OPERATIONAL LIMITS OF HIGH ACCELERATOR GRADIENTS

G. BIENVENU P.BRUNET

UNIVERSITE PARIS-SUD -Laboratoire de l'Accélérateur Linéaire-
Bâtiment 200 , 91405 ORSAY, Cedex - FRANCE-

Abstract. We report in this paper the experimental results of two S band warm accelerating structures under high gradient. Routinely a field higher than 40 MVm^{-1} has been obtained with long RF pulses and 80 MVm^{-1} for short pulses. We give also the shape and the spectral analysis of dark electric charges, the level of self-emitted charges, per unit length are plotted as function of surface field.

INTRODUCTION

High accelerating field are needed for future accelerators. For an accelerating electric field typically of 100 $MeVm^{-1}$ many problems occur, such as breakdown and dark current. For this reasons the Laboratoire de l'Accélérateur Linéaire carry on a R & D programme on high accelerating structures. 4 years ago LAL has built a high gradient test facility $NEPAL$ composed of a high RF power source,a relativistic electron source and an analysis zone,The experimental structure is laid between then.

This paper report a part of the experimental results, under a very pratical point of view, carried on two S band disk loaded warm structures.

STRUCTURES UNDER TEST

Two types of accelerating structures are presently under test :

- A short section derived from the end landing of LIL[1] structure, specially designed for high axial electric field.
- A new type of S band structure[2] developed by $GE/CGR-MeV$ company with the collaboration of LAL

The main characteristics of these structures are summarized in the table I.

STRUCTURES PARAMETERS

Structure	SERA	CGR
Frequency, f (MHz)	2998.5	2998.5
Operating mode	$2\pi/3$ Dir	$4\pi/5$ Back
Structure type	TW, C^{te} imp.	TW, C^{te} imp.
Cell shape	iris	nose cone
Coupling	electric	magnetic
Tuning	wall deformation	stub
Length, L (m)	0.504	1.270
Factor of merite, Q	14600	11100
Shunt impedance, r (MΩ/m)	64.24	75.0
Filling time, τ (μs)	0.297	0.203
Relative fondamental harmonic, T	0.90	0.85
Attenuation, X (Np)	0.198	0.172
Groupe velocity, v_g (m/s)	$6.4^{-3}c$	$21.2^{-3}c$
Peak axial field, $\hat{E}_{ax}$ (MV/m)	$6.8\sqrt{P}$	$5.04\sqrt{P}$
Average axial field, $\overline{E}_{ax}$ (MV/m)	$6.2\sqrt{P}$	$4.66\sqrt{P}$
Average accelerator field, $\overline{E}_{acc}$ (MV/m)	$5.57\sqrt{P}$	$3.95\sqrt{P}$
Ratio max surface field/axial field	1.9	2.6

Table I

BREAKDOWN IN STRUCTURES.

Two levels of breakdown has been fixed arbitrary

- An operational level, corresponding to a number of breakdown

$$\leq 3 \quad 10^{-4} s^{-1}$$

(roughly one breakdown per hour)

- A limit level corresponding to

$$\leq 3 \quad 10^{-2} s^{-1}$$

(roughly one breakdown per 30 s)

Behavior with the length of rectangular RF pulse

We assume that time dependence of the peak surface field (averaged over the structure length), is :

$$\overline{E}_s = \frac{K}{\tau^{\alpha}}$$

The experimental values of K and α are given in table II , for $\overline{E}_s$ in MVm^{-1} and τ in μs were τ is the pulse length.

We can noticed that the value of α is the same for the two sections .

Structure	LIL	CGR
α	0.2	0.2
$K_{lim.}$	100	88
$K_{op.}$	95	84

Table II

Maximal electric field with compressed RF pulses

For $SLED^3$ RF pulses, operational and limit values of electric surface field are given in the table III.

The timing of the compressed RF pulse is ajusted for eliminating the multipactor phenomenon yielded by the low power inverse queue. The values given by the table are probably partly limited by the poor vacuum level in the RF window region (5 $10^{-7} mbar$).

Experimentally obtained gradients With M.P.C.				
	Limit $3.10^{-2}/s$		Operational $3.10^{-4}/s$	
Structure	LIL	CGR	LIL	CGR
$\hat{P}$ (MW)	168	168	139	125
$\overline{E}_{ac}$ (MV/m)*	80	55	73	42
$\hat{E}_{ac}$ (MV/m)	88	68	80	58
$\overline{E}_s$ (MV/m)	153	109	139	126
$\hat{E}_s$ (MV/m)	167	177	152	152

* calculated with input power

Table III

DARK CURRENT

Dark current with rectangular RF pulse

The dark current shape as function of time is given by the photography 1. On the figure 2, the spectral analysis of this current is plotted. The first peak corresponding to the lower energy (≤ 3 MeV) is connected with the forehead of RF wave, its length is equal to the filling time of the section. The second pic and the last one are due to an overfield bound with reflected waves, and the flat region is the steady state regime.

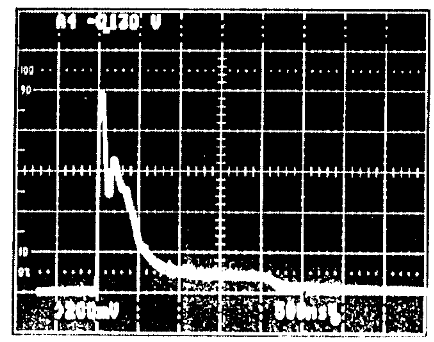

Fig 1

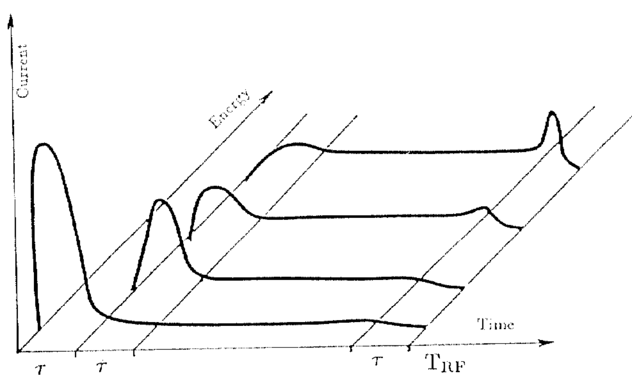

Fig 2

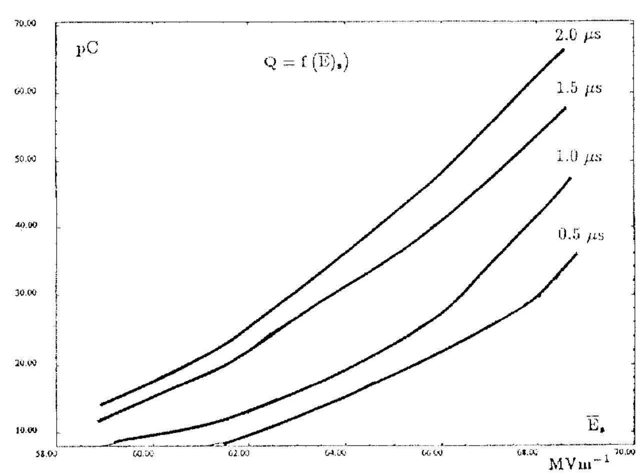

Fig 3

Electric charges

Dark electric charges are reported for different rectangular RF pulses length on the figure 3 for the section LIL.

The electric charge is roughly proportional to :

$$Q_{dc} = \overline{E}_s^{8.8}$$

Dark current with compressed RF pulse

The shape of dark current in compressed mode is given, for the section CGR on the figure 4. The photo has been recorded from a well adapted coaxial faraday cup. The dark electric charge per length unit is plotted, on the figure 5, as function of average surface field. We see that the nose cone CGR structure yields more dark current that the usual disk structures.

Spectrum of dark current

The spectrum of the dark current extendes from zero to the maximum of energy gain, with an maximal amplitude on the middle range of energy. The spectrum of figure 6 corresponds to the LIL structure, and an identical shape will be reported with the CGR section.

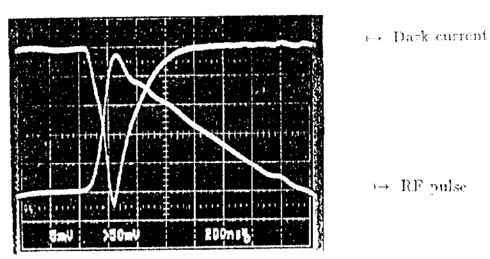

Fig 4

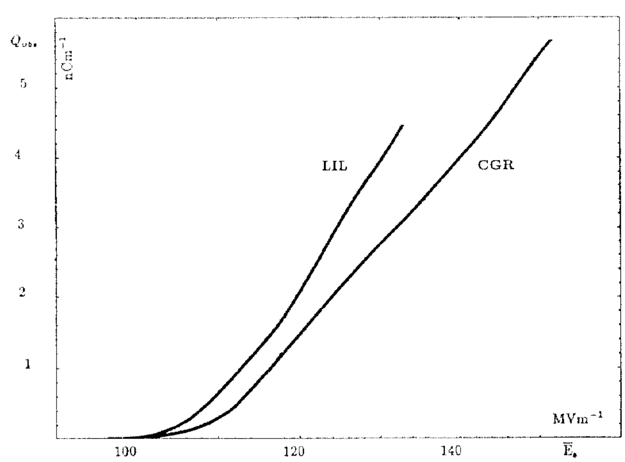

Fig 5

FOWLER NORDHEIN PLOTS

Figures 7-a and 7-b report F.N plots of the two sections. These curves are plotted with the dark electric charge and the average of the peak surface field. We notice around 230 MVm^{-1} a quite sharp change in F.N curves slopes in connection with a decreasing of field electronic emission.

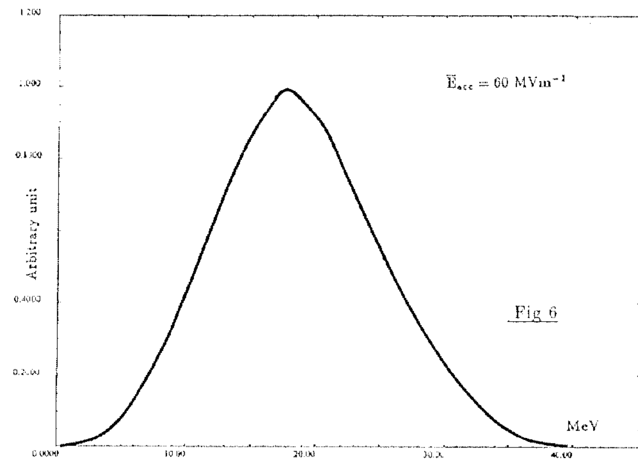

Fig 6

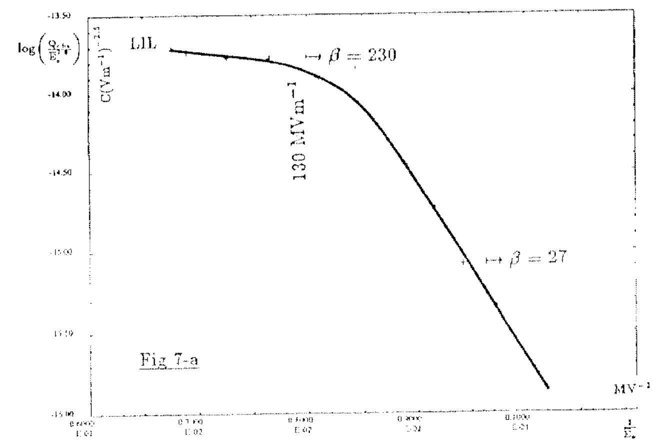

Fig 7-a

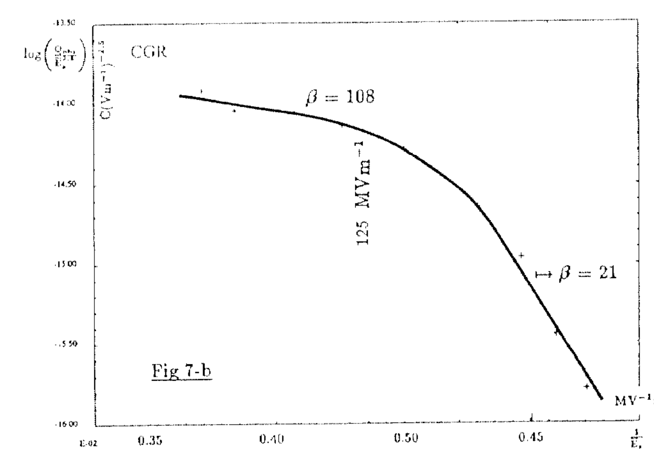

Fig 7-b

REFERENCES

(1) R Belbeoch et al. Rapport d' étude sur le projet des linacs injecteurs de *LEP* LAL/RT/82-01 jan 82

(2) D Tronc , IEE Trans.Nucl.Sci., NS 32 (1985) 3243