BEHAVIOUR OF WARM ACCELERATING RF SRTRUCTURES UNDER HIGH GRADIENT

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Abstract. -This paper reports on first results of the going program to study high gradient accelerator at *LAL*, which is a part of *LAL* R&D program on accelerator technology. The experimental set-up is a realistic constant impedence S band traveling wave disk loaded warm accelerator fed by long RF pulses. An energy of 18 MV corresponding to an acceleration gradient greater than 30 MV/m was actually measured.The dark current produced by field emission has been measured in term of electric charge. The global field enhancement β has been calculated. The level of dose rate emitted across the stainless steel vessel has been determined.

INTRODUCTION

Futur linear colliders require extremely high accelerator field - 80 MV/m for *CLIC*[1] , 190 MV/m for*SLC*[2] - For conventional accelerating structures recent works have shown that it is possible to reach surface fields of 300 MV/m in S band,overstepping highly the Killpatric[3] predictions. Due to the microscopic electric field $E^* = \beta E$ (β being the microscopic field enhancement factor), electrons are emitted,by tunnel effect,from cell inner walls.The ultimate field limit is bound to the developement of a plasma derived from the sublimation of microprotusions under Joule and Nottingham effect.Before this limit emitted electrons are captured by the accelerating field and produce a dark current bunched on all the crests of RF wave.
We report here the first results of the behaviour of high accelerating gradient structures operating with long RF pulses.

DESIGN CRITERIA

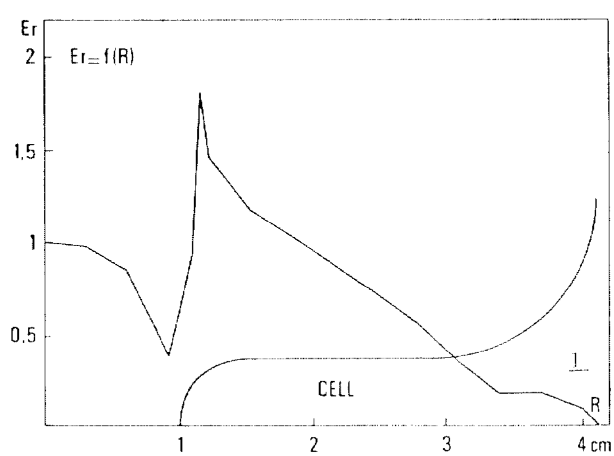
Choice. -Most of today RF accelerators work with a S band, $2\pi/3$,travelling waves structures (TW).The same structure working in a standing mode (SW),for the same incident RF power, would give a surface field two times higher than with a TW structure. But this field value will be reached with the drawback of a time distribution of E and H fields different of TW accelerating mode and consequently with a different distribution of the emitted electrons. These considerations and the availability of high power long pulses RF source dictated the choice of an high constant impedance TW structure.The availability of long RF pulses(4.5 μs) at variable repetition rate give us the possibility to study the problems occurring before the sublimation of microprotusions and connected to the average value of the RF power. In this case,we can write: $E^{t_2}_{lim} = E^{t_1}_{lim}\sqrt{\frac{t_1}{t_2}}$. Where t_1 and t_2 are two different values of pulse lengh. For an another frequency band than S band we can extrapolate the value of E^X_{lim} from the experimental level in S band if we assume that: $E^X_{lim} = E^S_{lim}\left(\frac{f^X}{f^S}\right)^\alpha$ whith $\alpha \approx 0.8$ for J. W. Wang[4] and $\alpha = 0.5$ for G. A. Lœw[5]

Cells. -We use the accelerating cells designed for *LIL*[6]. Their inner rounded shapes prevent the occurrence of multipactor effect. They are made of BE 58 copper and machined with a diamond tool giving a surface finish better than 0.1 μm Ra.The tuning of the resonant volume is done by dimpling the cell at four points where the wall is made thin. Before assembling by Ag diffusion in vacuum oven at 350^{0}C,the cells are cleaned in an alkaline detergent (PH=9.5), rinsed in demineralized water and backed at 120^{0}C

Section -It is a 0.5 m (without coupleurs) section,made of 15 identical cells assembled between two magnetic couplers. The leak tightness is provided by a stainless steel vessel. Pumping is done by a 250 l/s ionic pump giving a steady state vacuum of 10^{-8} Torr. The on axis maximal field strength is given by the relationship : $\hat{E}_{acc} = 6.74\sqrt{P_{in}}$ and the average field by : $\overline{E}_{acc} = 6.20\sqrt{P_{in}}$ where P_{in} is the incident power in MW and E in MV/m The following table gives the characteristics of the cell and structure.

Cells	
Iris diameter 2a	18 mm
Cavity diameter 2b	82.376 mm
Q	14100
r/Q	4700 Ω/m
v_g/c	$6.4\ 10^{-3}$
Section	
Resonance frequency	2998.500 Mhz
Filling time	0.297 μs
Phase shift	$2\pi/3$
Attenuation	0.198 Np
SWR	1.03

Field on Cell Surface - The computed surface field is reported on fig.1 The maximum surface field E^r_s occurs at r= 11.5 mm then: $E^{r=11.5}_s / E^{r=0}_{acc} = 1.9$



Structure Checking -Tuning was done by nodal technique. A metalic needle is pulled along the axis of the section,the square of axial field (proportional to the reflected field) is plotted as shown in figure 2

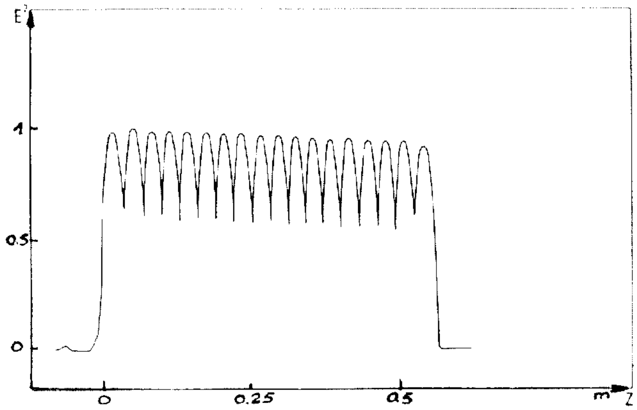


Fig.2 Square of relatif axial field

EXPERIMENTAL SET UP

The section is driven,at the present time,with a 25 MW klystron providing 0.5 μs to 4.5μs long pulses with a repetition rate of 100 Hz or submultiples of 100 Hz. The power injected in the section is measured with calibrated couplers.The FE emitted beam charge is measured with a Faraday cup followed by an integrator located at the end of the section after a 0.6 mm thick aluminium window.The energy measurement is made by a spectrometer under vacuum connected at the accelerating structure. The time distribution of the current is provided with plastic scintillators through the light signal . A 60/100 KV gun followed by a 3 MeV SW buncher may be swiched on to provide a bunched electrons beam. Ionization chambers parallel to the vacuum chamber allow the measurement of radiation produce by bremsstralung when the electrons hit the cells wall.

RESULTS

High Power RF Test. - The maximum klystron power (25 MW - 4.5μs) with a repetition rate of 100 Hz has been injected without breakdown during time intervals greater than 1H in the structure after a conditioning time of approximately of 200 H. For these conditions the axial field reaches 33 MV/m and the surface field 63 MV/m. The pression rises up to 2 - 4 10^{-8} Torr during the test. Electrons beams of 500 mA 20 ns has been accelerated at 18 MeV routinely. After 20 H of operation the cells has been inspected, no damage on the disks are visible.

Time Distribution. - The time distribution of dark current is showed on the photograph 3 .One will notice a overintensity over a constant time interval equal to twice the filling time of the section.

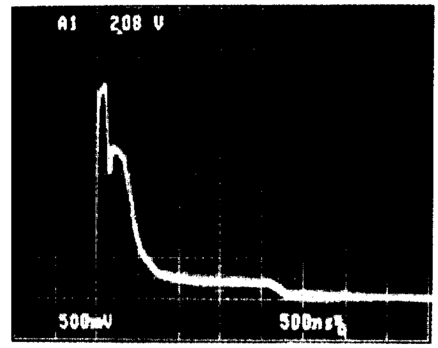


Photo 3 Time distribution of dark current

Peak and Steady State Electric Charge. - The peak and steady state charge are plotted as a function of surface field on the figure 4. The peak charge was plotted with a 0.5 μs RF pulse, the steady state charge is given over a 1μs time interval calculated from the difference betwen the 4 and 2μs RF pulses one.The corresponding dark current of the steady state is about 40μA for an accelerating field of 30 MV/m.

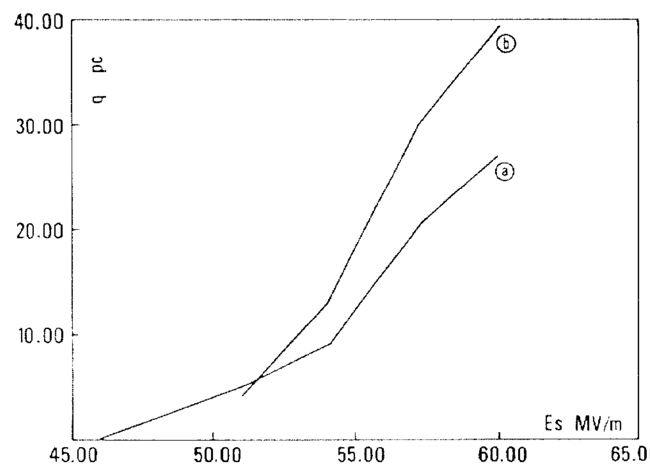


Fig 4 Peak and Steady Load

a) Steady state pc/μs

b) Peak load in 0.5μs head pulse

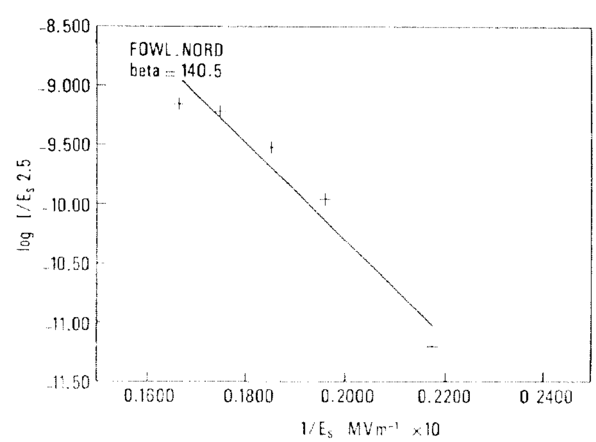


Fig 5 Fowler-Nordheim Plot

β Factor.- The study of the Fowler-Nordheim curve in AC condition allow the determination of β from :

$$\frac{d(log_{10} I_F/E_s^{2.5})}{d(1/E_s)} = \frac{-5.8\ 10^9\ \phi^{1.5}}{\beta}$$

This gives for the section (fig.5) , with $\Phi_{copper} = 4.65$ eV and for steady state: β=140.5

Dark Current Spectrum - The spectrum of dark current is reported in fig.6. It is a wide spectrum spreading from 2 to 18 MeV.The picture 7 shows the time distribution of FE current for 18 MeV.

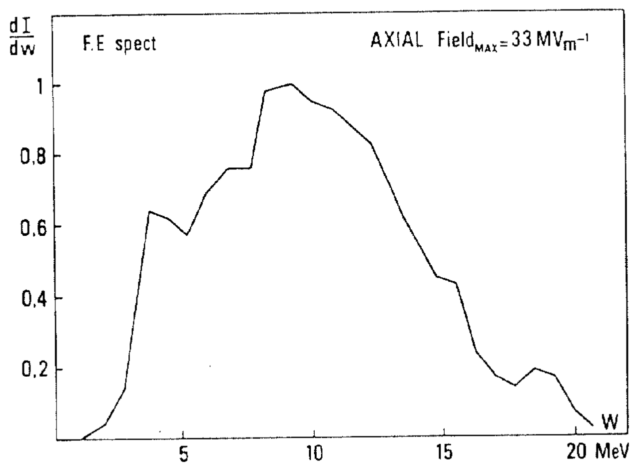


Fig.6 Dark current spectrum

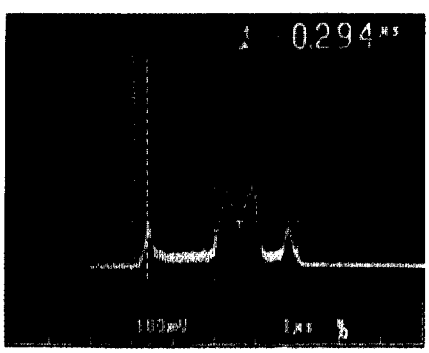


Photo 7 Time distribution for 18 MeV

Radiation Rate Dose. - For the radiation emitted around the vacuum envelope we found a dose rate lower than 4 rad/H.

REFERENCES

1 - SCHNELL, CLIC Parameters, CLIC Note 56 Dec.87
2 - ERICKSON, SLAC-PUB 4479 Nov.87
3 - W.D. KILLPATRICK, Criterion for Vacuum Sparking Designed to Include Both RF and DC. UCRL-2321 Sept.53
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6 - R. BELBEOCH et Al, Rapport d'étude sur le projet des Linacs-Injecteurs du LEP, LAL/RT/82-01 Jan.82