THE REAL-TIME WAVEFORM MASK INTERLOCK SYSTEM FOR THE RF GUN CONDITIONING OF THE ELI-NP GAMMA BEAM SYSTEM

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Abstract

The new Gamma Beam System (GBS) of the ELI-NP project [1], currently under installation in Magurele (RO) by INFN, as part of EuroGammas consortium, can provide gamma rays with characteristics that open new possibilities for nuclear photonics and nuclear physics.
ELI-NP gamma rays are produced by Compton back-scattering to get monochromaticity (0,1% bandwidth), high flux (10^{13} $\frac{photon}{s}$), tunable direction and energy up to 19.5 MeV. Such gamma beam is obtained when a high-intensity laser collides a high-brightness electron beam with energies up to 740 MeV.
The S-band RF-Gun, made with the novel clamping gasket technique [2], working in π-mode at 100 Hz with a maximum RF input of 16 MW, RF peak field of 120 $\frac{MV}{m}$ and filling time of 420 ns was fully tested and conditioned during December 2015 in Bonn University at ELSA facility.
This paper will describe the real-time fast-interlock system, based on waveform mask technique, used during RF Gun conditioning. Instead of relying only on vacuum pumps read-out, this system monitors on-line the reflected RF signals for a pulse-to-pulse breakdown detection, thus ensuring a higher safety of the Gun and modulator system.

INTRODUCTION

In order to monitor the ELI-NP-GBS RF-Gun performances during its conditioning we needed a control system able to monitor shot-to-shot RF signals, identify any kind of malfunction and, eventually, stop the power feeding before the next RF pulse. To satisfy these requirements a fast-interlock system able to sample and analyze the reflected power waveform and stop the RF source in less than 10 ms has been developed.

SETUP

As shown in Fig. 1, the whole control system is based on a National Instruments (NI) cRIO equipped with analog input module, to acquire vacuum signals from 4 ion pumps, and a DIO module, to acquire and send to the Scandinova RF modulator the interlock signal. The waveform mask is realized with a NI PXI system that acquires the reflected power down-converted signal from a schottky diode (HP 423B) with a digitizer NI PXI-5154 ($2\frac{GS}{s}$, 1 GHz BW and 8-bit resolution) and a DAQ NI PXI-6221 to interface the PXI with the cRIO.

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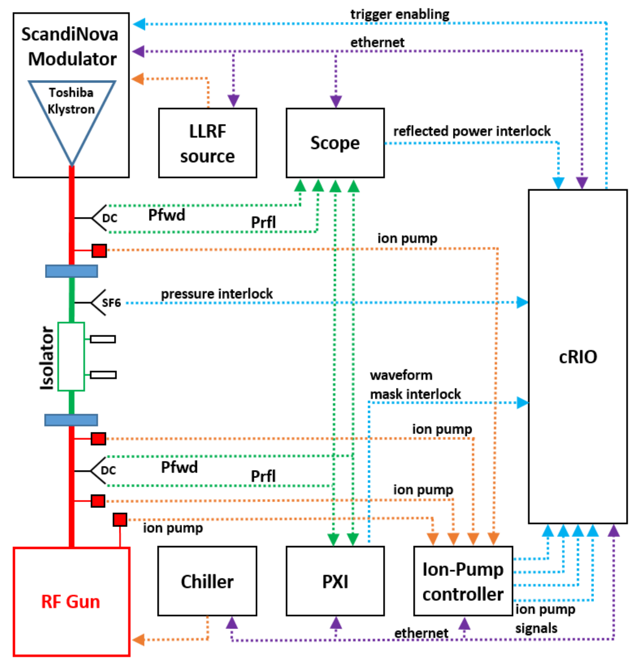

Figure 1: RF Gun conditioning setup in Bonn.

The cRIO system collects also signals from ion pump controllers and generates a vacuum interlock when the current absorption overcome a certain threshold. In this case, the TTL enabling signal supplied by the cRIO to the ScandiNova PLC is removed and the emission of RF pulses is stopped.

The choice to develop a pulse-to-pulse interlock system resides in the intrinsic slow response time of a vacuum system, which is of the order of hundreds of milliseconds from the breakdown occurrence to the interlock signal delivery to the RF source. Being 10 ms the maximum delay acceptable, an effective real-time interlock system has been developed digitizing the reflected power signal picked up at the RF-gun input port and down-converted with a schottky diode.

MASK ALGORITHM

The PXI digitizer acquires this signal and analyzes the waveform with the mask algorithm at 100 Hz repetition rate. If a breakdown is detected, PXI produces through the DAQ a TTL interlock signal to the cRIO that is used with the same logic of vacuum interlock already mentioned.

At each trigger, as shown in Fig. 2, the software computes the following operations:

1. During the initialization, the algorithm acquires the waveform to produce two arrays. The first one is the waveform plus a constant while the second is the waveform minus a constant. The difference between such constants identifies the region of tolerance (the so-called mask).
2. For each acquired waveform, the algorithm checks if each sample is included in the mask region.
3. If so, the waveform is assumed "healthy" and no interlock is generated. The actual waveform is used as reference to update the region of tolerance and the loop restarts from point 2.
4. If not, the mask it is "broken", then the software collects a screenshot of the waveform and changes the TTL Digital Output available on the DAQ inside the PXI from the logical state high to low. This interlock signal is propagated through the cRIO to remove the trigger signal to the modulator. This status persists until an operator acknowledges the breakdown event and resets the system.

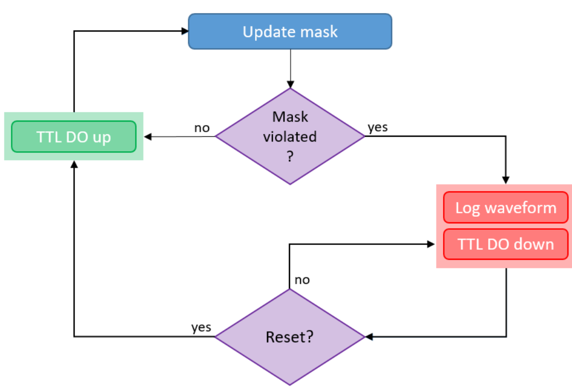

Figure 2: Mask algorith flow-chart.

The average time needed to acquire a new waveform, run the algorithm and propagate the interlock up to the RF source is about 2 ms. This results well below the constraint of 10 ms given by the 100 Hz repetition rate, and therefore demonstrates the benefit of the use of the waveform mask as real-time interlock during the conditioning.
Nevertheless, thanks to the waveform mask, it has been possible to detect about 550 breakdowns, an example of which is shown in Fig. 3, that were not detected by the conventional vacuum interlock method. Thus, such system allowed to carry out a safer conditioning both in terms of RF-source and RF-gun operation.

Currently, the waveform mask system is under hardware and software update for two main purposes: it has to handle simultaneously up to four analog signals (so to condition up to four structures in parallel); and it has to be integrated in the control system as permanent real-time interlock for the RF Gun during the linac operation. For this reason, the core algorithm will remain the same, but a new digitizer (cheaper and with better performances) will substitute the NI one.

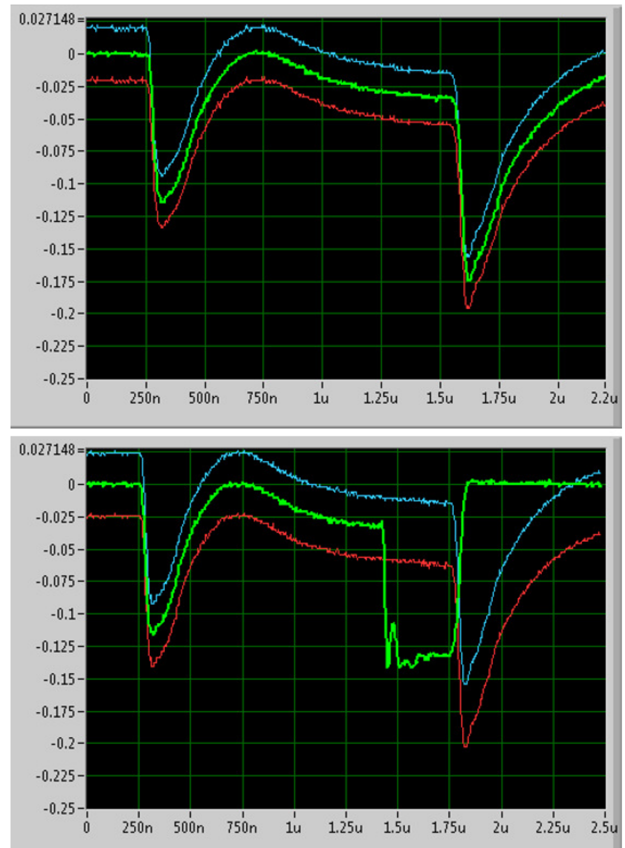

Figure 3: The green curve is the RF signal, the blue and red ones identify the tolerance region of the mask. Top image shows an healthy RF signal while the bottom one a detected breakdown.

CONCLUSION

The ELI-NP-GBS RF Gun produced with the new clamping gasket technique developed at INFN-LNF allowed a fast conditioning with low vacuum activity due to RF breakdown. Thanks to the waveform mask technique we were able to condition the gun in the safer way detecting also breakdowns invisible from any vacuum diagnostics. Due to the tested reliability of this system we choose to implement it inside the RF system of the accelerator in order to assist conditioning operation of the 13 RF stations and for the long run operation monitoring the RF reflected and probe signal of the RF Gun.

REFERENCES

[1] *L. Serafini et al.*, "Technical Design Report EuroGammaS proposal for the ELI-NP Gamma beam System ", arXiv:1407.3669, 2014.

[2] *D. Alesini et al.*, "High Power Test Results of the Eli-NP S-Band Gun Fabricated With the New Clamping Technology Without Brazing ", in Proc. of International Particle Accelerator Conference (IPAC'17), Copenaghen, Denmark, May 14-19, 2017, paper THOBB1, this conference.