An Accelerator for Testing Superconducting RF Structures

J.M.Cavedon, B.Aune, Ph.Bredy, S.Chel, M.Desmons, F.Gougnaud, J.Gastebois, J.F.Gournay, M.Jablonka, J.M.Joly, F.P.Juster, E.Klein, Ph.Leconte, A.Mosnier, B.Phung, H.Safa
DAPNIA/SEA, C.E.Saclay, FRANCE
S.Buhler, T.Junquera, IPN ORSAY, FRANCE

Abstract

A test facility for superconducting RF structures has been operating for one year at Saclay. This small-scale accelerator, called MACSE, provides realistic operating conditions for 1.5 GHz SRF cavities and related equipment, featuring 1.8K continuous operation, continuous wave RF power supply (5 kW per cavity) and feedback loops, beam injection up to 100 μA and beam diagnostics. Design goals for the cavities are an accelerating field of 8 to 10 MV/m, and a quality factor of 6.10^9. We present results on 5-cell Nb cavities, as well as on other subsets of the accelerator.

ACCELERATOR DESCRIPTION

This small accelerator has all the significant features of large-size electron linacs. It consists of five bulk niobium cavities, individually powered by 5 kW CW klystrons. The 1.5 GHz, 5-cell structures are equipped with coaxial couplers. The first cavity has a reduced phase velocity, in order to capture the 100 kV electrons delivered by the injector. The capture section is followed by a beam analysis line and delivers a 2 MeV CW beam to a cryomodule housing four standard cavities. Beam analysis and diagnostics are also made after the standard cryostat [1].

CAVITIES

The cavities mounted in MACSE had reached between 6.5 and 11 MV/m in vertical test cryostat, without any field emission and with Q values exceeding 8.10^9. After these tests, the cavities have been heat-treated at 750 °C, in order to get rid of hydrogen, known to be a source of severe Q reductions during slow cooldowns [3]. This process has lead to Q values above 5.10^9 (this corresponds to the sensitivity of our calorimetric measurement in horizontal cryostat).

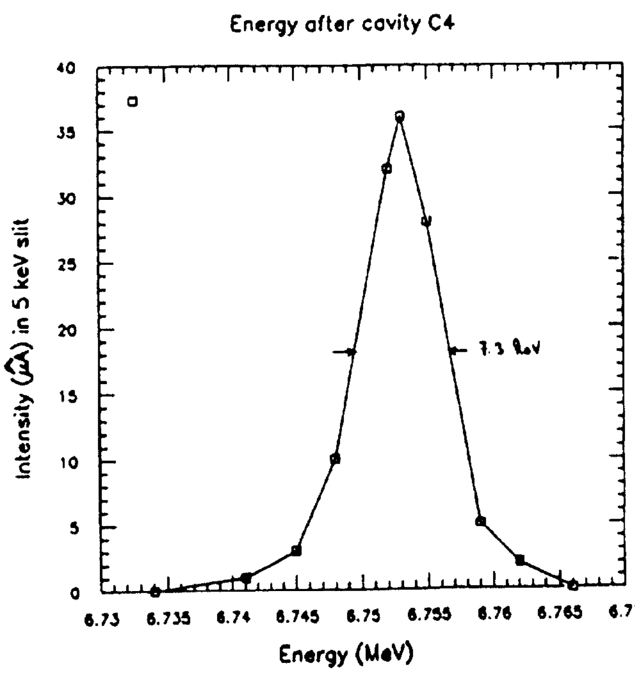
We have experienced varied cavity performances in horizontal cryostat. Due to a vacuum failure, one cavity had its Q degraded down to 2.10^8, resulting in a field limitation to 4.1 MV/m by power dissipation. First power tests on the other cavities showed electron loading at low field, limiting the maximum accelerating fields to the range from 5.1 to 6.7 MV/m. Pulsed peak power processing has been effective in curing the emitters found at low field, even if the existing klystrons did not allow processing fields above 20 MV/m, reached with 5 ms pulses. These cavities are now limited by quenches to the field range from 5.3 to 7.5 MV/m, without any field emission. The significant loss of performance between laboratory tests and accelerator conditions remains to be understood.

CRYOSTATS

Large amplitude mechanical vibrations have been observed in the capture cryostat (up to 60 degrees peak to peak), whereas a very stable operation was achieved with the cavities housed in the standard cryostat (less than 5 degrees without any feedback loop). These contrasting situations have been understood to come from a particular arrangement of the LHe supply of the first cryostat, leading to thermoacoustic oscillations, anomalous heat loads, and mechanical vibrations. This situation has been corrected by reducing all Helium gas paths between 300 K and 1.8 K, and by suppressing any two/phase bubbling into the helium bath. Stable operation was then also achieved in the capture cryostat.

OPERATIONAL EXPERIENCE

Early studies of this pilot accelerator took place in 1989, and construction took place in 1990. The first beam at 2 MeV was delivered by the superconducting capture section in January 1991 [2]. A 10 MeV beam has been achieved in October 1991 at low current. Three standard SC cavities, totalling 1.5 m of active structure, delivered the additional 8 MeV. The first CW beam has been obtained in March 1992. The intensity was 35 μA and the energy was 6.7 MeV. The best energy resolution has been obtained with a pulsed beam (50 μA, 3 μ s, 25 Hz). The energy spectrum shown on the figure has a witdh of 7.3 keV FWHM.



FUTURE EXPERIMENTS

CW beam operation will be pursued up to full beam current. The contribution of the SC cavities to the energy spread will be determined. Single klystron RF operation on four cavities will be tested, as well as the complete test of a second standard cryomodule equipped with four 3-cell cavities.

REFERENCES

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