S-DALINAC Status Report *

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Abstract

Since commissioning the superconducting electron accelerator S-DALINAC has produced some 9500 hours of beamtime. Presently the highest energy achievable in true cw operation is 85 MeV, and 50 % of the beam current are contained in $\Delta E/E = \pm 2.5 \cdot 10^{-4}$. In 1994 and early 1995 all the superconducting cavities were taken out of the accelerator, chemically treated and reinstalled after having been equipped with new rf input and output couplers. An additional, $\beta = 0.85$, 2-cell capture cavity has been installed in the injector linac. Unloaded Q values of all cavities presently range from $8 \cdot 10^8$ to $2 \cdot 10^9$, while all gradients exceed 5 MV/m, some cavities reach 10 MV/m. In particular in connection with the Free Electron Laser, numerous beam diagnostics stations have been installed, which, making use of transition radiation, serve for the determination of transverse and longitudinal beam parameters. The electron bunch length was determined to be 4.0 ± 0.25 *ps* with a charge of 4 pC per bunch at 10 MHz repetition rate.

1 INTRODUCTION

Starting with the third workshop on rf superconductivity held at Argonne, Ill., USA in 1987 [1], reports on the status of the S-DALINAC were given regularly and can be found in the proceedings (see e.g. [2]) of these workshops. Therefore this report covers the period since the 6th SRF workshop, held at CEBAF, Newport News, VA., USA in 1993. In Sec. 2 the operation or the accelerator is summarized and beam properties for the different types of experiments, performed at the S-DALINAC, are discussed. Section 3 gives an overview of the performance of the sc cavities, presently installed in the accelerator, while in Sec.4 new installations are described. The present status of the Free Electron Laser (FEL) is briefly summarized in Sec.5, together with improved diagnostics for both, transverse and logitudinal properties of the electron beam.

2 ACCELERATOR OPERATION

The S-DALINAC produces electron beams, covering a wide range of energies and currents, to serve the different nuclear and radiation physics experiments, performed at the facility. At energies below 10 MeV beams from the injector linac are used for nuclear resonance fluorescence (NRF) experiments [3] and for the investigation of channeling radiation (CR) [4] and parametric X-rays (PXR). Beam energies ranging from 22 to 85 MeV have been used to investigate CR at higher energies [5] and for single arm (e,e') and coincidence (e,e'x) electron scattering experiments. While all these measurements use a cw beam with a bunch repetition rate of 3 GHz, the FEL [6] requires a high peak current of 2.7 A. In order to achieve this a subharmonic injection is used which generates bunches with a charge of 6 pC at a repetition rate of 10 MHz. For driving the FEL, the main linac is used in single pass operation. Table 1. gives a brief summary of beam characteristics so far produced by the S-DALINAC. Since commissioning, the accelerator has produced some 9500 hours of beamtime. Presently the energy spread of the beam, produced in a three pass operation of the main linac (E = 85 MeV), is such that 50 % of the current are contained in $\Delta E/E = \pm 2.5 \cdot 10^{-4}$.

Table 1: Beam Characteristics

Experiment	**Energy** (MeV)	**Current** (μA)	**Mode**
NRF	2.5 - 10	40	3 GHz, cw
CR, PXR	3 - 10	0.01 - 10	3 GHz, cw
CR	35 - 75	1	3 GHz, cw
(e,e'), (e,e'x)	22 - 85	5	3 GHz, cw
FEL	32 - 38	1.5 A_{peak}	10 MHz, cw

3 CAVITY PERFORMANCE

In fall of 1993 two ceramic windows of rf feedthroughs had developed very strong leaks. This incident caused the unloaded Q of most of the cavities to drop to the lower 10^8 range and as a consequence (due to the very low refrigerator power of only 100 W at 2 K) limited the beam energy to some 50 MeV. Therefore it was necessary to apply a chemical treatment to the inner surface of all cavities. Two maintenance periods were scheduled (one in fall of 1994, one in early spring of 1995) to take the cavities (ten

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* Supported by BMBF under contract numbers 06 DA 655 I and 05 345 EAI 3.

20-cell cavities plus one 5-cell cavity) out of the accelerator cryostat, treat them chemically and reinstall them. Two different cleaning methods were applied: The help of DESY enabled us to use the new TTF [7] infrastructure (chemistry and clean room conditions). There two of the 20-cell cavities were first ultrasonically cleaned, then 1 μm of the inner surface was removed by BCP (1:1:2), and finally the cavities were rinsed with 18 $M\Omega cm$ water and dried in a class 10 clean room. All the other cavities were treated at our laboratory in a slightly different way. They were also cleaned ultrasonically, then the inner surface was oxidized by HNO_3. After removal of the oxide by HF the cavities were also rinsed with 18 $M\Omega cm$ water and dried by a flow of dry filtered nitrogen through the cavities, heated to $70°C$. As a result the unloaded Q of all cavities increased to a range from $8 \cdot 10^8$ to $2 \cdot 10^9$ and all cavity gradients after a short cw rf processing exceed 5 MV/m, some of them reach 10 MV/m. The fact, that also the cavities treated at DESY do not reach or exceed a Q_0 of $3 \cdot 10^9$ is an indication that the present limitation in Q_0 is not due to insufficient cleanliness. This is supported by the fact that for the range of gradients mentioned above no drop in Q_0 due to field emission was observed. We therefore presently investigate whether insufficient magnetic shielding or remnants of humidity inside the cavities are responsible for the limitation in Q_0.

4 INSTALLATIONS

Together with the replacement of the sc cavities, several new components were installed in the accelerator. All cavities are now equipped with new rf couplers. A prototype of the new variable rf input couplers and two new probe couplers had been tested in the S-DALINAC for more than one year and their performance has been reported [2] earlier. The variability of the new rf input couplers ($1 \cdot 10^7 \leq Q_{ext} \leq 10^{10}$) has proven to be very useful, since it allows optimum matching to different beam loading or microphonic perturbation conditions. In the very front end of the injector linac a new sc 2-cell capture cavity has been installed. It has a reduced phase velocity of $\beta = 0.85$ and provides an energy gain of 350 keV when operated at a gradient of 5 MV/m. Since this cavity had to be squeezed into the existing cryostat (in front of the 5-cell cavity), special rf couplers had to be developed. Coarse tuning is accomplished via a mechanical lever device, driven by a stepping motor, located inside the helium vessel. For fine tuning two magnetostrictive translators are used. In order to improve on the beam transport properties, the long straight section of the main linac has been equipped with four quadrupoles. One of them is located at the entrance of the linac, outside the cryostat. The remaining three quadrupoles had to be installed inside the cryostat of the main linac. Therefore their coils were fabricated from superconducting wire (NbTi filament, surrounded by copper). The poles and return chokes are made from laminated CRYOPERM 10. The effective length amounts to 56 mm at a maximum gradient of 1.5 T/m. After cooldown it turned out that the cooling of the quadrupoles (they are located between the helium vessels of adjacent cryomodules) is not sufficient to reach temperatures below 20 K. Nevertheless the resistance of the coils becomes so low ($< 1\Omega$) that the quadrupoles can be operated at their nominal gradients with a dissipation of less than 1 W per quadrupole.

5 STATUS OF THE FEL

For a successful operation of the FEL rather strict requirements are put on both, transverse as well as longitudinal properties of the electron beam. During the last two years, beam diagnostics could be improved significantly in both respects, mainly by making use of transition radiation in the visible and in the very long wavelength range. A description of this type of diagnostics, applied to the determination of beam emittance, energy spread, and bunch length is given in a seperate contribution to this workshop [8]. The rather sophisticated determination of the bunch length is discussed in detail elsewhere [9]. In a beamtime spanning November and December of 1994 and January 1995 significant progress towards stimulated emission of the FEL was achieved. Due to the diagnostics methods mentioned above it was possible for the first time to measure the bunch length to be $4.0 \pm 0.25 ps$, a result which was independently confirmed by a streak camera measurement, using a type C 5680 camera, rented from Hamamatsu. This figure is still a factor of two above the design goal, but once the bunch was compressed to 4 ps, clear indications of coherent spontaneous emission were observed for the first time. In the meantime more diagnostics stations have been installed, in order to control the process of bunch compression along the entire injector. Also online control of the energy spread is foreseen, since the small signal gain of the FEL is very sensitive to this beam property as well. For the optical cavity significant improvement was achieved in the meantime: A new set of cavity mirrors with higher reflectivity will assure a Q value of 100. At the same time the new mirrors (due to longer focal length) will yield a considerably better stability of the cavity. Finally a much more accurate method for the determination of the optical cavity's length has become available in the meantime, and should enable us to preset the cavity length to within less than 1 mm. With all these improvements and the experience from the last beamtime we expect the FEL to show stimulated emission early in 1996 when the next beamtime is scheduled.

6 ACKNOWLEDGEMENT

It is a pleasure to thank H.Lengeler and H.A.Schwettman for many fruitful discussions and numerous advice. The help of S.Calatroni in the production of rf couplers is greatfully acknowledged. We are very much indebted to many colleagues at DESY, in particular to A.Matheissen, O.Peters, and S.Wolff for their tremendous help and support. We take the opportunity to thank H.Gaiser and the galvanic workshop at GSI, as well as the mechanical workshop at CERN, for their continuing help.

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