FR9103380

COMMISSARIAT A L'ENERGIE ATOMIQUE
CENTRE D'ETUDES DE SACLAY
M I S T
Service des Bases de Données Spécialisées
F91191 GIF SUR YVETTE CEDEX

CEA-CONF- -10548

FIRST OPERATION OF MACSE, THE SACLAY PILOT SUPERCONDUCTING ELECTRON LINAC

AUNE B.- ANTOINE C.- BONIN B.- BOSLAND P.- CAVEDON J.M.- CHEL S.-
CHIANELLI, C.- CURTONI A.- DESMONS M.- FAGOT J.- GASTEBOIS J.-
GODIN A.- GOUGNAUD F.- GOURNAY J.F.- GOURCY G.- GUEMAS F.- HANUS X.-
HENRIOT C.- JABLONKA M.- JOLY J.M.- JUILLARD M.- KLEIN E.- KOECHLIN F.-
LECONTE P.- MOSNIER A.- PHUNG NGOC B.- PROME M.- SAFA H.-
TOURRETTE T.- VEYSSIERE A.-
CEA Centre d'Etudes Nucleaires de Saclay, 91 - Gif-sur-Yvette (FR).
Service de Physique Nucleaire

BUHLER S.- FOUAIDY M.- JUNQUERA T.
Paris-11 Univ., 91 - Orsay (FR). Inst. de Physique Nucleaire

Communication présentée à : Particle Accelerator Conference
San Francisco, CA (US)
6-11 May 1991

First operation of MACSE
the Saclay pilot superconducting electron linac

B.Aune, C.Antoine, B.Bonin, P.Bosland, J.M.Cavedon, S.Chel, C.Chianelli, A.Curtoni
M.Desmons, J.Fagot, J.Gastebois, A.Godin, F.Gougnaud, J.F.Gournay, G.Gourcy, F.Guemas
X.Hanus, C.Henriot, M.Jablonka, J.M.Joly, M.Juillard, E.Klein, F.Koechlin, Ph.Leconte
A.Mosnier, Phung Ngoc B., M.Promé, H.Safa, T.Tourrette, A.Veyssière
DPhN/STAS Centre d'Etudes de Saclay FRANCE
S.Buhler, M.Fouaidy, T.Junquera
Institut de Physique Nucléaire Orsay FRANCE

Abstract

MACSE, a pilot accelerator has been built at Saclay in order to fully develop the technology of superconducting electron linacs. It consists of five niobium cavities powered by five klystrons. The 1.5 GHz, 5-cell cavities are equipped with coaxial couplers. The first cavity has a reduced phase velocity to capture the 100 kV electrons coming from the injector. It is followed by a four cavities cryomodule. The present status and the first beam test are reported, along with some results of superconductivity R and D.

1 Introduction

The aim of the MACSE facility is to test successively several types of SC cavities and cryostats as elements of an operational accelerator. It has been built in the tunnel of the Saclay electron linac, which has been shut down in June 90. The cavities are the result of an R and D program started in 86 which is continuing and includes fundamental studies on RF superconductivity.

2 Description

MACSE is composed successively of a 100 kV injector, a SC capture cavity, a beam analysing section, four SC cavities in a common cryostat and a beam handling system. The RF frequency is 1.5 GHz and the operating temperature 1.8 K. [1]

The 100 kV beam line (lent to us by U. of Illinois) delivers a d.c. beam of more than 100 μA after chopping at 60 degrees and prebunching by copper cavities. The emittance is about 3 π mm.mrd. [2]

The beam is then further bunched and accelerated to 2.5 to 3 MeV by a 5-cell SC cavity of reduced phase velocity ($\beta = 0.84$) powered by a 5 kW klyston. The beam dynamics is described in more details in [3].

The second cryostat contains four 5-cell cavities (2 meters total active length) individually powered by 5 kW klystrons. The input couplers are of coaxial type. Each cavity is equipped with two coaxial HOM couplers. Tuning is made by adjusting the overall length of the cavity with a mechanical system driven by a stepping motor in liquid helium. A magnetostrictive rod is also installed. [4]

The cryogenic system provides a cooling power of 80 Watts at 1.8 K.

The linac is fully instrumented with beam diagnostics and computerized with distributed VME systems linked by Ethernet network.

3 First operation

The installation of the linac has been completed as scheduled by the end of 90 and the first cooldown took place in mid-January 91. A first set of measurements on static and dynamic heat loads have been performed.

The first results on the static heat load indicate a total static power level at 4.2 K in agreement with expected values. However, the heat load increases dramatically as temperature goes down. This overconsumption is being investigated.

The dynamic losses of the RF input couplers also exceed the computed values. This is attributed to a poor thermal conduction path between the niobium antenna of the coupler and the helium bath, probably due to brazings of the sapphire window. A direct helium cooling of the antenna is being designed.

The Q of the capture cavity has been measured by calorimetry and found to be 8.10^8 (instead of 10^{10} obtained in vertical cryostat). This low value is attributed to the slow cooldown rate of the cryostat, which is now known to affect the surface resistance (see section 5).A curative treatment has since been applied to all cavities.

A test beam has been accelerated up to 2.5 MeV by the SC capture cavity. This first operation has come to a premature end due to a failure of the cryogenic plant.

4 Beam measurements

Up to now, the only beam test consisted in acceleration by the capture cavity alone. Energy spectra have been

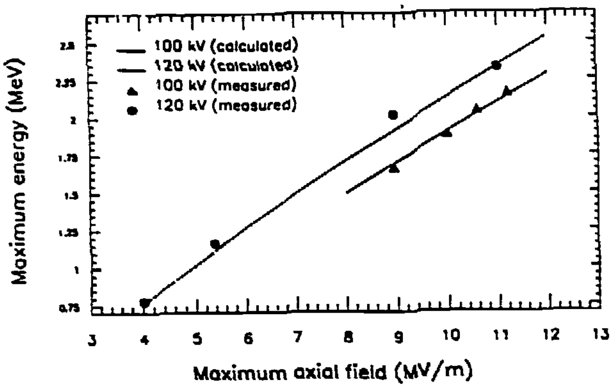

Figure 1: Output energy from the capture cavity for 2 values of incoming energy

measured for various levels of accelerating field and gun high voltage. The chopping and prebunching cavities were not used. As a result the spectra presented an extended low energy tail. The peak current was 300 μA in pulses of 3 μs at 25 c/s. The electric field level was estimated from the measurement of RF input power and the knowledge of the input external Q (5.10^6). The maximum beam energy obtained was 2.5 MeV, for a peak axial electric field of 12 MV/m, corresponding to an input RF power of 800 W. This field level corresponds to an accelerating gradient of about 6 MeV/m in a $\beta = 1$ cavity. The limitation was due to input coupler power dissipation.

On figure 1 maximum energies are plotted vs the axial electric field for two values of the incoming energy (100 and 120 kV). On the same plot are shown the corresponding computed curves from Parmela runs using a field distribution calculated by Urmel.

5 Progress report on superconductivity

In parallel with the construction of the MACSE accelerator, active fundamental research has been going on aiming at a better understanding of the behaviour of the superconducting surfaces under strong RF fields.

A special cause of degradation of the Q value of Niobium cavities upon slow cooldown has been specially investigated: this degradation is a problem shared by most of the laboratories involved in superconducting accelerator technique, and hampers the reliability of Niobium cavities [5]. The chemical buffering ordinarily used to clean and polish the cavity surface incorporates substantial amounts of Hydrogen in the cavity wall, with probably a subsequent Hydride precipitation when the cavity is cooled down slowly. The presence of this Hydride then enhances the dissipation of the surface under the influence of RF fields. Measurements of Hydrogen concentration by various techniques have revealed that Hydrogen was trapped in a surface layer of thickness 200 nm, and that the amount of trapped Hydrogen depended on the nature and duration of the chemical treatment. A heat treatment of the cavity (750°C, during 2 hours) eliminates the Hydrogen. Various acid mixtures are under investigation, in order to cure the problem more conveniently.

Another activity has been devoted to the study of superconducting materials potentially more interesting than bulk Niobium for making accelerating cavities. Among the best candidates is NbTiN, reactively sputtered on a copper substrate [6]. Critical temperatures of 15 K were obtained. The surface resistance of samples, measured using a cylindrical TE011 cavity with a dismountable end plate, was still high : 400 nOhms at 1.6 K and 4 GHz. This surface resistance increased with RF power, leading to quenches at a level of B=25 mT.

Many superconducting materials, including NbTiN have a non homogeneous surface, due to their polycristalline nature. The surface resistance of granular superconductors has been theoretically investigated, using a model of Josephson junction arrays [7]. The model assumes that the superconductivity is weakened at the grain boundaries, causing grain decoupling at high RF fields. The dissipation due to the decoupling has been evaluated. This model successfully reproduces experimental data for high Tc superconductors, whose granular nature is notorious, as well as for the NbTiN thin films mentioned above. In fact, all materials made by sputtering seem to exhibit granular characteristics, causing a RF field dependent residual surface resistance. These materials will become usable for accelerator purposes if the grain size is increased, and if the electrical resistivity of the grain boundaries is decreased. Investigations are in progress in order to optimize these quantities by varying the sputtering parameters of NbTiN.

6 Conclusion

The first tests with MACSE have been performed on schedule. Several difficulties have been encountered. Next operation will take place in June 91, the five cavities having been heat treated at 800°C.

References

[1] Ph. Leconte et al. "MACSE : Accelerating electrons at Saclay with SC cavities " Proc. of the 90 linear accelerator conference. Albuquerque USA

[2] Nuclear Physics Research with 450 MeV microtron. Urbana. U.of Illinois NPL,March 1986 Report Chap IV

[3] B. Aune et al. "The MACSE injector" Proc. of the 2nd EPAC Nice, France p 1246

[4] A. Mosnier et al. "MACSE superconducting cavity RF drive system"Proc. of the 2nd EPAC Nice, France p 1064

[5] B.Aune et al. "Q degradation of niobium cavities during cooldown" Proc. of the 90 linear accelerator conference. Albuquerque USA

[6] P.Bosland et al. Proc of the 2nd ICMAS conference Grenoble, France

[7] B.Bonin and H.Safa, submitted to Superconducting Science and Technology