MULTIPACTING STUDY OF LINAC PREBUNCHER AT CAMD*

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Abstract

Multipacting currents can absorb RF energy and produce breakdown in the prebuncher cavity of CAMD linac. This phenomenon starts when the magnetic field to focus the electron beam is applied [1]. The multipacting has been studied in different magnetic field and RF electric field, and can be eliminated by RF processing. In the paper, the theoretical and experimental results of multipacting study will be presented; moreover, the operability of the system will be analyzed.

INTRODUCTION

A 500 MHz pillbox cavity in the linac [1] acts as the prebuncher, which is excited to a TM_{010} mode to produce an accelerating field. It can remove the unused electrons for the storage ring [2-3]. The cavity main specifications in operation are listed in Table 1.

Table 1: Prebuncher Specifications

Electron energy	50keV
Frequency	499.7MHz
Peak field	100kV
Cavity gap	9cm
Pulsed power	4.75kW
β	1
Q	4360
Filling time	5.6uS

EXPERIMENT SETUP

The prebuncher RF system in the linac is shown in Figure 1. In order to produce proper RF power for the cavity, there are a 500MHz, 54 dB, 250 W, pulsed amplifier and a 500MHz, 16 dB, 5 kW, pulsed amplifier to amplify the 500MHz, 0 dBm, CW signal coupled from storage ring master signal generator.

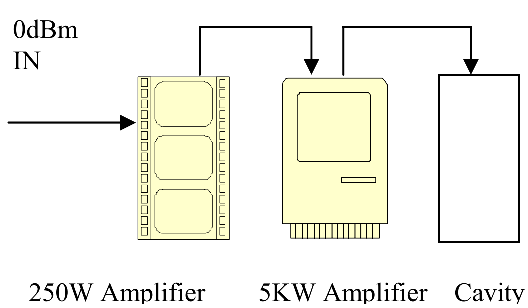

Figure 1: Diagram of the experiment.

The RF output waveforms from the two amplifiers are shown in Figure 2. The top one is the RF output of the 500MHz, 54 dB, 250 W, pulsed amplifier, and the bottom one is the RF output of the 500MHz, 16 dB, 5 kW, pulsed amplifier. The 30 μS pulse length is required by the cavity filling time in Table 1.

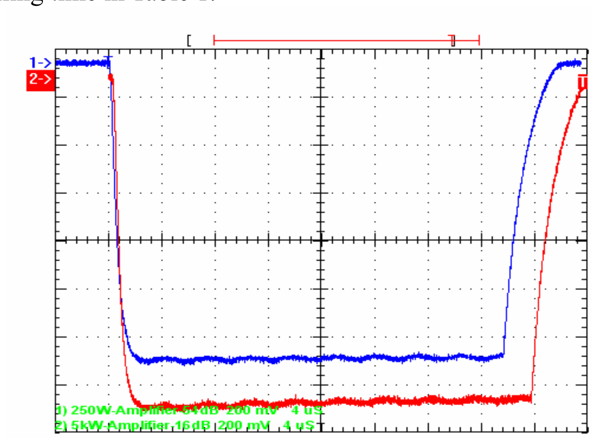

Figure 2: The RF output.

PRELIMINARY EXPERIMENT RESULTS

The RF system of prebuncher was tested and cavity was conditioned by RF power during recommissioning prebuncher. But when attending to operate the prebuncher work, multipacting in the cavity started when the power supplies for the focusing coils which generate magnetic field perpendicular to cavity surfaces in the buncher were turned on. In Figure 3, the signal is gotten by a coupler in the prebuncher cavity, the bottom waveform is without power supplies on, and the top one is with the power supplies on.

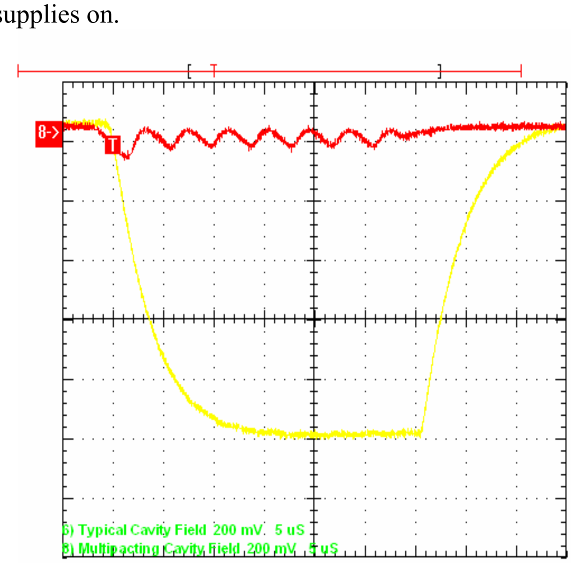

Figure 3: Cavity field.

In order to condition the cavity, the multipacting has been studied in RF power vs. magnetic field as shown in

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Figure 4. The multipacting happens between low boundary and upper boundary at different focusing coil magnetic field.

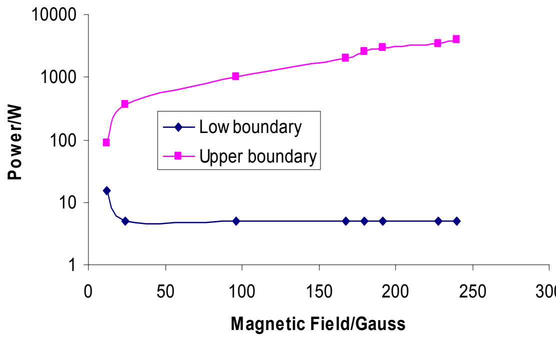


Figure 4: RF power vs. magnetic field in the cavity.

ANALYSIS

Through the experiment in Figure 5 and materials studied [3-8], the multipacting in the cavity is a half-cycle mode. The equation for an electron of mass m and charge e in a sinusoidal field of peak voltage V and frequency f of the cavity with gap d is [5-6]

$$V = \frac{4\pi^2 (fd)^2}{(e/m)\Phi} \qquad (1)$$

Where

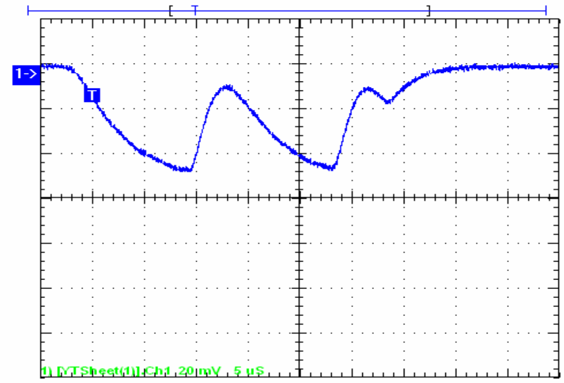
$$\Phi = (\frac{k+1}{k-1})\pi \cos\varphi + 2\sin\varphi \qquad (2)$$

Where φ is the time phase angle at which secondary electrons are emitted, and k is the assumed constant ratio of electron arrival velocity to emission velocity.

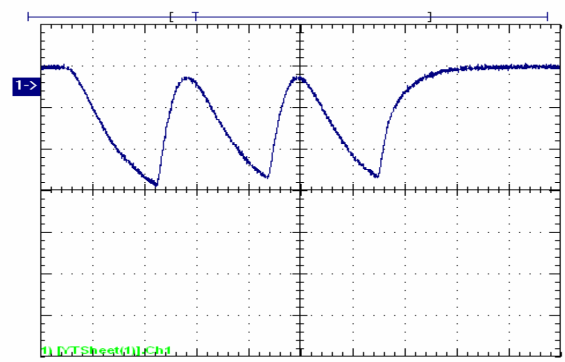
There are four waveforms at magnetic field 24 Gauss in Figure 5 from multipacting beginning to the multipacting ending with RF power from 5 W to 360 W. In the Figure 5, there is a modulation with a frequency increase accompanying the RF power to the cavity increase. This modulation can help to pass the multipacting region described in [5] from equation (1) because the modulation is equivalent to the frequency decrease. From (a) to (d) in Figure 5, there is amplitude increase which is also required to pass the multipacting region.

In the experiment, the resonant frequency of the cavity is changed when multipacting occurred. As shown in figure 5 (d), the frequency is already about 300 kHz at very low magnetic level, but the bandwidth of the cavity is about ±50 KHz; therefore, it is impossible to eliminate multipacting by detuning cavity.

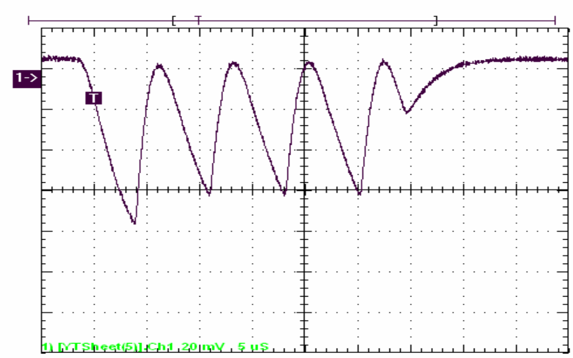
Figure 6 shows that there are high amplitude and high modulation frequency at high magnetic field because the higher magnetic field, the bigger the time phase angle; therefore, the larger multipacting region.



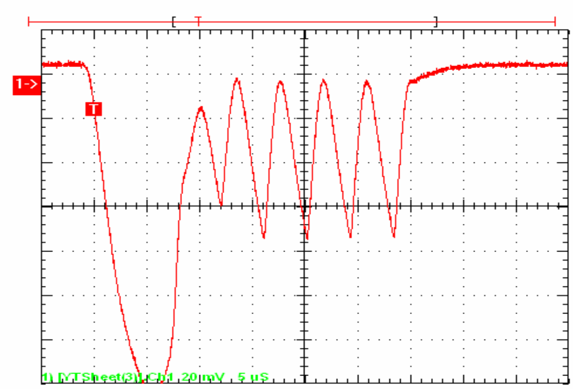
(a): 5W



(b): more than (a) & less than (c)

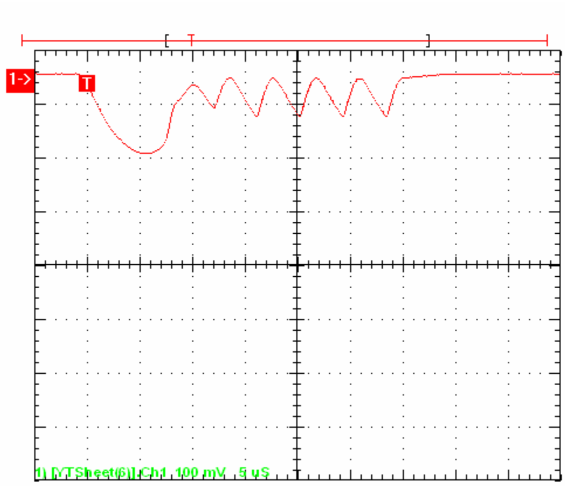


(c): more than (b) & less than (d)

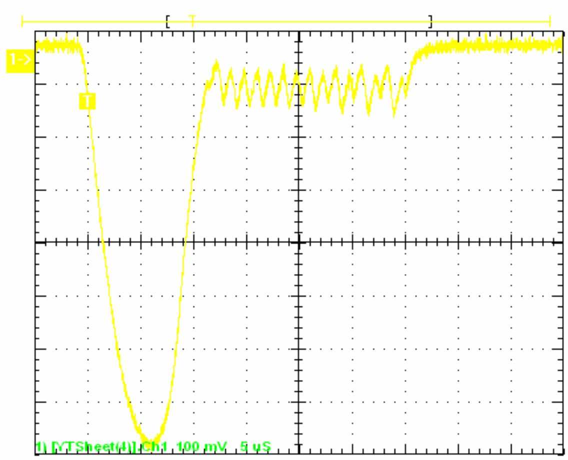


(d): 360W

Figure 5: Cavity field at magnetic field 24 Gauss with the power to cavity increase.



(a): RF power 360 W & magnetic field 24 Gauss



(b): RF power 2 kW & magnetic field 168 Gauss

Figure 6: Cavity field at upper boundary in Figure 4 at different magnetic field.

RF CONDITIONING

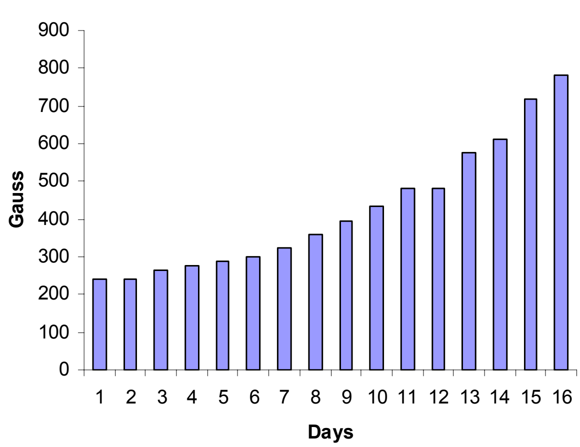


Figure 7: Magnetic field vs. days in commissioning

Commissioning the cavity begins after careful investigation by feeding reasonable RF power with focusing coil magnetic field increase in the upper boundary in Figure 4.

The very interesting results are shown in Figure 7. It takes 16 weekdays, about 12 hours per day, to reach the operation value at magnetic field 720 Gauss. The time is even longer if the investigation time is counted. The RF conditioning is very slow because the RF power duty cycle is very small (30 μs and 10 Hz, minus fill time of the cavity in Table 1), maybe, partly because the surface condition is poor.

CONCULSION & OPERABILITY

The RF conditioning makes the surface secondary ratio δ [9] big, and eliminate the multipacting in the prebuncher cavity.

When the RF conditioning reaches the operation value of magnetic field, the study to operation begins, the prebuncher is operated soon, and the multipacting does not affect operation afterward. A few months of operation later, this phenomenon totally disappears whenever the prebuncher RF system is maintained or checked.

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