Early results of beam acceleration in the SC linac LISA

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Abstract

The 25 MeV, 2 mA SC linac LISA, equipped with 500 MHz bulk Nb SC cavities, has been constructed and the beam has been accelerated through the full structure and analysed with a spectrometer. Preliminary results on beam intensity and energy distribution, performance of the cavities and beam loading are presented.

1. INTRODUCTION

The construction of the superconducting (SC), radiofrequency (RF) electron linac LISA [1] at Frascati INFN Laboratories has been completed at the end of 93 and its commissioning has been carried on in the first half of 94.

The project started in 89 to provide our Labs with a test machine for technologies related to linear colliders. Originally an FEL program was also launched as a useful application and test of the beam quality [2]. Such a program has now been canceled by INFN and the machine is devoted to the test of instrumentation also in view of the collaboration to the Tesla Test Facility project in course at DESY.

The room temperature 1 MeV injector had been completed two years before and beam transport tests had already been performed, obtaining about 0.5 mA in several millisecond pulses at the entrance of the SC linac, after the achromatic 180 degrees arc [3]. The energy spread was about 2%, consistent with theoretical predictions.

In 93 three of the cavities were reconditioned with RF power and at the end of the year acceleration of the beam with only two cavities was obtained. The Q_0 remained rather low at high field levels (several 10^8 at 3.5 MV/m) [3].

2. COMMISSIONING RESULTS

Acceleration through all four SC cavities has been first achieved in a two weeks shift in March 94. The cavities were driven with 40 ms RF pulses and 1 Hz repetition rate, so as to obtain high peak field values without overloading the refrigerator, even with such low Q values.

A precious aid in guiding the beam through the SC linac is the voltage induced by the beam itself in the resonators. In the case of unpowered cavities the induced voltage gives also a measure of the peak current value.

The beam crossing a powered resonator can also be detected from the reaction of the voltage feedback loop to beam loading. In Fig.1 are shown the error voltage and RF waveforms. The high peak at the start is due to the delay in feedback response. The small peak at the end of the RF pulse is due to the beam passage. In between one notices a random reaction to tune fluctuations of the resonator caused by pressure fluctuations.

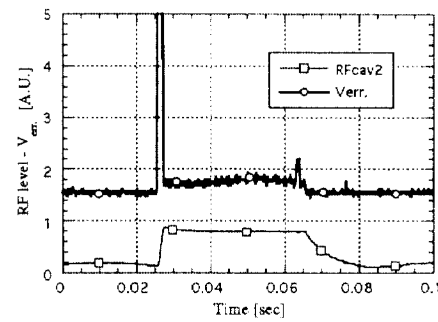

Figure 1. Feedback error voltage and RF waveforms.

Such vibrations have a continuous spectrum from a few Hz to several tens of Hz. At times and in some of the resonators a permanent 34 Hz line comes to evidence, but it is not the most relevant one. The fluctuations are evident on the pedestal outside the pulse, where the feedback is not effective. This pedestal is introduced to consent the tuning of the cavities (see Fig. 2).

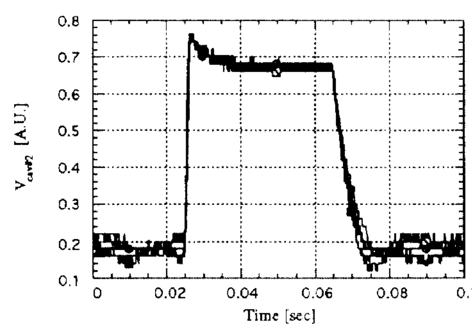

Figure 2. Waveform evolution in quiet cavity.

The pressure fluctuations seem therefore to be attributable more to particular states of the refrigerator than to thermo-acoustic oscillations. The associated vibrations disturb the linac operation considerably; at times they are so strong that, to cope with the large detuning the electronic feedback system saturates the power margin of the klystrons. Luckily such periods of strong agitation alternate with long lapses of relative quiet, during which a sufficient stabilization is achieved (< 10^{-3} as can be inferred from the loop error voltage). Figs 2 and 3 show the superpositions in time of various pulses in a quiet and in a vibrating cavity.

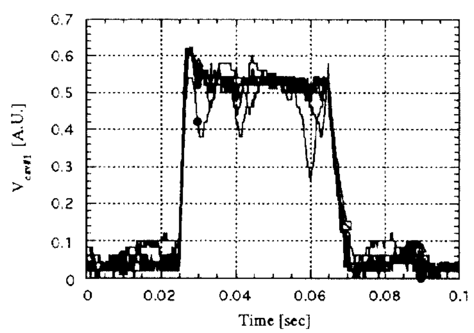

Figure 3. Waveform evolution in vibrating cavity.

The energy spectrum of the beam has been elaborated from the image on a fluorescent viewscreen following an analyzing dipole magnet with a resolution of 1.8 mm per 10^{-3}.

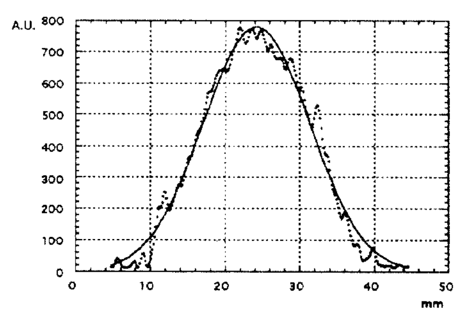

Figure 4. Beam energy spectrum (1.8mm = 1 ‰).

As it can be seen from the histogram of Fig. 4, the measured energy spread is $\sigma_E = 4 \times 10^{-3}$ in good agreement with the combination of the 1 MeV injected beam energy spread (2%) divided by ≈10 because of adiabatic damping from acceleration to 14 MeV, and the contribution from cavity voltage fluctuations.

Cavity # 3 (numbered in ascending order along the beam direction), not tested in 93 because of malfunctioning of the corresponding refrigerator channel, was also set in operation and tested. After a conditioning time corresponding to only about three weeks of short pulse operation at a peak field of about 4 MV/m, calorimetric Q measurements gave a value of 7×10^8 in normal operation practically constant from 1.9 to 3.5 MV/m. Higher fields values were achieved but were not stable enough for normal operation.

3. CONCLUSIONS

An average current of 0.5 mA has been accelerated to 20 MeV with an rms energy spread of 4 x 10^{-3}. Considerable fluctuations in transverse position and peak current were stil present, at least partly attributed to residual fluctuations of the injector RF parameters, especially phases, and to the SC cavities voltage fluctuations, particularly those of cavity #1 (the first encountered by the 1 MeV beam).

As for the injector, a campaign of improvement of the control and stabilisation circuitry is in progress. Improved stability of the voltage and phase of the forward RF wave feeding the capture section have already allowed us to transport 2 mA through the 1 MeV arc, practically without losses.

Vibrations of SC cavities are still a problem. The stability is seen to improve as the pressure on the LHe bath is increased; at present, the maximum attainable pressure is however limited at 1.4 Bar absolute by the safety valves that protect cavities against deformation.

4. REFERENCES

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