LATEST DEVELOPMENTS AT THE S-DALINAC*

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Abstract

Presently, at the S-DALINAC several developments are in progress to improve on its beam quality as well as on its general reliability.

A concept for a new modern uniform control system is presented. It will be either a commercial system with industrial standards or a corresponding proprietary development to replace the existing over years grown system and to simplify, fasten and standardise maintenance and beam operation. Also a concept for a new rf control system for the superconducting accelerating structures is discussed. To improve the energy spread of the electron beam from presently 50 keV (FWHM) by a factor of 3-5, a hybrid system (fast analogue feedback system and DSP based unit) is under development. To study injector beam dynamics, a new fast computer code (V-Code, which was first used successfully at the DESY TTF) was implemented. A new experimental setup was installed at the S-DALINAC to generate a narrowly collimated, low background bremsstrahlung beam with end point energies up to 130 MeV for an experiment which uses Compton scattering off the nucleon to measure its polarizability. Finally, results from a first attempt to increase the unloaded Q value of niobium cavities by moderate “in situ” heating are presented.

1 INTRODUCTION

The S-DALINAC [1] is a recirculating superconducting (sc) linear electron accelerator. It provides high quality continuous wave (cw) electron beams with energies in the range from a few MeV up to 130 MeV and currents up to 20 µA for different experiments in the fields of nuclear and radiation physics. It also serves as the driver for the Darmstadt Free-Electron-Laser (FEL) in the near infrared.

After a brief introduction into the accelerator and the associated experimental facilities (sect. 2), the present proposals for a new accelerator control system (sect. 3) and an improved rf control system (sect. 4) are shown, as well as the adaptation of a new tracking formalism, the V-Code [2], for the injector of the S-DALINAC (sect. 5). Beyond this, a new experimental area is described, which was installed to create a high energy Bremsstrahlung beam for nuclear structure experiments (sect. 6), followed by first experience with moderate “in situ” baking of niobium cavities (sect. 7).

2 ACCELERATOR

At the S-DALINAC (see fig. 1) the electrons from a thermionic gun are preaccelerated electrostatically to 250 keV. They get the necessary 5 ps time structure with a repetition rate of 3 GHz in the following chopper-pebuncher section. Alternatively a 600 MHz subharmonic chopper-prebuncher section together with a pulsed electron emission provides a 10 MHz time structure with a bunch charge of 6 pC for FEL operation. The sc injector linac consists of a short cryo module, housing a two-cell capture cavity (ß = 0.85) and a five-cell cavity (ß = 1.0), and a standard cryo module with two 20-cell cavities. With accelerating gradients of 5 MV/m the injector can deliver an electron beam with an energy up to 11 MeV. These electrons can then be used for low energy radiation or nuclear resonance fluorescence experiments. Alternatively they can be bent by 180° for injection into the main linac which consists of 4 standard cryo modules, each containing two 20-cell cavities, so the main linac provides a maximum energy gain of 40 MeV. Two recirculating beam lines allow 3 passes through the main linac, resulting in a maximum beam energy of 130 MeV. After each pass the beam can be extracted to the experimental hall for use in different experiments like electron scattering, high energy radiation experiments or nuclear structure physics. Alternatively the beam can be used as a driver for the infrared FEL, which is situated in a bypass section of the first recirculation.

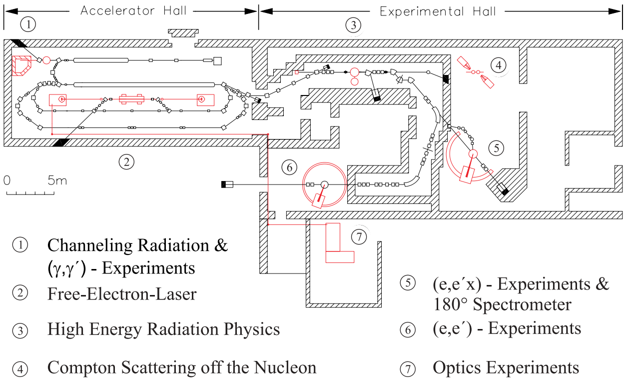

Figure 1: Overview of the S-DALINAC and the experimental areas.

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3 NEW MAIN CONTROL SYSTEM

The existing accelerator control system at the S-DALINAC is based on VME bus computer with a DEC Alpha CPU running under WindRiver's VxWorks acting as the control computer, while the user interface runs under VMS on a VAX station. Both systems are interfaced by Ethernet with the communication over an in house developed protocol called LCP (Linac Control Protocol). Different events presently lead to the situation that there is no support for neither hardware nor software.

One aim of the new control system is to recycle as many of the existing magnet power supplies (some 200) as possible. Since most of those devices have a proprietary parallel interface, an adaptor to a standard interface using a micro controller with an attached field bus controller has been developed.

The connection between the devices and the control computer has to be simple and fail-safe. This led to the decision of using the Controller Area Network (CAN), predominantly used in the automotive industry, as field bus. A normal PC will be used as control computer. Different clients have access to all relevant data stored in its database, like e.g. accelerating settings, through IP. This allows e.g. online simulations using codes like V-Code (see sect. 5). The most important user interfaces at the S-DALINAC are the in house developed knob boards. They consist of four rotary encoders, each having two related displays and one push button for showing the device's name and its set value and toggling between a dial and a set mode. The modification of this hardware interface to CAN is currently in progress. A Graphical User Interface (GUI) for changing all settings will be designed using National Instrument's LabVIEW.

4 NEW RF CONTROL SYSTEM

The present rf control system at the S-DALINAC works now for some 12 years without major problems, but the achieved energy spread of $\pm 10^{-3}$ (fwhm) is larger than the design value ($\Delta E/E \leq \pm 10^{-4}$ (fwhm)). A new system (see fig. 2) is presently under development to accomplish the design figure.

Therefore the rf part of the control system has to be improved to measure the probe signal more accurately. The fast growing market of cellular phones and wireless LAN applications yields a wide variety of integrated rf components like amplitude detectors or I/Q vector modulators and demodulators. Unfortunately most of those components are specified up to a frequency of 2,7 GHz only. Because of the advantages of using integrated components in the new rf control system, their properties are presently investigated at a frequency of 3 GHz are in progress. Additionally the control loop will be improved by applying feed forward corrections besides feedback.

The idea of a purely digital control loop as discussed currently at different accelerator labs [3] was resigned in favour of a hybrid system, consisting of a fast analogue proportional feedback loop with an attached DSP based diagnostics unit by modifying the setpoints for the analogue control loop. The DSP is able to apply feed forward corrections. In addition to the probe signal, signals like I and Q of forward and reflected power, will be fed to the diagnostics part of the RF control to get more information on the different parts in the self-excited loop. With these signals, online measurements of e.g. the loaded Q and the coupling strength become possible.

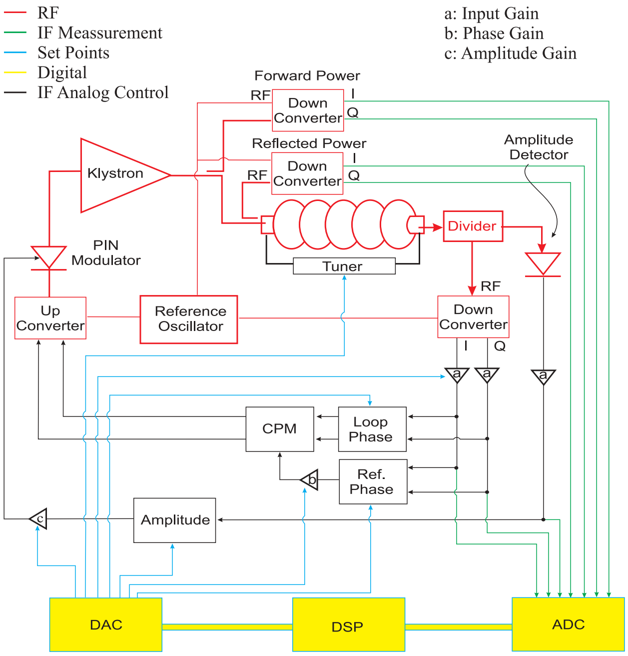

Figure 2: Block diagram of the new rf control system.

5 V-CODE

V–Code [2] is a new beam dynamics simulation that represents the beam by the model of ensembles [4] consisting of six centroid and 21 correlation parameters. The code, which tracks only the ensemble through the accelerator, is much faster than conventional tracking codes that calculate the trajectories of several thousand macro particles. Compared to matrix-based approaches V-Code is more versatile, covering a wider application field without significant speed penalties. These features make V-Code an attractive alternative to traditional beam dynamics simulations. V-Code will support the accelerator operator with online information about the longitudinal and transverse phase space distributions of the beam at any position along the accelerator, calculated from the current machine settings.

At the S- ALINAC V-Code was implemented as a pilot scheme to cover the injector [5], which consists of a prebuncher cavity, a magneto static lens, eleven steerer magnets, one dipole, two quadrupole magnets, and three superconducting cavities. Running on an AMD Athlon™ 800 MHz CPU V-Code needs about 5 seconds to calculate and visualize the beam dynamics of the injector. Currently as a starting ensemble the beam properties at the chopper iris are calculated by a separate simulation.

6 BREMSSTRAHLUNG BEAM SETUP

At the S-DALINAC an experiment was set up to measure the electric and magnetic polarizability of the nucleon. A new experimental technique will be used to determine the energy dependence of the differential cross section of elastic (γ,p) and (γ,d) scattering in a model-independent way for bremsstrahlung photons with energies from 20-130 MeV. In former experiments tagged photon beams were used [6] and only the angle and energy of scattered γs were measured. In this experiment bremsstrahlung photons are used and angle and energy of the recoiled nucleons are measured with a special high pressure ionization chamber filled with hydrogen, which is used both as target as well as detector gas, at 100 bar. This increases the luminosity and lowers the background considerably.

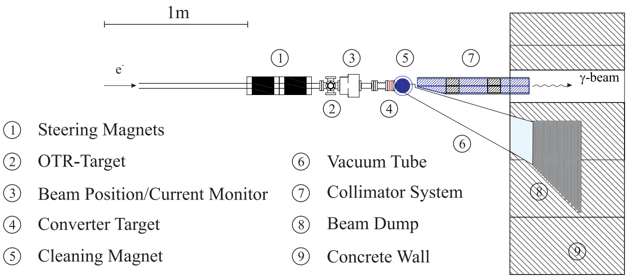

Figure 3: New bremsstrahlung beam setup.

The electron beam from the accelerator with an energy up to 130 MeV and a current up to 10 µA will be manipulated in phase space by a quadrupole triplett and several steerer magnets to satisfy the requirements of the experiment. Part of the electron beam will be transformed into a highly intensive photon beam by a bremsstrahlung target (see fig.3) made of gold with a thickness of 0.3 mm (10% radiation length) and a diameter of 2 mm. The precise position of the electron beam will be determined with optical transition radiation (OTR) coming from a thin aluminium foil, which can be moved into the electron beam. During the experiment the beam position will be controlled continuously with the help of a position- and current-sensitive rf monitor system. After passage through the target a dipole magnet deflects the slightly divergent electron beam out of the propagation direction of the bremsstrahlung into an air cooled beam dump, composed of aluminium and lead and placed in the wall of the concrete shielding, allowing monitoring the beam current. Behind the dipole magnet the bremsstrahlung cone will be collimated into a 10 x 20 mm^2 photon beam. The collimator consists of several layers of lead with different slit parameters and some additional layers of polyethylene for shielding of fast neutrons produced in the collimator. The collimated photon travels through a transport tube in the concrete shielding to be used for the scattering experiment.

7 FIRST EXPERIENCE WITH MODERATE „IN SITU“ HEATING

The ten standard niobium cavities of the S-DALINAC consist of 20 cells, they are operated at a frequency of 3 GHz and a temperature of 2 K. The unloaded Q values of the cavities installed in the accelerator do not exceed $1\cdot10^9$ and a slight deterioration over the years has been observed. Several laboratories report a significant increase in unloaded Q values after a moderate (100 – 150°C) heat treatment (see e.g. [8]).

Therefore, during the last warm up period the cavities of the injector linac were heated up to 55°C using a heater installed inside the helium vessel of the accelerator. Thus, the outside of the cavities was surrounded by helium and the inside was under high vacuum conditions. During the heating process the pressure inside the cavities increased by a factor of two which may be due to dissolving contaminants from the surface. After cool down the Q values of all injector and main linac cavities where measured and compared to a measurement two months before. The average Q value of the three injector cavities had improved by 8% whereas the average Q value of the eight main linac cavities had deteriorated by 5%. This first result gives a hint that even such a moderate heating may be able to improve the Q values of our cavities by e.g. removing adsorbed gases. To benefit from the method in the future separate heaters with good thermal contact to the cavities will be installed in each cryomodule to increase the heating temperature; also the mass spectrum of the residual gas will be observed during the heat treatment.

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