1997) 498.