INITIAL COMMISSIONING OF THE LISA SUPERCONDUCTING LINAC

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Abstract

The installation of the Lisa superconducting (SC) electron linac was completed in December 91 and the first 90 keV beam was run through the low energy section in the same month. Beam transport optimization has proceeded in the first months of 92 and is described. Acceleration of the beam to 1 MeV through the capture section is reported. The cool-down procedure of the SC cavities has been optimized and is described. Measurements on frequency fluctuations due to bath oscillations and microphonics have been performed and are described.

1. Introduction

The most relevant parameters of the accelerator and FEL experiment are listed in table 1.

Table 1 - Parameter list of the LISA accelerator and FEL

Energy	25	MeV
Bunch length	2.5	mm
Peak current	5	A
Duty cycle	<2	%
Average macropulse current	2	mA
Invariant emittance	10^{-5}	πm rad
Energy spread (@25 MeV)	$2\ 10^{-3}$	
Micropulse frequency	50	MHz
Macropulse frequency	10	Hz
Undulator periods N	50	
Undulator wavelength λ_u	4.4	cm
Undulator r.m.s parameter K	0.5÷1.0	
Radiation wavelength @ 25 MeV	11÷18	µm
Linewidth @ 15 µm	0.5	%

The accelerator has been described in various conferences. We just remind that its main parts are a room temperature injector, composed of a 100 kV thermionic gun, a double chopper at 50 and 500 MHz, a 500 MHz prebuncher and a 1.1 MeV β−graded 2500 MHz capture section and four SC RF cavities [1]. The machine layout is completed by two spectrometers , that allow the analysis of the beam at 1 and 25 MeV energies, and a transport channel to the FEL undulator.

2. The SC linac

The 500 MHz SC linac is composed of four independent cryostats, each housing a 4-cell cavity. The design energy at the linac exit, assuming an average accelerating field of 5 MeV/m, is 25 MeV.

The factory-measured Q_0 of the cavities at the above nominal field has an average value of 10^9 , a factor 2 lower than the design specifications, but no quenching has been observed up to ~ 6 MeV/m. CW operation at maximum field will be prevented by the capability of the refrigerator, but this limitation does not affect pulsed FEL operation with less than 2% duty cycle. Some improvements are also expected after RF conditioning.

2-1 Cryogenic performance of the cavities.

The four cryostats contain an overall mass of about two tons of Alluminium filling bodies to be cooled down. This operation was accomplished successfully in March on all four cryostats simultaneously; it takes about 60 hrs and a typical curve is shown in Fig.1.

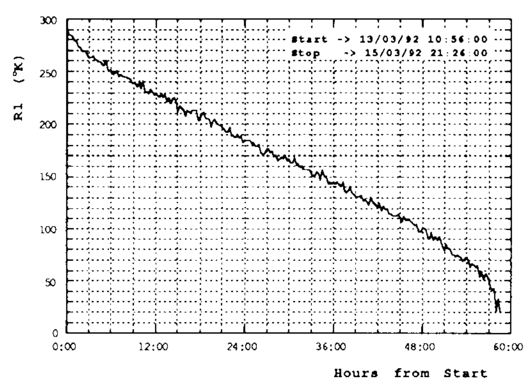

Fig.1- Cool-down curve (four cryostats)

To maximize refrigerator efficiency it is necessary to operate at the limit of relief-valve intervention, i.e. 0.5 bars overpressure.

In a successive cool-down of a single cavity (module #1) , some disturbances were evidenced: a large fluctuation of the LHe level and resonant frequency modulations associated with pressure fluctuations, whose typical spectrum is shown in Fig.2. From tests with accelerometers it resulted that the strongest oscillations were not caused by environmental noise, but were to be attributed to pressure fluctuations inside the cryostat.

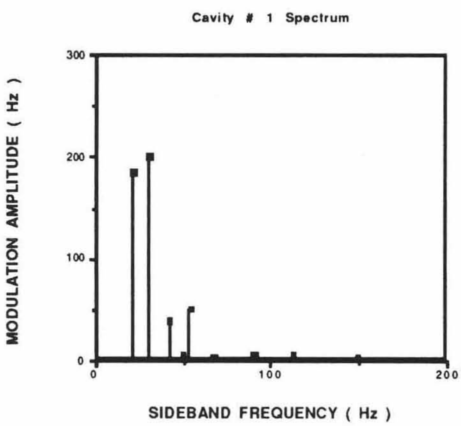

Fig.2- Spectrum of frequency modulation

In July another cool-down on a couple of cavities has been performed to study these phenomena. The level fluctuations were attenuated by thermally loading the cryostats with heating resistors so that the refrigerator, which is proportioned for 300 W cooling capacity, could have a better working point. The pressure oscillations were practically absent on module # 2 , while they seemed to be still present on module #1 , although smaller. They are not accompanied by a relevant increase in power dissipation , therefore it is not sure that their origin is thermo-acoustic , as their line spectrum seems to suggest.

A calorimetric method for measuring static losses and eventually high field Q_0 has been preliminarly tested. It consists in shutting off the LHe flux to the cryostat and measuring the rate of variation of LHe volume in the container for various heat loads supplied by heating resistors. A typical set of values is shown in table 2. The errors of this method are due to the uncertainty in the level probe position and transient fluctuations that are more relevant on short measurement time intervals.

Table 2 - Behaviour of cryostat #1 cut-off from the refrigerator

Heat load	LHe vol. dec.	Extim. power
Static losses	3 lt / 15 min	8.5 W
+ 11 W	16 lt / 30 min	22.5 W
+ 24 W	9 lt / 10 min	37 W

3. Commissioning of the injector

Gun performances were already measured in a separated test bench, and previously reported [2].

The chopper, prebuncher and buncher cavities have been RF conditioned without difficulty, but the first acceleration tests have been made with the buncher alone, because the circuit that drives synchronously the various elements was not ready.

The initial operation was the transport of a 100 mA, 75 keV, 0.35 ms beam from the gun to the capture section, with the aid of two fluorescent screens and two transformer current monitors.

This current value is near to the required value for the FEL optimized operation. A lower current would require a more critical optics due to the strong focusing of the gun electrodes resulting in a large beam divergence at the gun output.

At the beginning, geometric misalignments, the presence of stray transverse fields and an unperfect compensation of the earth's field prevented us to obtain a sufficient transport efficiency.

After a careful realignment, a correction of the iron yokes around the solenoids and the adding of a couple of steering coils, we easily succeeded in transporting about 40% of the beam.

The resulting current is much larger than that acceptable by the buncher without the chopper selection, so we did not made any effort to increase this value, on the contrary we reduced the current to about 10 mA by defocusing the beam and using the vacuum pipe as a beam scraper.

This beam was successfully transported through the buncher fed with 15 kW of RF power, corresponding to an accelerating voltage of .9 MV. The image of the beam on a screen placed just after the buncher is shown in Fig. 3.In the image is evidenced an asymmetry due to the dispersive nature of the dipole fields of the steering coils.

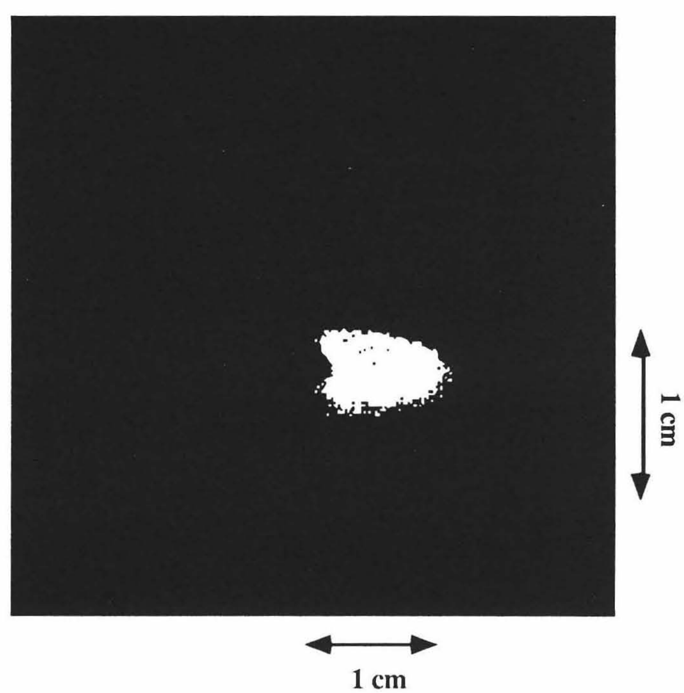

Fig.3- Image of the beam on a 45° tilted screen after the 1 MeV buncher

The expected energy spread does not allow to transport further a substantial part of the beam.

We are now performing accurate measurements of the effects of all magnetic elements on the beam to fully characterize the trajectory and optimize the transport efficiency.

These preliminary commissioning operations have made full use of the machine control system, allowing its first "on field" test. The control system actually consist of six CPUs (M68K based) distribuited along the machine and two Apple MacIIfx as the operator's consoles. Neglecting the problems related to the obvious "bugs" of the software, the control system [3] is now showing its flexibility due to the modularity of the structure, a helpful feature especially during the accelerator's commissioning. This, together with the simplicity and the power of the environment we chose for the console's software (LabVIEW from National Instruments), have made possible to implement with the minimum effort special tools for the injector commissioning and SC Cavities cool-down operations.

The informations flowing through the system's levels and the velocity of the reaction to events is as good as expected because of the use of busses instead of a network. This feature could even be improved with an optimization of the software performing the communication protocols.

At least seventy per cent of the optical elements of the machine are now operated via the control system together with the monitoring of diagnostic instrumentation (current monitors, BPM, CCD camera, etc.) and other relevant machine parameter (RF, vacuum, interlocks system, etc.).

The next steps in machine commissioning will be to set in operation the chopper and prebuncher . This will also consent the use of the strip-line transverse position monitors that are sensitive to the 50 MHz component of the beam. They are the only position monitors available along the 1 MeV arc.

Acceleration through the SC cavities is planned for the beginning of next year.

References.

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[2] - M.Castellano, S.Kulinski, P. Patteri, F. Tazzioli, M. Vescovi, N. Cavallo, F. Cevenini: Commissioning and Performance of a low emittance, Long Pulse Electron Gun for the SC Linac LISA. to be published

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