HIGH GRADIENT EXPERIMENT FOR X-BAND TRAVELLING WAVE STRUCTURE

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ABSTRACT

High gradient performance of a travelling wave X-band accelerating structure of 20cm long was examined. Various observables were measured such as RF pulse waveform at various positions, dark current versus accelerating field level, energy spectra of emitted electrons toward downstream and so on. The field level of 80MV/m at input coupler cell was obtained after 500 hours' conditioning at a typical repetition rate of 10pps. This field level is equivalent to 70MV/m accelerating field in 20cm long structure. Peak dark current decreased down to 1μA level at accelerating field of 50MV/m at input coupler cell.

INTRODUCTION

In the Japan Linear Collider (JLC)[1], an acceleration via a high frequency accelerating structure is needed to save wall plug power while obtaining a very high energy. Furthermore, the accelerating field should be reasonably high to preserve the emittance through the linac and make the length of the linac as small as possible. In the JLC, the accelerating field of several tens MV/m and possibly up to 100MV/m is considered.

The breakdown limit of the accelerating structure in S to X band frequency range was examined.[2] Though the results show much higher field level than stated above, it is not clear whether such a field can be stably obtained in a long travelling wave structure, because the experiments were performed only in standing wave condition for a few cells. The high field experiment for travelling wave structure was performed at S-band and showed the possibility of nearly 100MV/m at S-band but also observed a large amount of dark current of the order of mA.[3]

Following these background, a high gradient experiment on X-band accelerating structure was comissioned to examine the possible field level for stable operation. Various physical aspects such as the amount of the dark current, the energy spectra of the dark current, breakdown mechanism in a long structure, vacuum characteristics and so on were also examined. In this paper, the results of the experiment were briefly described.

EXPERIMENTAL SETUP

The tested structure is of a constant impedance type and has 20 regular cells with 2 coupler cells. It is operated in 2π/3 mode at 11.4GHz. The structure parameters were summarized in Table 1. All the numbers of the accelerating gradient in this paper are refered to the field at input coupler cell. The average gradient of the whole structure of 20cm long is 13% less than this value. The cells in the structure were machined in a usual lathe and brazed in a hydrogen furnace. The thin iris in the coupler cells were deformed after brazing for matching and tuning purpose.

The RF power generated by a klystron "XB50K" [4] was fed to the structure through 4.9m long waveguide.

The experimental setup is shown in Fig. 1. Various components in the figure are A,B: RF monitor, C: current transformer, D: Faraday cup, E: analyser magnet and slit, F: 20 l/s ion pump, G: cold cathode gauge, H: plastic scintillator, J: profile monitor, K: TV camera and S: accelerating structure.

Table 1
Parameters of the accelerating structure

Aperture	a	3	[mm]
Group velocity	vg/c	0.01177	
Shunt impedance	r	103.6	[MΩ/m]
Surface field in TW	Ep/Eacc	3.91 / 2	
Total attenuation	τ	0.284	[neper]
filling time	Tf	55	[ns]

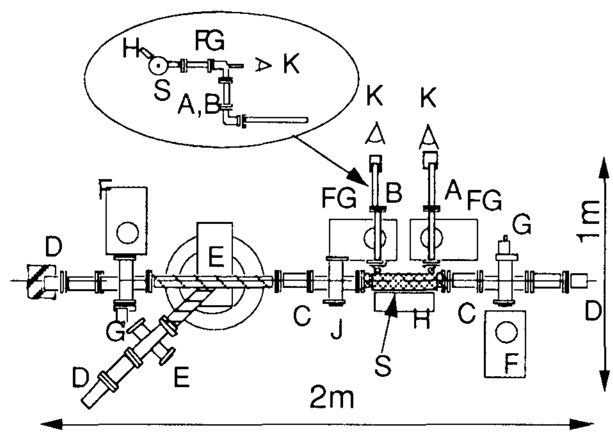

Fig. 1 Experimental setup

RESULTS

Most of the conditioning were performed with 50ns pulse length and at 10pps. The input power was shut off in case of a large reflected power from the structure or when the vacuum at the pumping port exceeds 10^{-6} Torr.

Typical RF waveforms, current transformer output and scintillator output amplified by photomultiplier are shown in Fig. 2. Large reflection of about 0.3 in voltage from the structure comes from a small band width of the structure due to the small beam aperture. Note that the scintillator output signals were delayed by about 70ns due to the time delay in photomultiplier tubes. Then, the dark currents to both directions and the X-rays along the structure were found to appear at the same time as just the filling up of the structure.

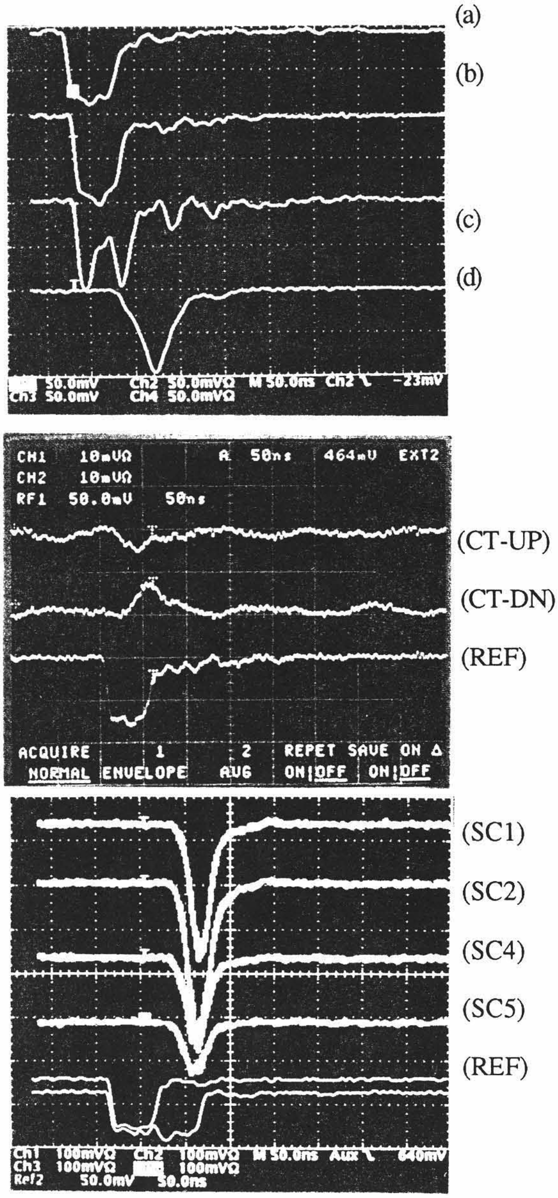

Fig. 2 Typical waveforms at E_{IN}=75MV/m. (a) Klystron RF output, (b) input RF to structure, (c) reflected RF from structure, (d) transmitted RF from structure, (CT-UP/DN): current transformer output at upstream and downstream side, respectively, (SCi) i=1 to 5: scintillator output aligned from i=1 at input to i=5 at output coupler cell (envelope of a number of shots) and (REF): input RF to structure to show the time reference. All the scopes were triggered by the rise of this signal. Horizontal scale is 50ns/div.

Conditioning history

Obtained accelerating field versus conditioning time was shown in Fig. 3. Further conditioning above 80MV/m seems difficult due to frequent breakdown and/or sudden jump of the vacuum level. A decrease around the time 350 hours is due to the conditioning with long pulse length of 100ns.

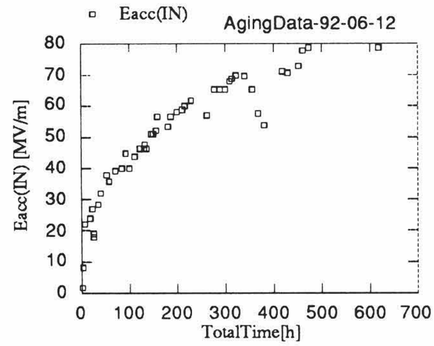

Fig. 3 Accelerating gradient versus conditioning time.

Fig. 4 shows a decrease of dark current during the conditioning down to 1μA at 50MV/m, though the decrease stopped after 500 hours, which coincides with the stop of increase of maximum field level.

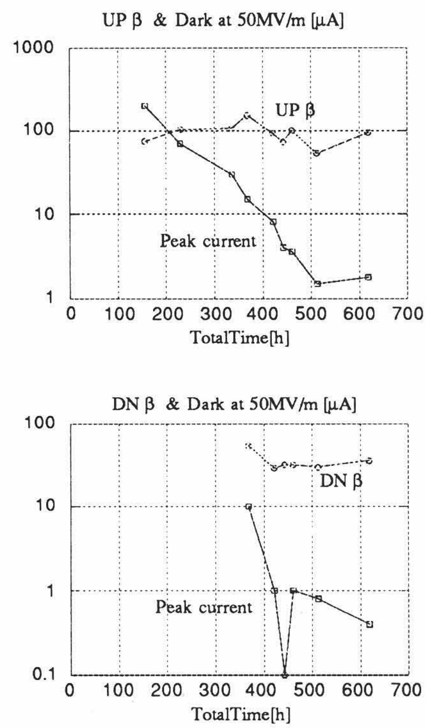

Fig. 4 Dark current towards upstream(top) and downstream(down). UP β and DN β are the field enhancement factors obtained from fitting of modified Fowler-Northeim plot.

Dependence on pulse length

Fig. 5 (a) shows the dark current versus pulse width in case of well below the already conditioned level. It was found that the dark current towards downstream does not increase as pulse length increases, indicating a dark current generation only during the filling time of 55ns. It still increases as pulse width if the field reaches near the maximum conditioned level as shown in Fig. 5 (b).

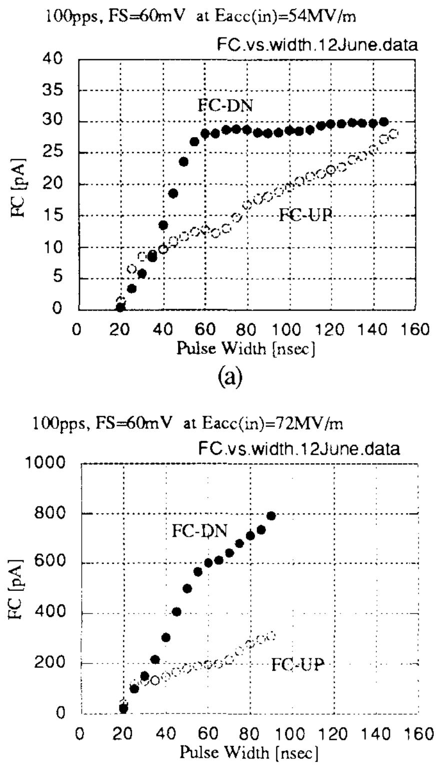

Fig. 5 Dark current versus pulse width. (a): well below the conditioned maximum level, (b) near maximum level.

Energy spectra

Fig. 6 shows typical energy spectra of dark current toward downstream. Peak energy is smaller by a factor of 3 than the one accelerated sitting on RF crest.

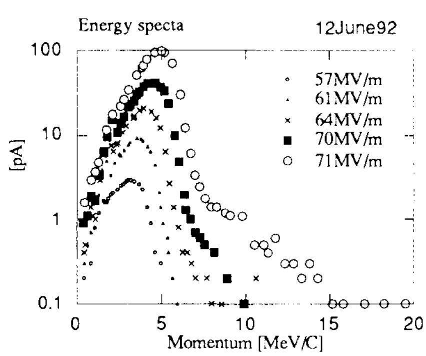

Fig. 6 Energy spectra of dark current. Vertical axis is measured current per unit relative momentum acceptance of about 4%.

FN plot

In Fig. 7 are shown the modified Fowler-Northeim plots for dark currents to both directions. The dark current to upstream and Ein>65MV/m and that to downstream in full energy range show a similar field enhancement factor of around 35, while that to upstream and Ein<65MV/m is 95. It should be noted that the acceptance of downstream side is one order of magnitude smaller than that of upstream side. The spot of the dark current was measured between the structure and the current transformer in downstream to be 1.5cm wide and 1cm high, indicating almost all dark current to downstream was detected.

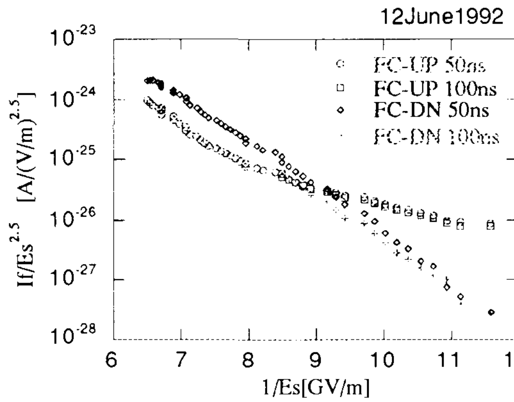

Fig. 7 Modified F-N plot.

DISCUSSION

It was found from this experiment that the operation at the accelerating gradient less than 50MV/m level is very promising for future linear collider, though a longer structure should be examined before actual use. Considering a difficulty to increase the gradient above 80MV/m, it seems necessary to carefully understand what happens in this field level in order to realize 100MV/m class acceleration. It is to be noted that a simulation study by Yamaguchi [5] shows that the emitted electrons can be captured to input RF field only in the field level higher than 80MV/m in case of 11.4GHz structure.

ACKNOWLEGEMENT

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