DEVELOPMENT OF PEAK-HOLD MODULE FOR ELECTRON EMISSION IN STF-TYPE POWER COUPLER FOR THE ILC

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Abstract

The peak-hold module for the electron emission in the power coupler driven by the pulsed operation, like ILC (International Linear Collider) and E-XFEL, was developed in 2013. This module can detect two kinds of signals. One is the peak height, and the other is the integrated charge in one pulse. During the RF conditioning for the STF-type power couplers in the STF-2 cryomodules, this module perfectly worked, and detected different trend between the peak height and the integrated charge. In this paper, the detailed result for the peak-hold module is presented.

INTRODUCTION

In Superconducting RF Test Facility (STF), the RF conditioning for the STF-type power coupler [1] is done in several pulse widths from 10μsec to 1650μsec and the repetition rate of 5Hz, as specified in the Technical Design Report (TDR) for the ILC [2]. The most important monitoring signals during the RF conditioning are the vacuum level in the cold and warm part, and the electron emission by multipacting. The both vacuum levels, measured by the ionization gauges (ANELVA, M-431HG), continuously change during the high power operation. On the other hand, the electron emission, measured by the probe antenna to trap the emitted electrons, as shown in Figure 1, has the pulse-like behaviour with much faster response. Therefore, it was necessary to develop the peak-hold and the isolation modules to monitor the electron emission for the power coupler driven in the pulsed operation. Additionally, to detect the integrated charge in each pulse, the integration circuit module was also developed to investigate the electron emission in detail.

These newly developed modules perfectly worked in the RF conditioning at the test bench for the STF-type power couplers. Figure 2 shows the test bench for the RF conditioning of the STF-type power coupler. Two sets of the power coupler are simultaneously processed. Then, there are two electron emission signals; one is upstream (electron #1) and the other is downstream (electron #2).

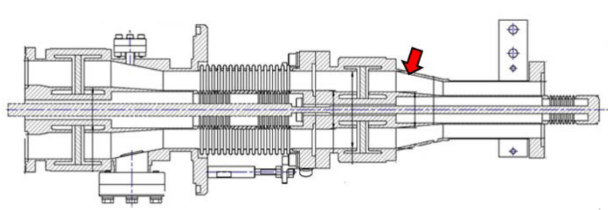

Figure 1: Position of probe antenna to trap the emitted electrons around the cold window, shown as the red arrow in the cross-sectional view of the STF-type power coupler.

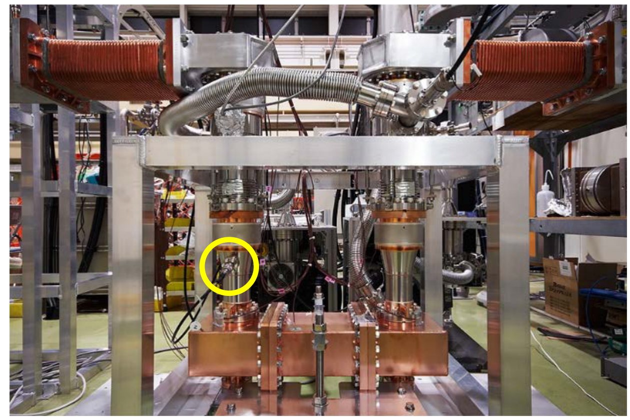

Figure 2: Test bench for the RF conditioning of the STF-type power coupler. Two sets of the power coupler is processed per batch. There are two probe antennas for the electron emission in the cold parts of the upstream (right) and downstream (left), as shown by the yellow circle.

NEWLY DEVELOPED MODULES

The newly developed modules are the peak-hold module, the insulation amplifier circuit module and the integration circuit module. Each module has four input/output channels. In the following, the feature for each module is described.

Insulation Amplifier Circuit Module

The electrons emitted by the multipacting are trapped by the probe antenna attached around the RF window in the cold part of the STF-type power coupler, and directly led to the insulation amplifier circuit module through the cable. Because it is the current signal, it is necessary to use the insulation amplifier circuit module for cutting the DC signal, and the conversion to the voltage signal. The type of the insulation amplifier is “AD215AY”. Figure 3 shows the two electron emission signals after the insulation circuit module where the current signal is converted to the voltage signal.

Peak-hold Module

The peak-hold module can detect the peak height in each pulse with the pulse width from 10μsec to 1650μsec every 5Hz, and hold it up to the next pulse. This module has one input channel for the RF timing trigger. At the beginning of each pulse, the peak-hold module carries out the zero reset within a few micro-seconds. The type of IC is “EPM7128STC100-15N” with the programmable logic device (PLD) control. In Figure 3, the peak height is shown as “h” in “electron #1”.

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Integration Circuit Module

To investigate the behaviour of the electron emission in the power coupler, the integration circuit module was also developed. The integrated charge is shown as "Q" in Figure 3. The same type of IC as the peak-hold module is used. Presumably, in a simple picture, there is a linearity between the peak height and the integrated charge. However, generally, the multipacting has the different behaviour at the various power levels. It is interesting to compare the peak height and the integrated charge for the various power levels.

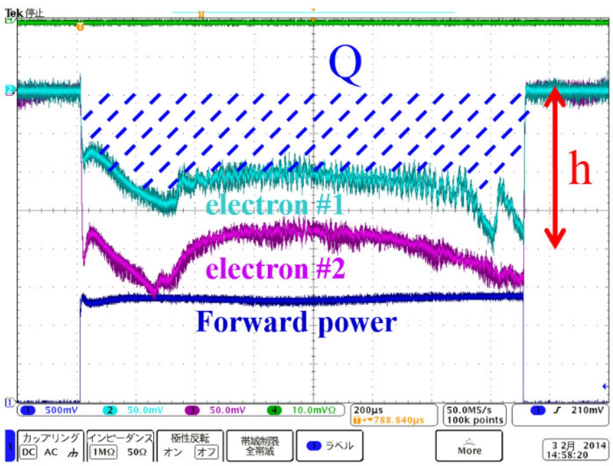

Figure 3: Electron emission signals after the insulation amplifier circuit module. Light blue (electron #1) and purple (electron #2); two electron emission signals at upstream and downstream, Blue; Forward power signal. The pulse width is 1500µsec. The peak-hold module can detect the peak height ("h") of "electron #1" emission signal, and the integration circuit module can detect the integrated charge ("Q") in the signal.

TEST OPERATION

Before the RF conditioning for the STF-type power couplers, the test operation for these newly developed modules were done. Figure 4 shows the two electron emission signals after the insulation circuit module, light blue; upstream (electron #1), and purple; downstream (electron #2). The peak-hold output #1 from upstream electron emission and the forward power are also shown there. The pulse width is 500µsec. In the peak-hold module, the "zero reset", as shown by "red arrow", is done within a few micro-seconds at the beginning of each pulse. After that, the module chases the peak height for the electron emission #1, detects the peak at 400µsec, where the both emission signals actually have the peak, and holds it up to the next pulse. This process is repeatedly done every pulse. The behaviour of the electron emission is not simple, because it depends on the forward power level and the pulse width (RF duty). However, this peak-hold module perfectly worked during the RF conditioning for the STF-type power couplers, installed into the STF-2 cryomodules [3].

In this test operation, the integration circuit module was also tested. Figure 5 shows the integrated charge for the both electron emission signals, light blue; upstream (electron #1), and purple; downstream (electron #2). The blue rectangular pulse is the forward power. The pulse width is 1500µsec. The integration circuit module works above the pulse width of 500µsec, because of less charge below that. Generally, the electron emission continues from the starting to the end point in each pulse. Therefore, the integrated charge shows the trend of the monotonic increase. Another peak-hold module detects the peak height for the both integrated charge, and, similar to the situation in Figure 4, holds it up to the next pulse. The "zero reset" in the integration circuit module is done at the end of each pulse, as shown in Figure5.

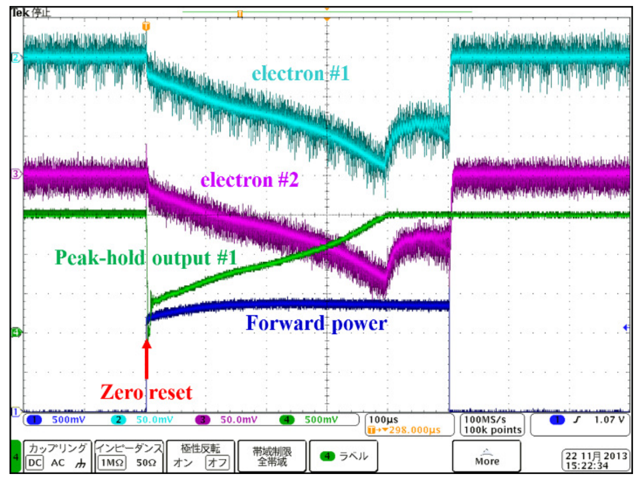

Figure 4: Example of the peak-hold detection for the electron emission during the RF conditioning. The position of the peak height is around 400µsec in the both electron emission signals. The peak-hold module chases the peak height for "electron #1" up to 400µsec, and after that, holds the constant output up to the next pulse. At the beginning of each pulse, the "zero reset" is done within a few micro-seconds.

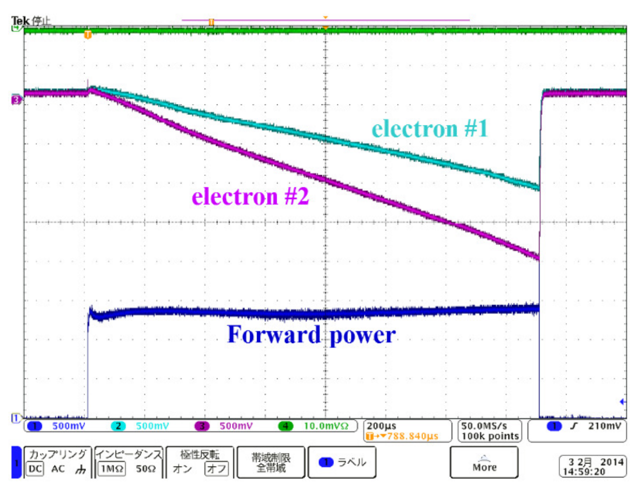

Figure 5: Two electron emission signals after the integration circuit module. Blue; forward power, light blue; upstream electron emission (electron #1), purple; downstream (electron #2). The integration circuit module works above the pulse width of 500µsec with sufficiently much charge.

ISBN 978-3-95450-182-3

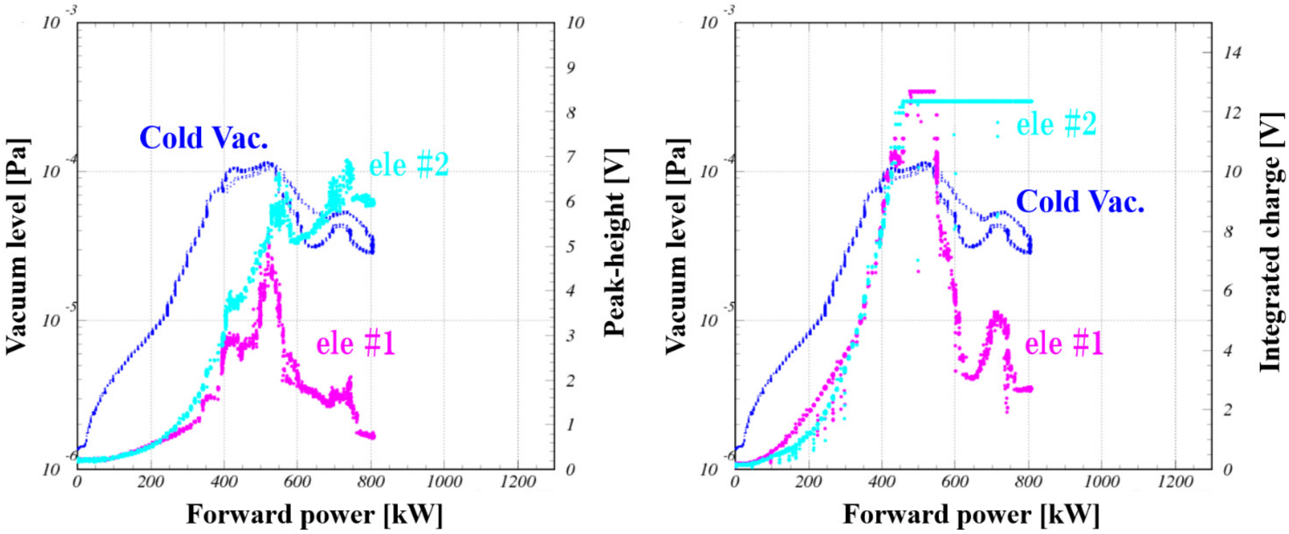

Figure 6: Correlation plots between the cold vacuum, and the peak height (left) and the integrated charge (right) in two electron emission signals for the forward power. The pulse width is 1500μsec for the both plots. The peak height shows the sharp response, and the integrated charge shows the redundant response. The saturated voltage is 12 V in the integration module. Then, the integrated charge for the electron emission #2 (downstream) is saturated above the forward power of 450 kW.

PEAK HEIGHT V.S. INTEGRATED CHARGE

Figure 6 shows the correlation plots between the cold vacuum, and the peak height (left) and the integrated charge (right) for the electron emission at the upstream and downstream of the test bench, for the forward power. The saturated voltage is 12 V in the integrated circuit module. There are two multipacting levels around 400-500 kW, and 700kW, as shown in the cold vacuum. On the other hand, there are three or four peaks, including small ones, in the peak height for the both electron emissions. As for the integrated charge, it is clear that it has the different trend from the peak height; rather, it is similar to the trend of the cold vacuum. This means the peak-hold module can detect the sharp response, and the integration circuit module can detect the redundant response. Although the same type of power couplers is processed, it is interesting to show the different trend between the electron emission #1 and #2.

CONCLUSION & FUTURE PLAN

The insulation amplifier circuit, the peak-hold, and the integration circuit modules were developed and tested in STF. These modules perfectly worked for the RF conditioning of the STF-type power couplers installed into the STF-2 cryomodules. It was clear that there is the different trend between the peak height and the integrated charge.

In future, the new modules with 20 input/output channels will be developed for the STF-2 cryomodule operation.

ACKNOWLEDGEMENTS

Special thanks are given to H. Uematsu and Y. Furuhashi (TUJICON) for the development of these modules; T. Yanagimachi, S. Imada, M. Asano (NAT), and R. Ueki (moved from NAT to KEK) for the operation in the RF conditioning; T. Okada (K-VAC) for the assembly work of test bench in the clean room; A. Hayakawa (KIS) for the maintenance of control and monitoring system for the operation of RF conditioning.

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