Status of the S-DALINAC and experimental developments [*]

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Abstract

During the last two years the superconducting linear electron accelerator S-DALINAC was operated routinely and was used successfully for a wide spectrum of experiments. Additionally, further developments at the accelerator were accomplished. By means of new rf couplers it became possible to achieve a variable and reproducible coupling strength to the accelerating cavities. The operation of the FEL requires a special time structure of the electron beam with very high peak currents. This was realized during the last year by means of a pulsed electron gun and a subharmonic chopper-prebuncher system. Thus, all necessary developments for the first lasing of the FEL are completed. Spontaneous emission and its amplification at different energies was already observed. A new 180 degree electron scattering facility was installed at the QCLAM spectrometer in spring 1993 and first measurements were performed in the beginning of this year. In order to improve the handling of the detector system, new multi wire drift chambers were developed. The major part of the available beamtime was used for coincidence electron scattering experiments. Resonance fluorescence measurements as well as channeling radiation experiments were continued.

1 PRESENT STATUS AND DEVELOPMENTS

During the last two years the S-DALINAC [1,2] was operated routinely and electron beams for various atomic, nuclear, and radiation physics experiments were delivered. At energies below 10 MeV the low energy experimental area was used for nuclear resonance fluorescence experiments (γ,γ') [3-6] as well as for the production of channeling radiation [7] and parametric X-rays. Electron beams with higher energies (25 – 80 MeV) were delivered for the free-electron laser [8], for high energy channeling radiation experiments [9,10], and – mostly – for single arm (e,e') electron scattering experiments as well as coincidence experiments (e,e'x) [11,12] at the QCLAM spectrometer.

The major problem presently is the fact that the superconducting cavities exceed their design gradient of 5 MV/m, but do not achieve the design Q-value of 3×10^9. Additionally, they decreased last autumn, when two cold rf windows developed massive vacuum leaks. This reduction in Q together with the very limited capacity of the liquid Helium refrigerator (100 W at 2 K) presently limits the beam energy. We are preparing a very clean chemical treatment of the cavities, which will (by removing some μm of material) generate a new niobium surface, a measure that should raise the Q-values into the 10^9 range.

Besides the routine operation of the accelerator and its improvements, several new developments were tested successfully and were partially installed in the accelerator as described in the following chapters.

1.1 The new 2-cell capture cavity

First of all, a newly designed superconducting capture section consisting of a β-graded 2-cell cavity is ready for installation. It will be placed in front of the present 5-cell capture section and will prevent phase slippage in the following cavities. Calculations exhibit improved beam dynamics and an energy upgrade for the injector, which is important for the experiments located in the experimental area behind the injector. To avoid additional feedthroughs into the cryostat, a new concept for the frequency tuning has been developed. It consists of a stepper motor working at LHe temperature, which drives a mechanical coarse tuner resulting in a tuning range of 4 MHz. The fine tuning is performed by magnetostrictive elements similar to those used for the standard 20-cell cavities. The cavity

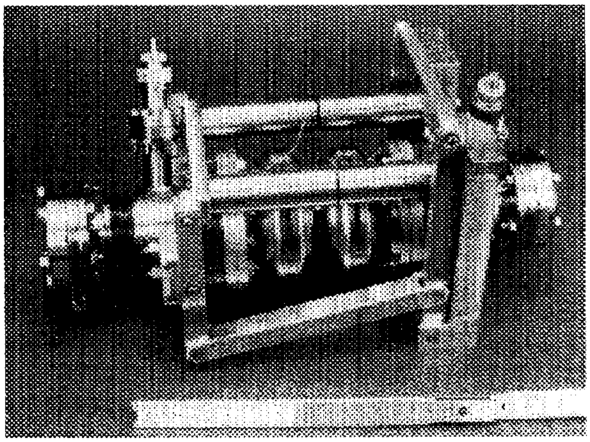

Figure 1: The new superconducting 2-cell capture cavity within its mechanical tuning device.

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with couplers and tuner is shown in Fig. 1. The installation will be done in the next shutdown period in July of this year.

1.2 *The new rf couplers*

A prototype of new rf couplers is in successful operation since more than one year. Its geometry is shown in Fig. 2.

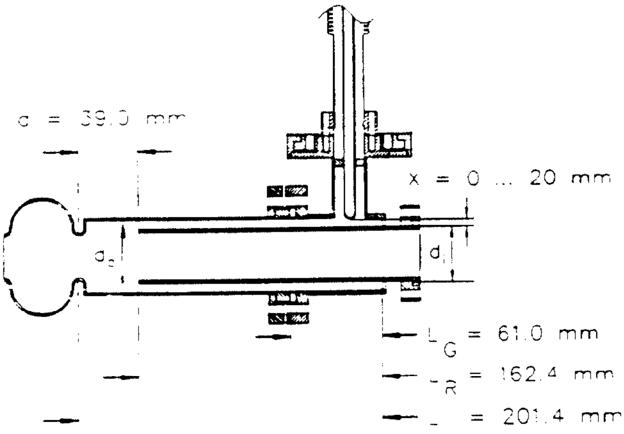

Figure 2: Geometry of the new rf input coupler.

It allows a reproducible setting of the coupling factor from the outside of the cryostat to match the beam requirements. This is achieved by a movable antenna guided by an rf bellow feeding the klystron power into the cavity. The operating range allows large coupling factors ($\beta \approx 100$) for high current operation are possible as well as $\beta = 1$ for diagnostics, which is essential for the determination of the unloaded Q-values of the cavities. In Fig. 3 the variation of the external quality factor is given as a function of the distance between antenna and coupling resonator. The superconducting niobium surface also helps to minimize the heat load into the liquid Helium, which is crucial for high energy operation of the accelerator. The serial production of the couplers was performed by the CERN workshops, they will be installed in July of this year.

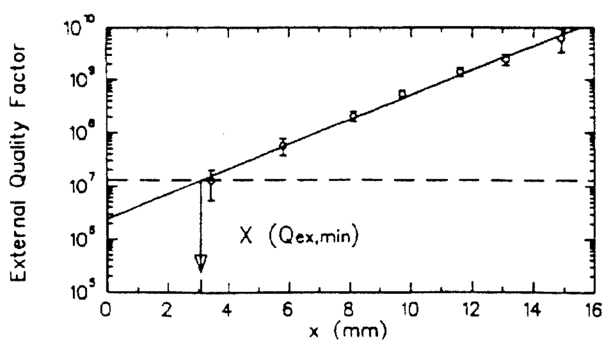

Figure 3: Measured external quality factor of the new rf input coupler at 2 K as a function of the distance between antenna and coupling resonator.

1.3 *The new multi wire drift chambers*

As a replacement for the first multi wire drift chambers that were successfully operated in the QCLAM spectrometer for several years, a new set of multi wire drift chambers was built. With the experience made in the operation of the old chambers, several improvements could be made. Thinner Tungsten-Rhenium wires (15 μm) with selected material grades of highest strength an best roundness were used. The material of the support frames was replaced by another material with less surface roughness for better positioning precision. The absolute positioning was further improved by two precision combs, which were used during manufacturing. The gas sealing foils are made of Aramid films providing a much lower oxygen and water vapour penetrability. The tensile strength of the high voltage foils was improved by using polyimide films. For the next generation, a new wireframe is designed. Single wires are soldered on copper foils, instead of gluing the whole plane in one step. This enables the replacement of single broken wires, thus improving the availability of the entire detector system.

2 STATUS OF THE FREE-ELECTRON LASER

The 10 MHz high current injection for FEL exeriments went into full operation during the last beam time in 1993. Utilizing electron beams with different energies, the pulse structure, charge per pulse and the energy resolution were studied and found to meet or almost reach the requirements needed. The average current used was 60 μA which corresponds to a peak current of the design value of 2.7 A. The injection set-up allows the generation of variable macropulses by switching off the emission of the gun in approximately 200 ns which corresponds to two micropulses. This fast cut-off is needed for a measurement of the ringdown time of the optical cavity of the FEL to determine its Q-value.

The spontaneous emission of the FEL was investigated carefully. Optical spectra at electron energies of 32.8 and 38.4 MeV and different magnetic field strengths of the undulator have been taken. A significant analysis could be deduced from the 3rd harmonic of the spontaneous radiation. The results of simulations indicate that the spectra can be explained by an energy spread $\Delta E/E$ of 0.3% of the electron beam [8]. This is five times larger than the energy spread measured in cw operation of the accelarator and seems to be caused by beamloading as an aftereffect of unfavourable tuning of the rf control circuits of some of the accelerating structures. For a better observation of the energy spread an electron spectrometer consisting of a wire chamber and the magnets of the FEL-bypass behind the undulator has been installed in front of the FEL beam dump.

The examination of the power output of the optical spectrum of the undulator showed another result. A length region with distinct amplification of the spontaneuos emission could be established by varying the optical cavity mirror spacing. But the amplification was insufficient to cause a laser start-up. The main reason for this may be a disadvantageous matching of the undulator thus causing a strong betatron oscillation of the electron beam. Such betatron oscillation could be observed by utilizing a movable viewscreen that can be placed anywere in the undulator. To get rid of the betatron oscillation a less sensible electron beam optics for matching the undulator has been designed and set up recently. Two new quadrupole magnets lead to a better defined injection into the FEL-bypass and allow a reduced powering of the following focussing elements. The new concept gives much more flexibility in focussing the electron beam into the undulator.

These improvements being done after the last beam time are prerequisite for the production of laser emission.

3 THE 180° ELECTRON SCATTERING FACILITY

Electron scattering at 180 degrees is a proven technique for investigating the magnetic and transverse electric excitations of nuclei. At 180 degrees, the cross section for longitudinal excitations decreases nearly to zero, greatly suppressing the backgrounds and increasing the sensitivity for transverse transitions. In order to continue the research on these excitations at Darmstadt by taking profit out of this advantage, a new system for 180-degree electron scattering has been put into operation at the S-DALINAC, using the large-aperture QCLAM spectrometer. The schematic layout of the 180-degree system at the S-DALINAC is shown in Fig. 4. The electron beam from the accelerator (upper left corner) enters the bypass system and is injected into the scattering chamber at an angle of 25 degrees with respect to the original beam axis. The separating magnet which is positioned in the centre of the scattering chamber deflects the beam back to the original direction and onto the target. Since the direction of the electron momentum is inverted by 180-degree scattering, the separation magnet separates the backscattered electrons from the incident beam and deflects them into the QCLAM spectrometer.

In April of this year the 180-degree system has been commissioned successfully and first measurements on ^{28}Si, ^{48}Ca and ^{90}Zr were performed. The incident energies varied between 41 MeV and 60 MeV, the achieved energy resolution was in the range of 80 keV.

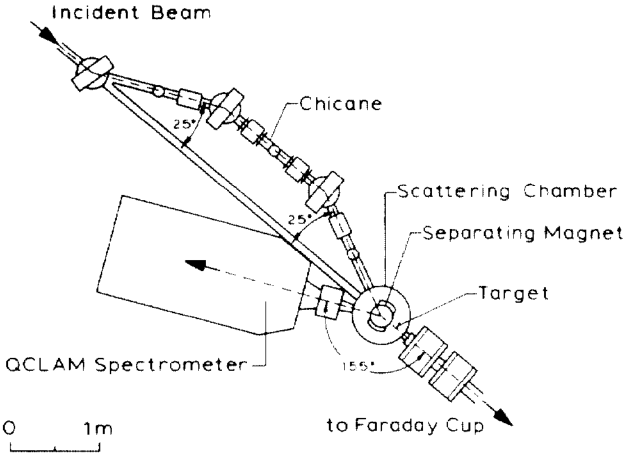

Figure 4: Schematic layout of the 180-degree electron scattering facility.

4 ACKNOWLEDGEMENT

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