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RF HIGH GRADIENT EXPERIMENT OF AN S-BAND 0.6 m DISK LOADED STRUCTURE

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Abstract High gradient operation of 100 MV/m at an S-band 0.6 m-long constant gradient disk loaded structure is proposed in the Japan Linear Collider(JLC). High power RF source uses paralleling two SLAC 5045 klystrons with 25 Hz 1 μsec RF pulse duration. The maximum field gradient on the beam axis was 57.1 MV/m has been obtained after 400 hours conditioning with peak current of 100 mA. In this time,the microscopic field enhancement factor β=22 was attained. This level is limited only by the break down of the around output coupling cell of 0.6 m structure.

INTRODUCTION

One of KEK's plans for doing high energy physics in the future involves 0.5TeV order e+e- linear collider. Before such a machine can be realized a great number of research and development questions must be solved. Accordingly a Test Accelerator Facility (TAF) has been established at KEK. The linear collider proposal calls for the S-band and X-band accelerators portion to be able to employ 50 MV/m and 100 MV/m electric field strengths. Experimental studies on the upper limit to electric field strengths in conventional disk loaded structure accelerators have been reported by SLAC [1,2,3,4] and KEK [8], and similarly by VARIAN ASSOCIATES [5,6,7] for the single cavity case. SLAC attained a 146.7 MV/m and KEK a 104.5 MV/m upper limit for conventional structures without beam. (The KEK result was actually limited by the available klystron output RF power at the time.) In none of these experiments was a 100MW class RF source readily available for direct use; the SLAC experimenters used a standing wave mode setup, and then calculated what the corresponding expected traveling wave result should be. At KEK a resonant ring was used as the RF source to produce a traveling wave for the experimentation. From these various experiments the basic behavior of the accelerator without beam has been clarified, and it was then decided at TAF to launch an even more realistic study on beam behavior under a 100 MV/m acceleration field in a 0.6m constant gradient disk loaded type structure. This report describes the basic behavior of a 0.6 m-long S-band structure operated in the $2\pi/3$ traveling wave mode.

EXPERIMENTAL SET-UP

The overall organization of the experimental set-up is shown in Figure 1. RF source uses paralleling two SLAC 5045 klystrons with maximum RF output power of 200 MW which correspond to accelerating gradient to Eacc=100 MV/m. RF pulse width used was 1μsec at a 25 Hz rep. The RF phase deviation and amplitude variation in the combined output was held to less than 2 degrees and 1% during any pulse.

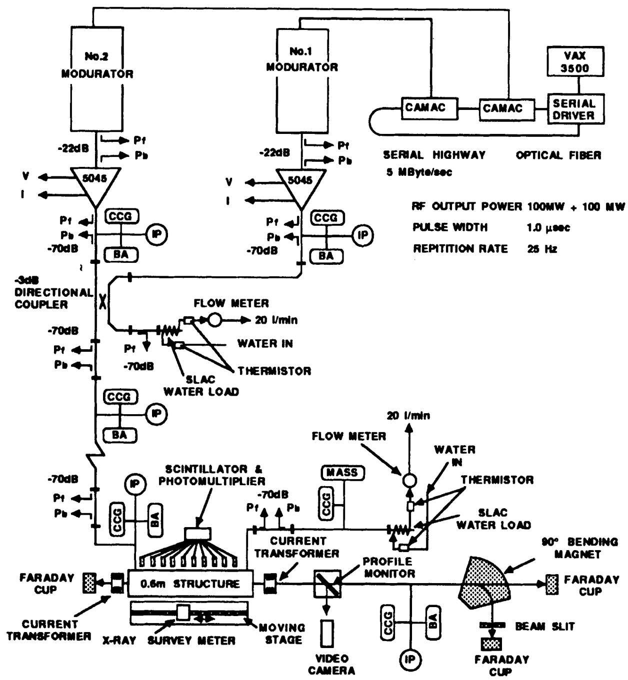


FIGURE 1 The overall organization of the experimental set-up

The RF power in both the forward wave and reflected wave was monitored some dual Bethe-hole couplers with a coupling ratio of -70 dB. The RF power is fed into an accelerating structure and through the power is terminated an SLAC RF water load. The whole wave guides and structure are pumped down to 5 x 10^{-9} torr by five 60 l/s ion pumps. The vacuum system has also some cold cathode gages and BA gages for monitoring of vacuum interlock and vacuum level during the RF operation. A massanalyzer for monitoring of residual gases during the RF processing of the structure located just after the output coupling cell. The 0.6 m structure is the same type as one in the SLAC linear accelerator. The accelerating structure consists of a 17-cell regular section, an input and an output coupling cells. The disks and cylinders are machined from OFHC copper blocks with a diamond tool. The final surface roughness of the periphery of the disk holes and the other parts are less than 250 nm and 20 nm without any chemical treatment, respectively. Those parts are stacked, blazed with hydrogen atmosphere. The structure dimensions and low power measured field parameters are summarized in Table.I.

TABLE I Parameter of the accelerator structure

Phase Shift/Cell	$2\pi/3$	Constant Gradient
Structure Length	66.5	cm
Iris Diameter (2a)		
in	1.8998	cm
out	1.5900	cm
Cavity Diameter (2b)		
in	8.172	cm
out	8.124	cm
Resonant Frequency (f)	2856	MHz at 36.5 °C
Q	11600	
Shunt Impedance (r)	62	MΩ/m
Attenuation	0.48	Neper /m
Average Group Velocity (vg/c)	0.00445	
Filling Time (Tf)	0.475	μsec

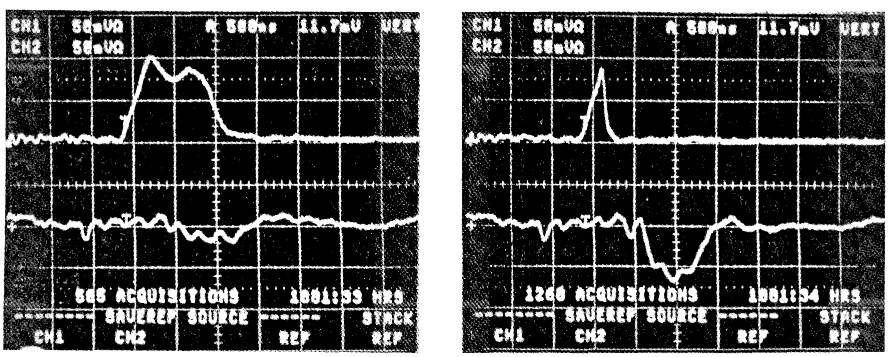
From parameters of the Table I, the accelerating field Eacc can be estimated in the following way:

$$\text{Eacc}\ [\text{MV/m}] = 7.13\sqrt{\text{Pin}\ [\text{MW}]}$$

where Pc is the RF input power in MW. The filed gradient was evaluated by measuring the energy spectrum of the field emission current though out of the structure. For this purpose, a simple energy analyzer of 90° bending angle was installed down stream of the accelerator structure and electrons transmitted by a Faraday cup of the ICF-152 SUS-flange. The peak current and pulse shape of the field emission current are monitored with calibrated current transformers. The two current transformers were added at the up-stream and down-stream of the accelerator structure, respectively. An integral type ionization meter(x-ray survey meter) installed horizontal beside the structure to measure the radiation levels, and another one, ten simple x-ray pinhole probes installed to detect emission of along the beam axis from structure. This pinhole probes are located along beam axis of the structure with 3.5 cm constant space which are consist of scintillator photo guiders and photomultipliers. A luminescent ceranics inside of the vacuum chamber with glass view port and black and white video camera were installed to profiles of the field emission current during the RF processing which are located behind of the structure. Whole experimental devices are controlled by a VAX station 3500 computer and CAMAC system. High gradient operation must need a conditioning up to a peak power level of 200MW. We use automatic conditioning program which is monitors vacuum of waveguide and structure, RF output power and interlock status and controls the RF power, as a both vacuum changes.

EXPERIMENTAL RESULT and DISCUSSION

An accelerating field gradient Eacc of 57.1 MV/m has been obtained after 400 hours processing with an input power of 64 MW at pulse width of 1 μsec and 25 Hz repetition rate which correspond to a microscopic field enhancement factor ß=22. At this gradient, accelerating structure can be successive operation with occasional notice RF breakdown. Figure 2 shows the refrected and transmitted RF power for both the normal condition and for condition at the breakdown level.



a) Normal operation b) Breakdown level

FIGURE 2 Refrected and transmitted RF power

Figure 3 shows the typical electron energy spectra of the field emission current for various RF input power. The each points where the spectra crosses the minimum current level would correspond to the maximum electron energy for various given gradient. The lines of the 41 MW and 47 MW with large value of the field emission current represents a newly reached domain. Figure 4 shows , also the energy spectra at same accelerating gradient were taken on the different day. The upper line was taken after 10 hours and lower line was taken after 300 hours RF conditioning An upper line show the grows of field emission current was whole the structure. A lower line show the region where the surface is sufficiently RF processing without low energy regions. This suggests that the RF processing reduce the effective area of the field emission.

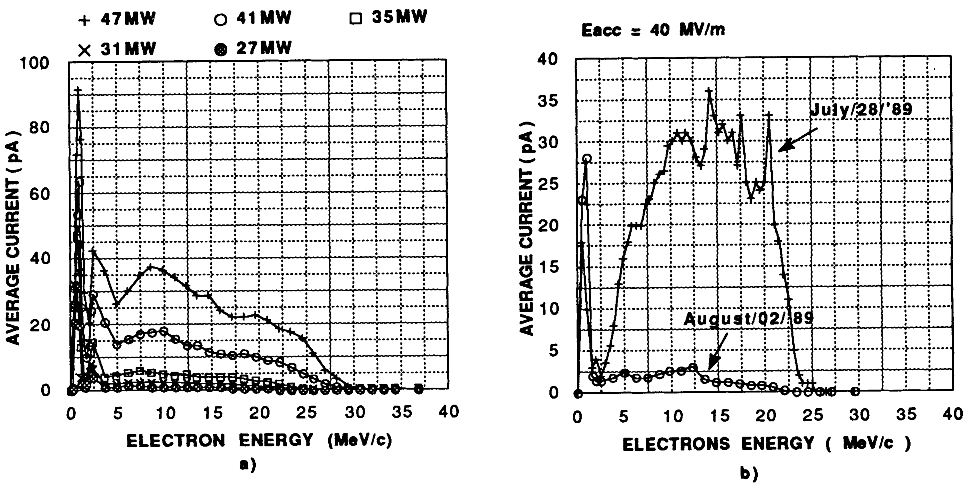


FIGURE 3 Electron energy spectra at various accelerating gradients. a) Energy spectra at various RF input power. b) Energy spectra at same accelerating gradient on the different day.

Figure 4 shows a typical field emission dark current is measured by scintillation x-ray probes and current transformers. Such an event was recorded by using a first digital scope and store four pulses produced at real time of operation. The first and second lines are current transformers, the 3td to 13th lines are scintillation x-ray probes and last two lines are forward rf power and through rf power of the structure, respectively. Whatever field emission current is observed at given power level before breakdown, the current jumps spiky by a factor of twice, as viewed on current transformers and x-ray probes.Figure 4 also showed, occasional breakdown event takes place, dominantly in the end of the structure, it is observed on tree x-ray probes which are put on the end of structure. Figure 4 suggest that the RF breakdown events appears first 0.5 μsec or later in to the any pulses, which correspond to the end of 0.6 m structure.

ACKNOWLEDGMENTS

The authors gratefully acknowledge T.Naitou set up the pulse monitors system to record the any pulses. S.Kawamoto set up the VAX 3500 computer programmes for operation of the klystron modulators.

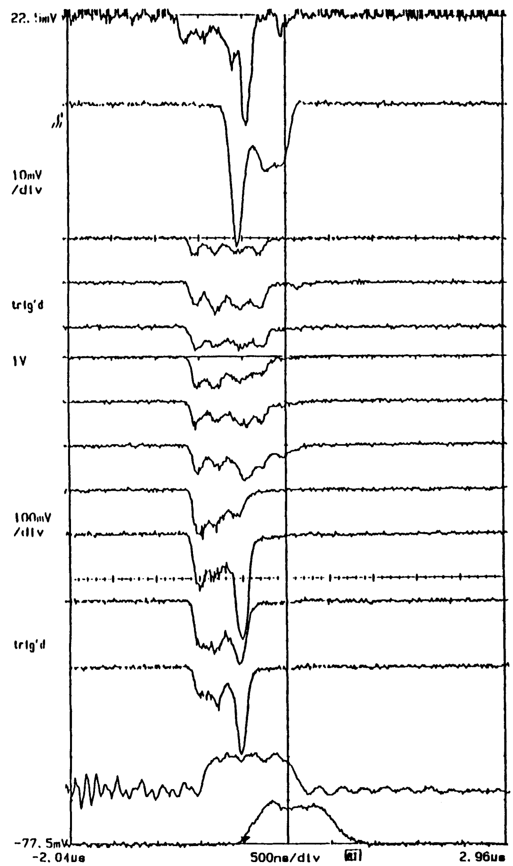


FIGURE 4. Typical field emission dark current.

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