NORMAL CONDUCTING HIGH-GRADIENT STUDIES AT KEK

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Abstract

Normal-conducting high-frequency high-field studies have been pursued at XTF, which is a high power X-band RF facility of KEK developed for linear collider. Three traveling-wave structures dedicated for development for X-band linear collider were studied in high field at more than 70MV/m. High-field characteristics such as field emission properties and trip rates were studied carefully as the processing proceeds. Operation at 400ns and at 50MV/m level was found very stable while breakdowns happened once an hour or so at more than 70MV/m, indicating some critical point. Further basic studies on field/power limitation or robustness against breakdowns in various materials are planned using narrow waveguide configuration. These recent studies at KEK are described in this paper.

INTRODUCTION

After ITRP recommendation for ILC [1] to date, the high-field evaluation activity on LC structure has been kept at KEK to obtain as much information on high field as possible [2]. Two more structures, KX02 and KX03, were made following KX01 to establish the fabrication technology developed for LC [3]. The final one KX03 is the fully damped-detuned structure. The breakdown rate required for LC was 0.1 breakdowns per hour at 60Hz [4]. This requirement was barely met with detuned structure, KX01, as of ITRP with a 400ns practical pulse shape [2]. We have been trying to evaluate the difference and similarities of these structures. In the present paper are described the present status of this comparison study.

THREE TESTED STRUCTURES

Fig. 1 shows the last structure KX03 we made at KEK. Three structures, KX01, KX02 and KX03, are all 60cm long and detuned cell design. The KX02 and KX03 are damped in addition, resulting in constituent cells milled high field area. The last structure KX03 is equipped with the HOM extraction ports, while in the KX02 only its cells with damped structure shape.

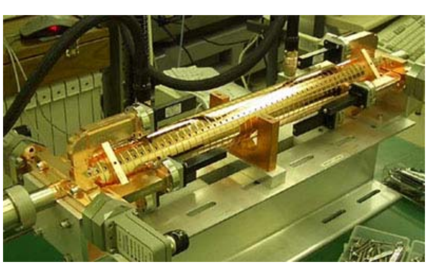

Figure 1: KX03 as of final checking with low level RF.

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Fabrication

The structure were made and prepared for high power test as follows.

1. Cell fabrication with milling part to final dimension.
2. Cell fabrication with diamond turning.
3. Chemical etching of ~0.5μm (or less).
4. Diffusion bonding and brazing in a hydrogen furnace.
5. RF bead pull and tuning for KX03.
6. Vacuum baking at 500degC for a week.
7. RF bead pull and tuning for KX01 and KX02.
8. In-situ bake at 200degC for a week for KX01.

The field smoothness was tuned better in KX02 and KX03.

HIGH POWER PROCESSING

Power Ramping and Long Run

All the high power test was performed at XTF [5] of KEK. In the KX01, the power ramping speed was fairly high comparing to the other two because of a rush to be in time for ITRP visit. It took only 50 hours before reaching the level of 65MV/m with 400ns pulse [2]. In the KX02 the ramping was a little moderate than KX01 as shown in Fig. 2, while in KX03 it was even more moderate as shown in Fig. 3. However, the final Eacc values for the same pulse width are similar.

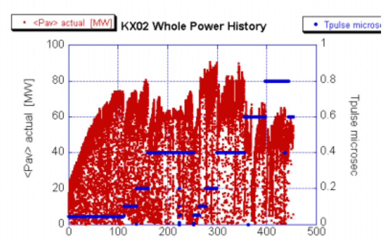

Figure 2: KX02 history. Red=power and Blue=Pulse width.

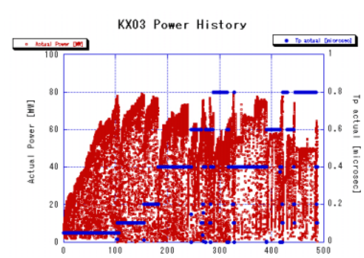

Figure 3: KX03 history. Red=power and Blue=Pulse width.

It was discussed that the surface heating during RF pulse is an important value to limit the ramping rate of any processing [6]. Figs. 4 and 5 are shown the same plot as Figs. 2 and 3 but with value proportional to the pulse temperature rise, Power*(Pulse width)$^{1/2}$. Both structures reached roughly 1500 MW*nsec$^{1/2}$ but KX03 reached the level more smoothly and linearly. The smooth manner in KX03 may be attributed to the moderate ramping speed and the better cleanness by avoiding the bead pull after high-temperature baking.

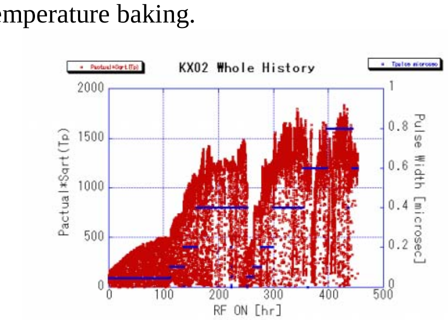

Figure 4: KX02 Power * Sqrt(Tp).

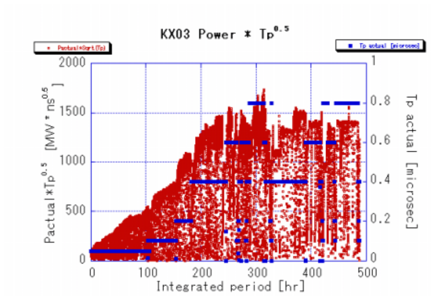

Figure 5: KX03 Power * Sqrt(Tp).

Dark Current

Dark current evolution in KX02 at the pulse width of 400nsec was observed as shown in Fig. 6. It monotonically decreased as processing proceeded except for the data lastly taken shown in black dots. We speculated that this is because of the aggressive processing run with 800ns at 65MV/m level or higher for more than 20 hours.

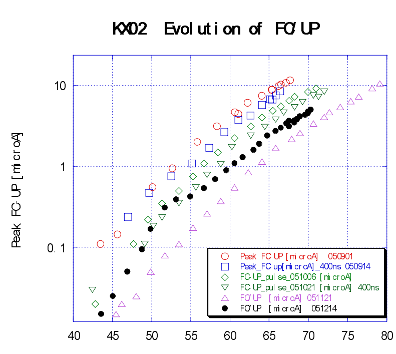

Figure 6: Dark current measurement on KX02.

The dark current was analysed by modified Fowler-Northeim formula [7]. As shown in the typical results in Figs. 7 and 8 the dark current is well reproduced with the formula. The field enhancement factors were found high for upstream dark current compared to the downstream one. It weakly depends on pulse width except for very short pulse as 50ns as shown in Fig. 9. Comparison with KX03 is in progress.

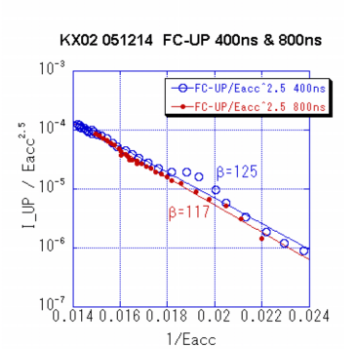

Figure 7: FN plot of upstream dark current in KX02.

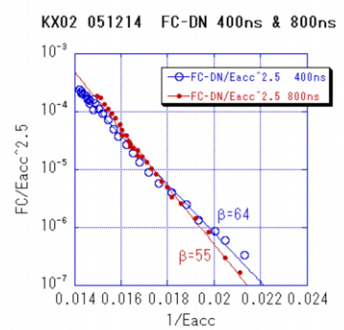

Figure 8: FN plot of downstream dark current in KX02.

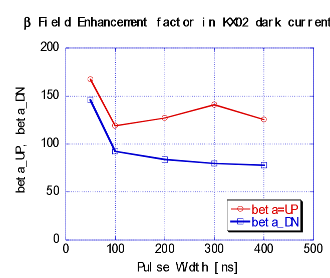

Figure 9: Field enhancement factor vs. width in KX02.

Energy spectra of the dark current were also measured as shown in Figs. 10 and 11. In Fig. 10 are shown the comparison with different pulse widths, while in Fig. 11 with different acceleration fields. Both when the pulse width increases and when the acceleration field increases, the low energy peak mainly increased.

Breakdown Rate

Careful breakdown rate evaluation was performed in KX03 long-run operation during the integrated RF-ON period from 300 to 440 hours. The result is shown in Fig. 12. It can be concluded that the rate with 400ns flat pulse is below 0.1BD/hr assuming the exponential behaviour of breakdown on Eacc, ~$10^{-Eacc/5(MV/m)}$ [8]. We speculate that the high rate at 800ns may be due to the limited conditioning period at this pulse width.

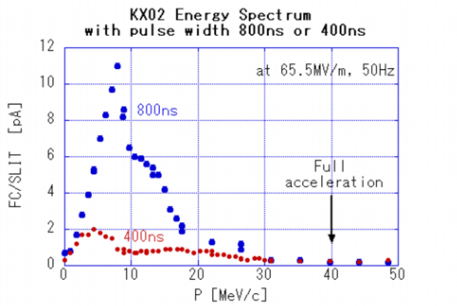

Figure 10: Energy spectrum of KX02 at 65.5MV.

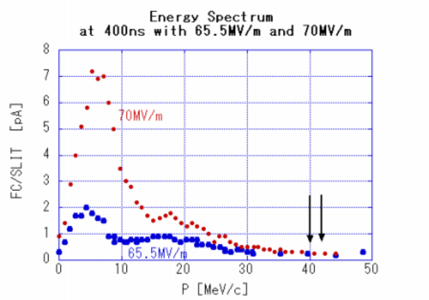

Figure 11: Energy spectrum of KX02 at 400ns pulse.

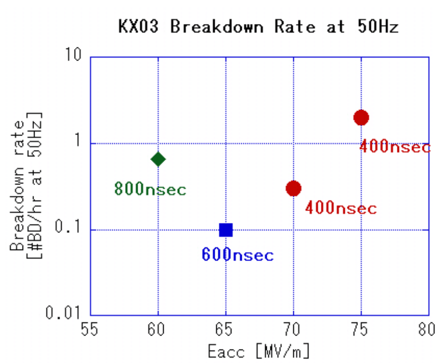

Figure 12: Breakdown rate of KX03.

UPCOMING BASIC STUDIES

For further study to higher field, we are planning to study high field performance in rectangular wave guide of reduced cross section such as shown in Fig. 14. Here both height and width are reduced. Typical size is 1mm high and 14mm wide so that the group velocity becomes 30% of light velocity and the electric field becomes 200MV/m at 100MW transmission. In Fig. 15 are shown parts to be brazed to make a test wave guide. The same geometry will be applied for up and down E-plane surfaces to study various materials other than copper. Other material studies are being performed in collaboration with SLAC [9]. Following the idea of P. Wilson [10], we will proceed studies on Moly and other materials.

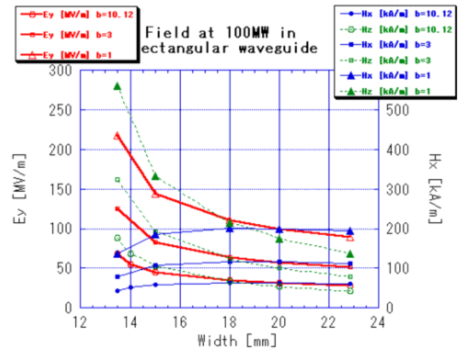

Figure 13: Narrow wave guide field.

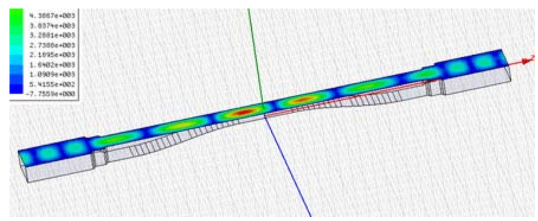

Figure 14: Electric field in narrow waveguide.

Figure 15: Narrow waveguide parts.

ACKNOWLEDGMENTS

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