AUTOMATIC CORRECTION SYSTEM FOR THE TLS BOOSTER LINAC KLYSTRON MODULATOR

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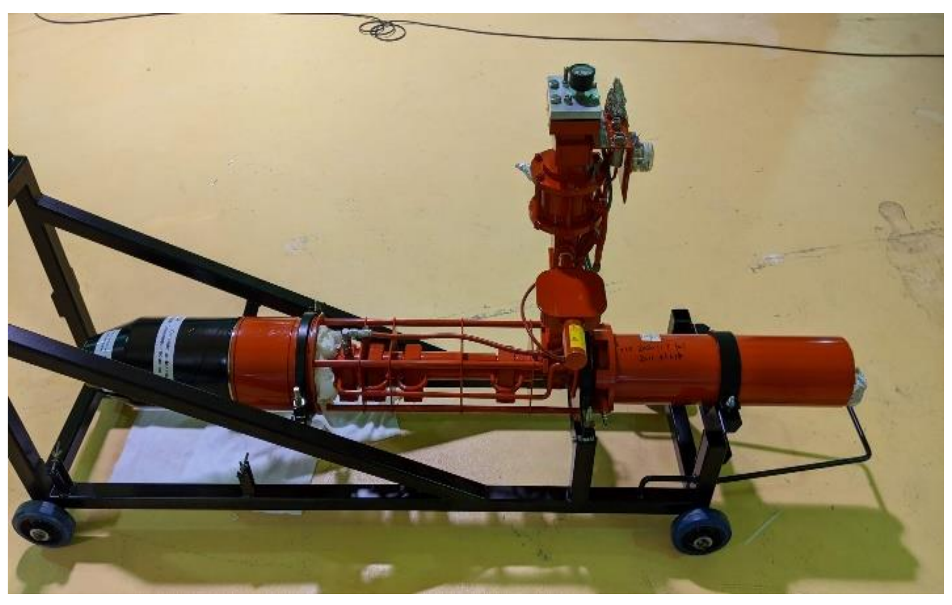
The aim of this article is to analyse the performance output of the klystron modulator, which is based on the observation of the output voltage and current performance of the linear-accelerator klystron modulator; we modify the operating-point parameters based on those results or assess whether the klystron needs to be replaced. For this purpose, we collect the observation data of the klystron performance; we then develop a program to adjust automatically the high-voltage setting of the klystron to ensure that the storage current maintains beam current 360 mA in the top-up mode operation.

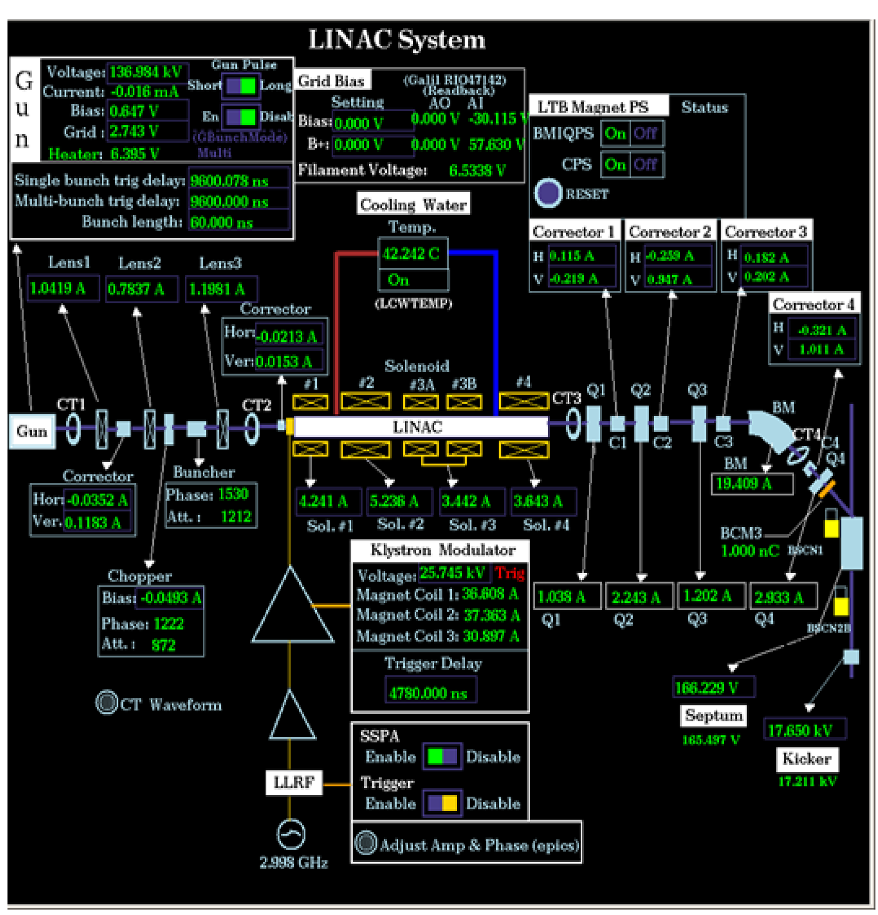
MOTIVATION

We therefore purchased a spare klystron to replace the old one. However, because of the impact of COVID-19, the transport has been delayed, so we could not replace it in time, while the performance of the old klystron then becomes unstable. An operator must therefore adjust the operating parameters according to the variation of the output state.

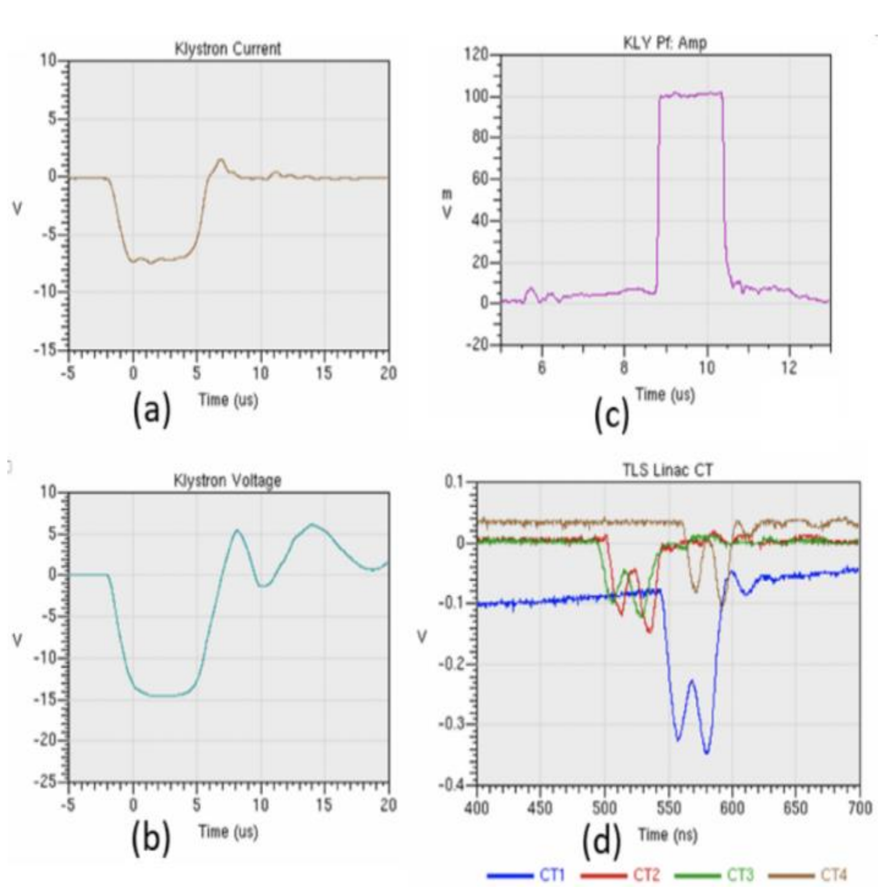
To decrease the burden on the operators, we used the output data of the klystron to develop a program to correct the system automatically, which is described in the following sections.



WAVEFORM DATA COLLECTED FOR THE ANALYSIS



Among many monitoring systems developed by the instrument control group, the four waveforms that we used in the analysis are the klystron output current, the klystron output voltage, the klystron output power and the current transformers (current transformer, CT). The installed positions of the CT can be seen in Figure.



(a) Klystron output current

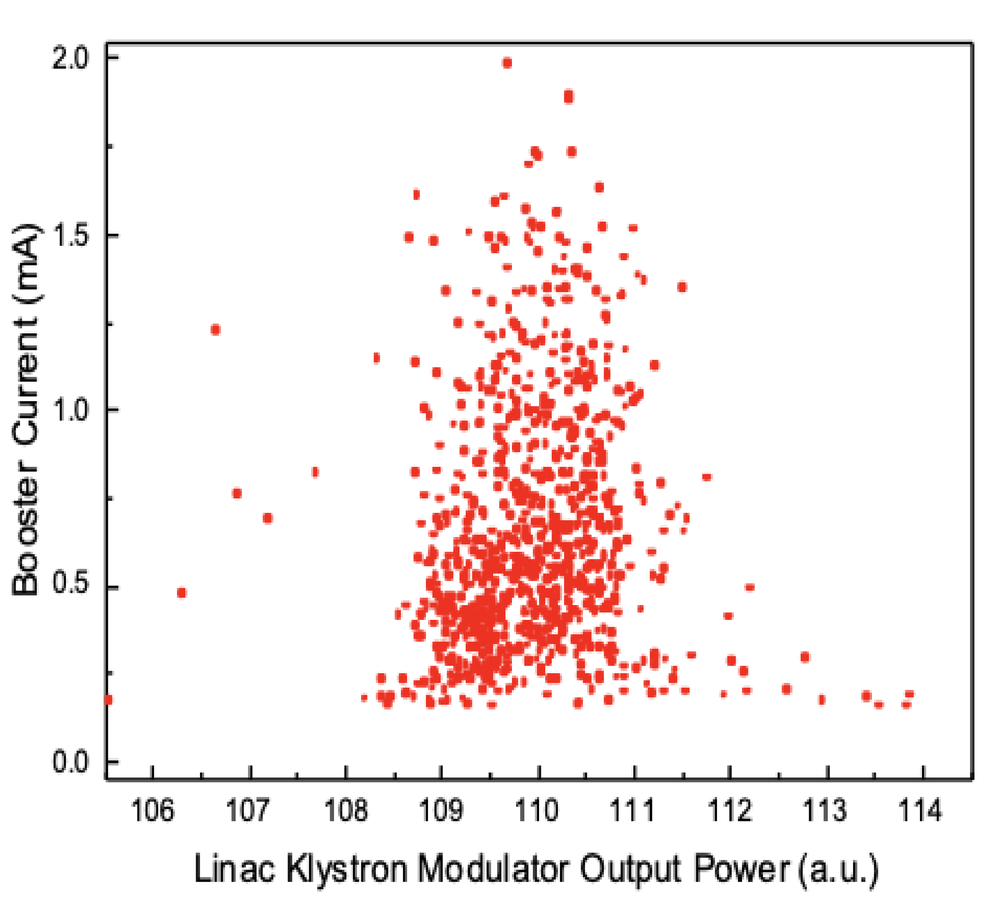
(b) Klystron output voltage

(c) Klystron output power

(d) CT1~CT4 waveforms

(a) and (b) can be used to assess whether the klystron is working normally.

(c) can use it to assess whether the output power meets the power required by the Linac.



For the klystron output power, one can use it to assess whether the output power meets the power required by the linear-acceleration stage. If no break-down phenomenon occurs in the klystron, the output power does not change abruptly; the effective working point falls into a range 108.5 to 111.

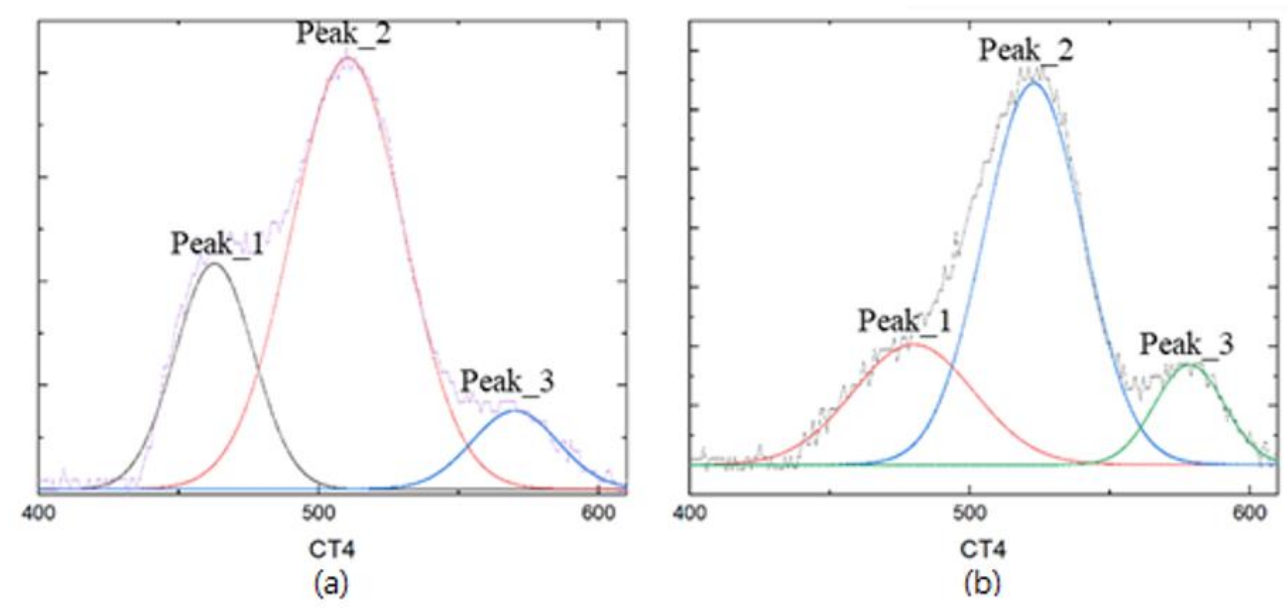
•CT1: electron beam downstream of the electron gun

•CT2: electron beam upstream of the linear accelerator

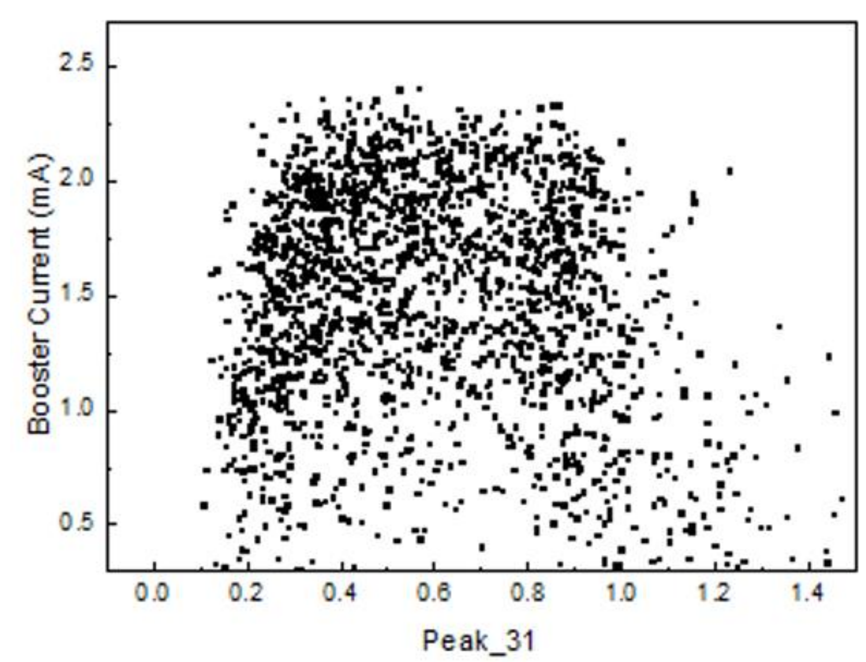
•CT3: electron beam downstream of the linear accelerator

•CT4: electron beam downstream of the 60° bending magnet

CT3 and CT4 are both downstream of the linear- acceleration section, but the CT4 waveform is the main object of this analysis because the waveform of CT3 lacks energy discrimination.



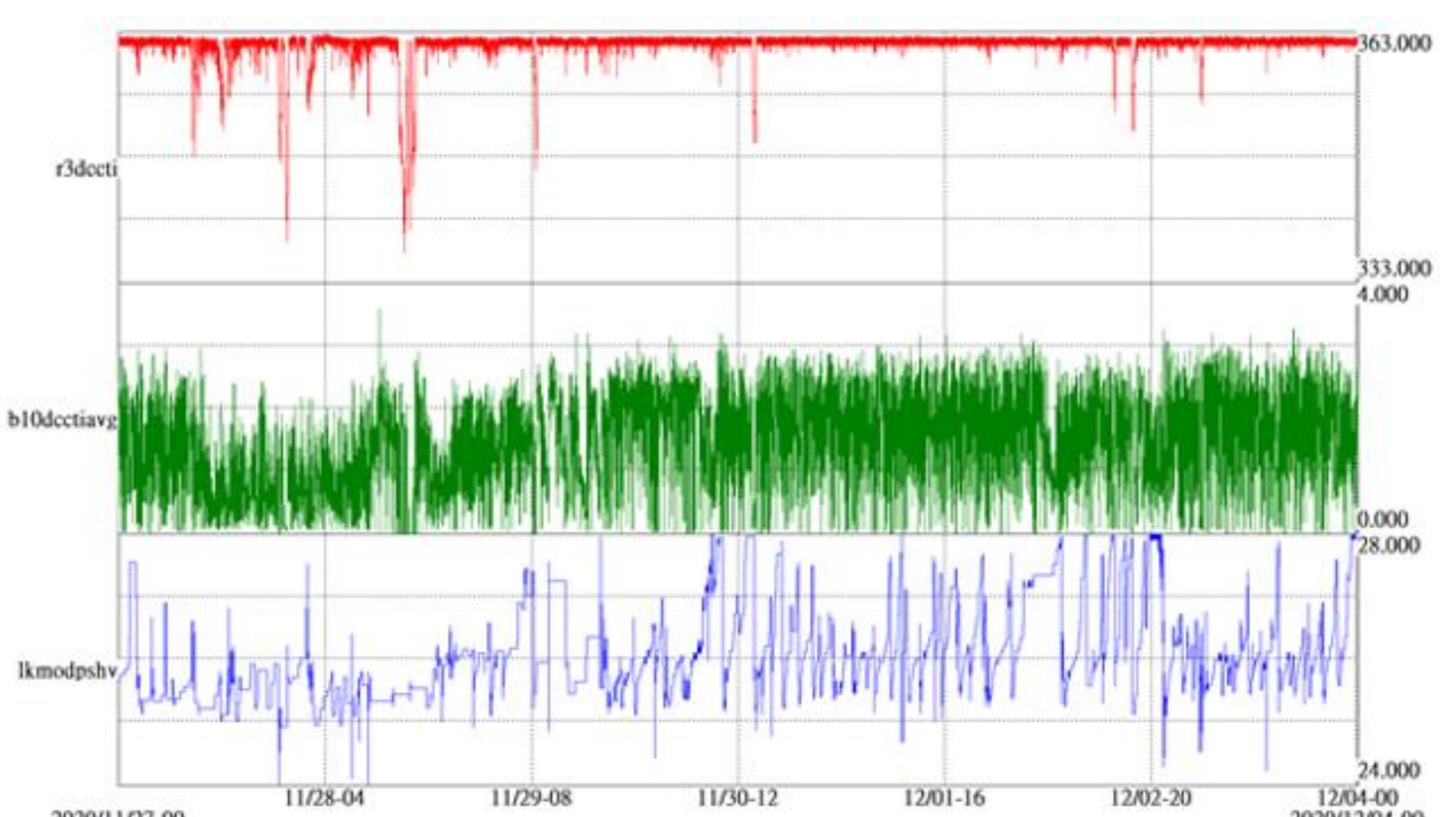
The waveforms of the CT4 are separable into several peaks with Gaussian fitting; for example, three peaks in Fig. (a) and (b), which are for a low-energy state and for a high-energy state respectively.



In the experience of this study, if the ratio of peak 3 to peak 1 (peak_31) is outside the range 0.2~1, the output booster current becomes unstable, as the statistics show in Fig.

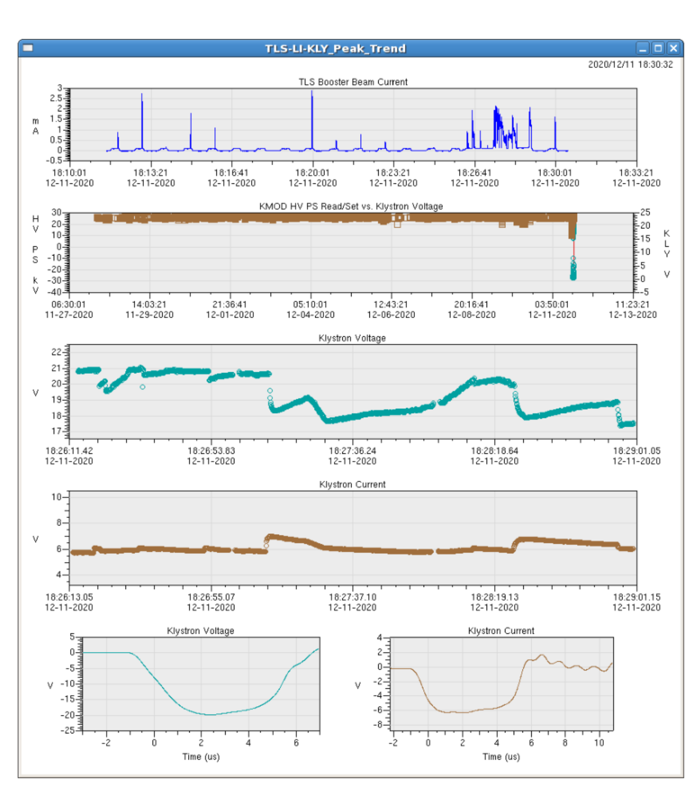
These waveforms and the range also depend on the settings of other components.

PROGRAM EXECUTION RESULTS



The performance of our program in one week. One can clearly see that the booster current output can be stabilized with our program, so that it can also ensure that the storage current can maintain the rated 360 mA during the user's time period. One can see the break-down phenomenon occurring at a frequency about once per hour.

Conclusion



Through adjusting the high-voltage setting of the modulator in time with our program, the klystron can still maintain a normal output at the end of its life, thereby increasing the final residual value of the klystron, of which the cost is approximately 20,000 Euros.

However, since we ran this program for a half year, the status of the klystron deteriorated, such that the frequency of the break-down phenomenon became once per 3 min. The situation was hence beyond the ability of our program to cope; the klystron had to be replaced.