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Rapid recovery after RF break down of high average power RF Gun

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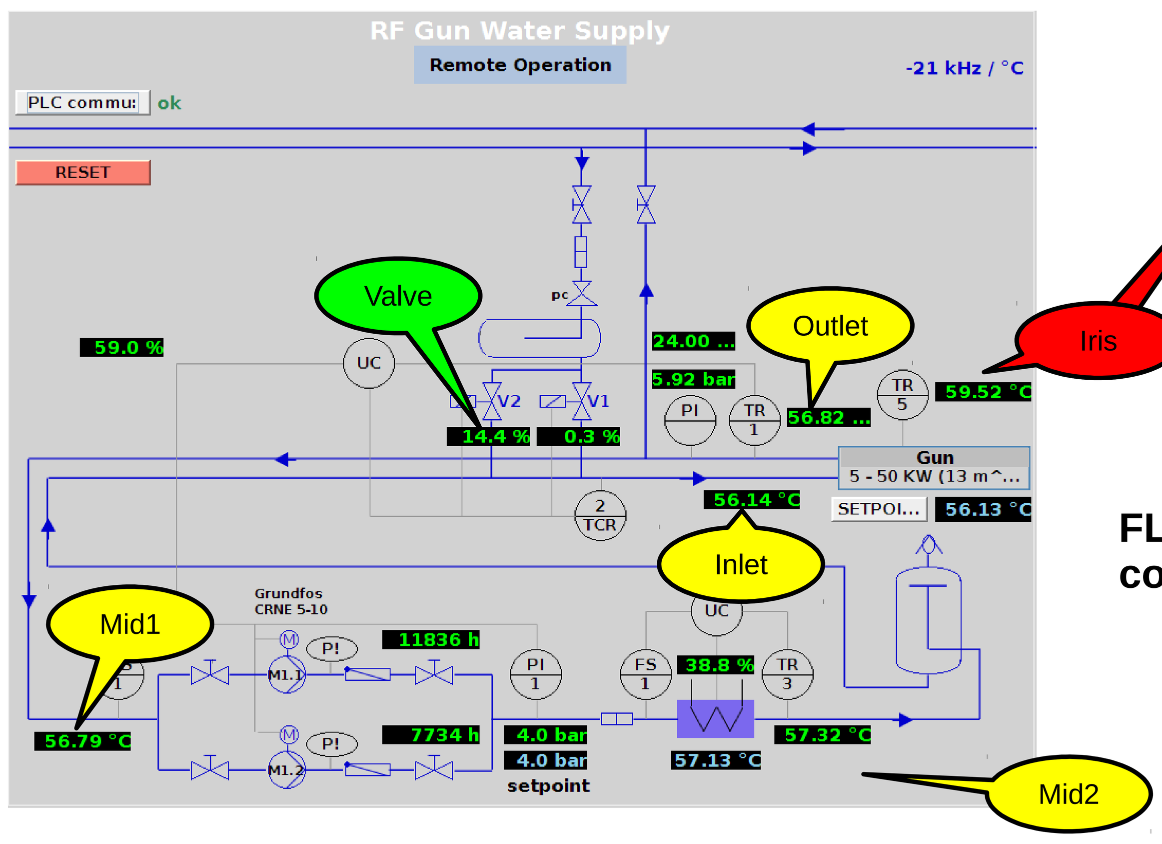
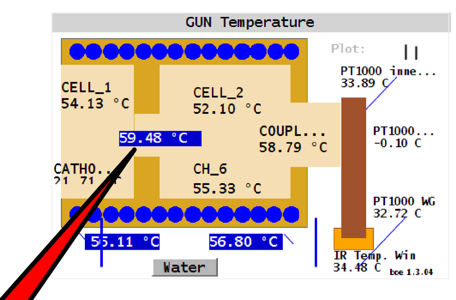
Abstract

The new procedure for Gun start up after trip was proposed, implemented and tested. It uses modulated RF frequency to follow cavity resonance frequency temperature rise resulting from increased power dissipation at RF ramp up. It controls the RF frequency, power and parameters of the cooling system. The resonance conditions are determined through the shape of reflected power amplitude.

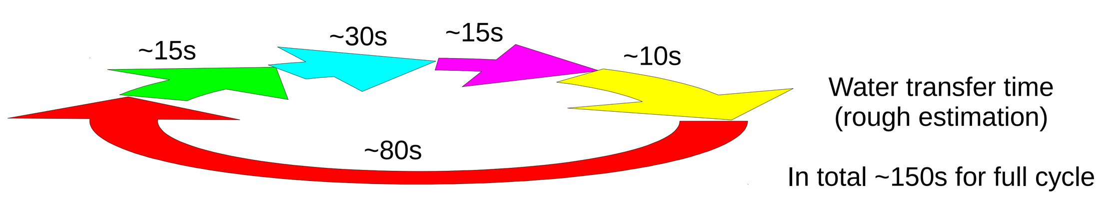
Gun operation

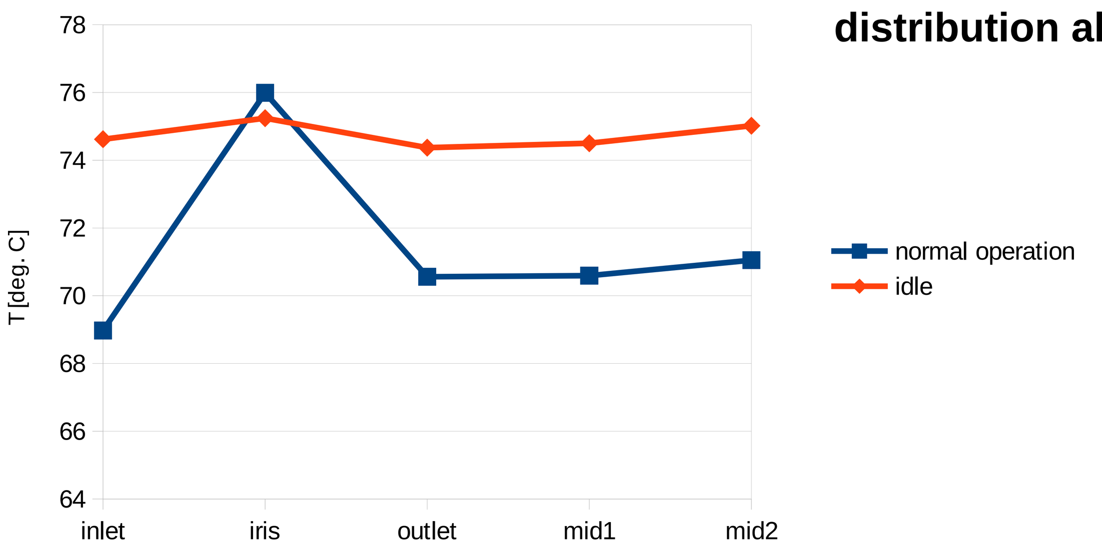
The source of the electron beam at FLASH (and also currently build XFEL) is normal conducting RF Gun consisting of a 1.5-cell copper cavity operated at 1.3GHz. The resonance frequency of the cavity is precisely tuned by the temperature with sensitivity ~21kHz/deg.C. Due to high power dissipation (~tens of kW) the cavity is equipped with high performance water cooling. The temperature control is optimized for steady-state conditions (typical mode of operation of the Gun).





FLASH RF Gun water cooling system



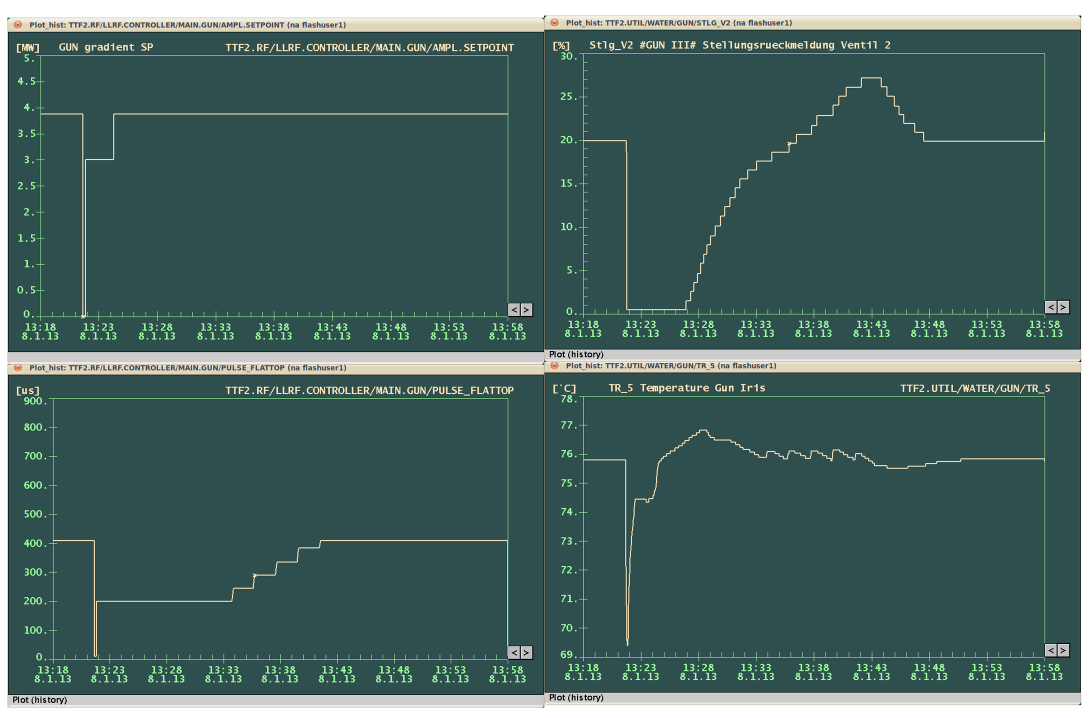


Water circulation and temperature distribution along the loop

Trip recovery

Strong perturbations (e.g. Gun trip and successive lack of RF power delivered to the Gun) throw out the Gun from thermal equilibrium and suddenly changes the Gun temperature (depending on the power level and puls length this drop can be as high as several centigrades, that corresponds to ~200kHz).

When trip happens the operation recovery starts when the iris temperature again reaches nominal value (heating water by heater). Then RF power is ramped up slowly while keeping the Gun temperature inside the range corresponding to cavity resonance at 1.3GHz. This procedure is not automatized and requires operator supervision and control. It takes time, usually at least 20 minutes are needed to restore full RF power and then even more time is needed to fully stabilize thermal environment.

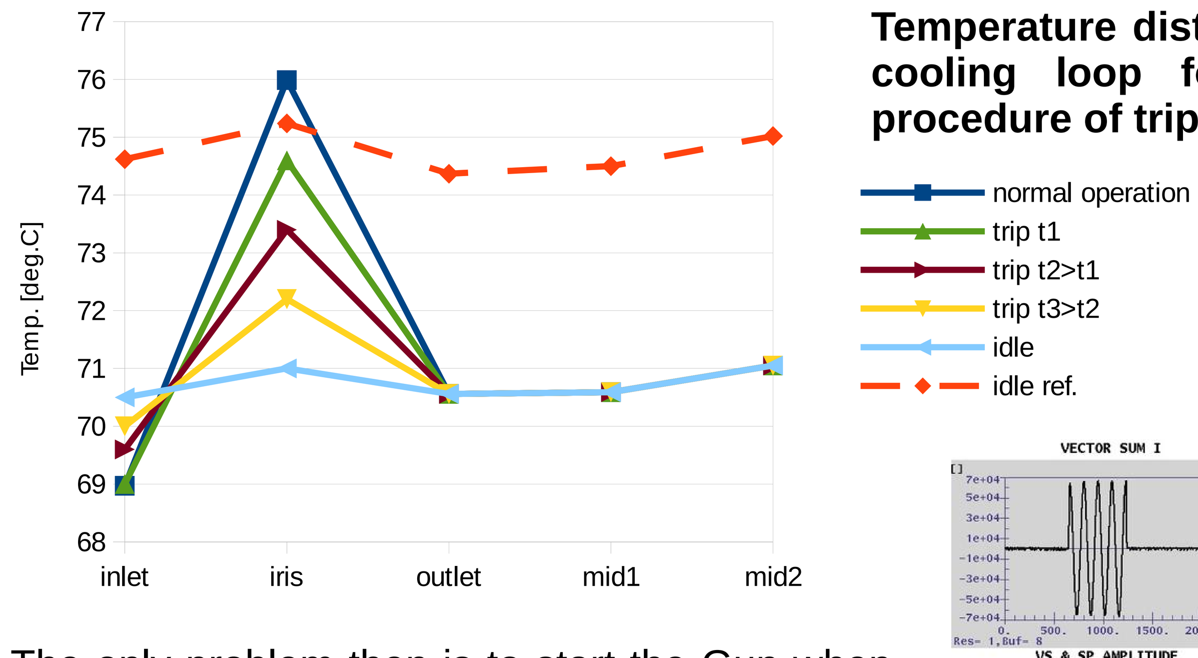


Trip recovery in the RF Gun (clasical approach, recovery time ~20 min.)

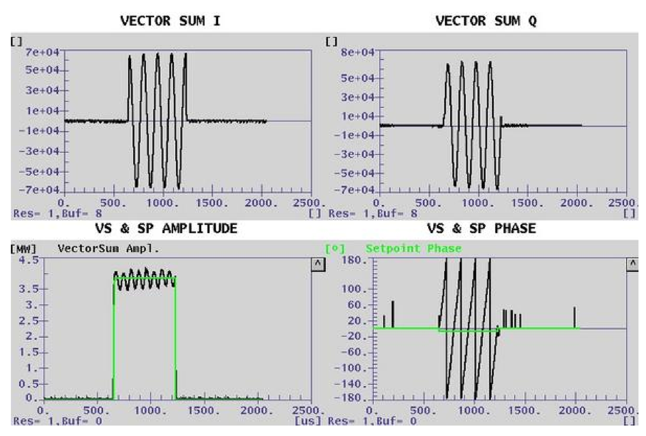
New procedure of trip recovery

The main „time consumer" in classical approach of trip recovery is temperature stabilization. First the water in the cooling system has to be warmed up to nominal temperature (at which the resonant frequency of the Gun is 1.3GHz) and then it must be cooled down together with increasing dissipated power while keeping the iris temperature at nominal level.

One can avoid lengthy process of water warming and cooling if the water temperature at the cooling system is kept constant at the level corresponding to nominal operating conditions.

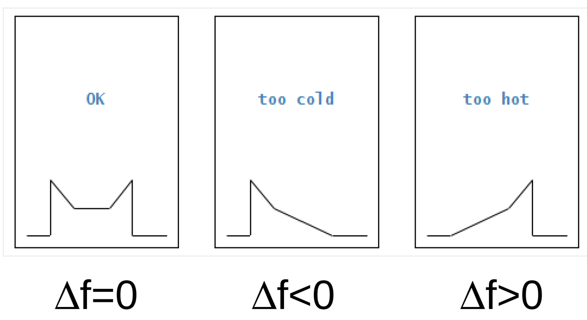


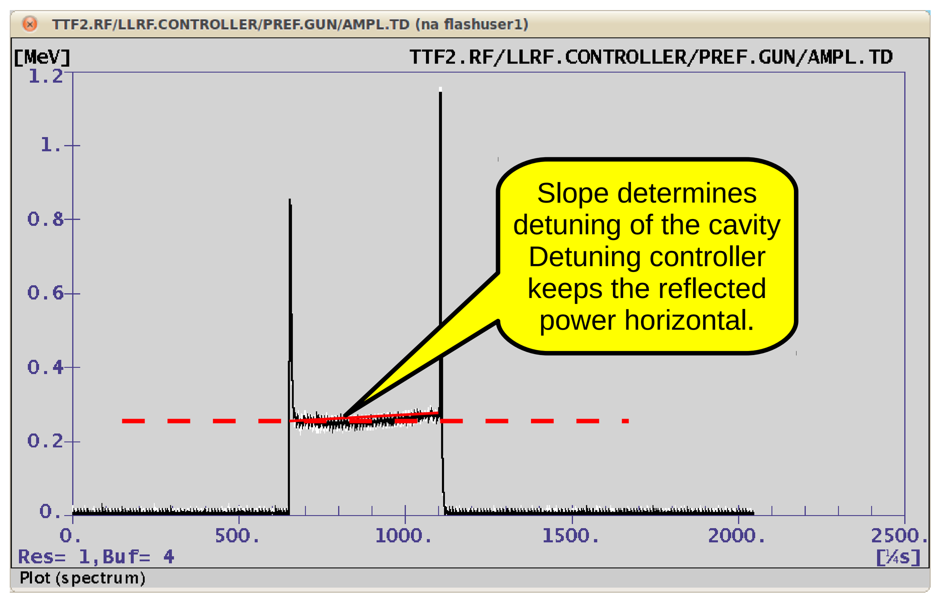
Temperature distribution along the cooling loop for the proposed procedure of trip recovery

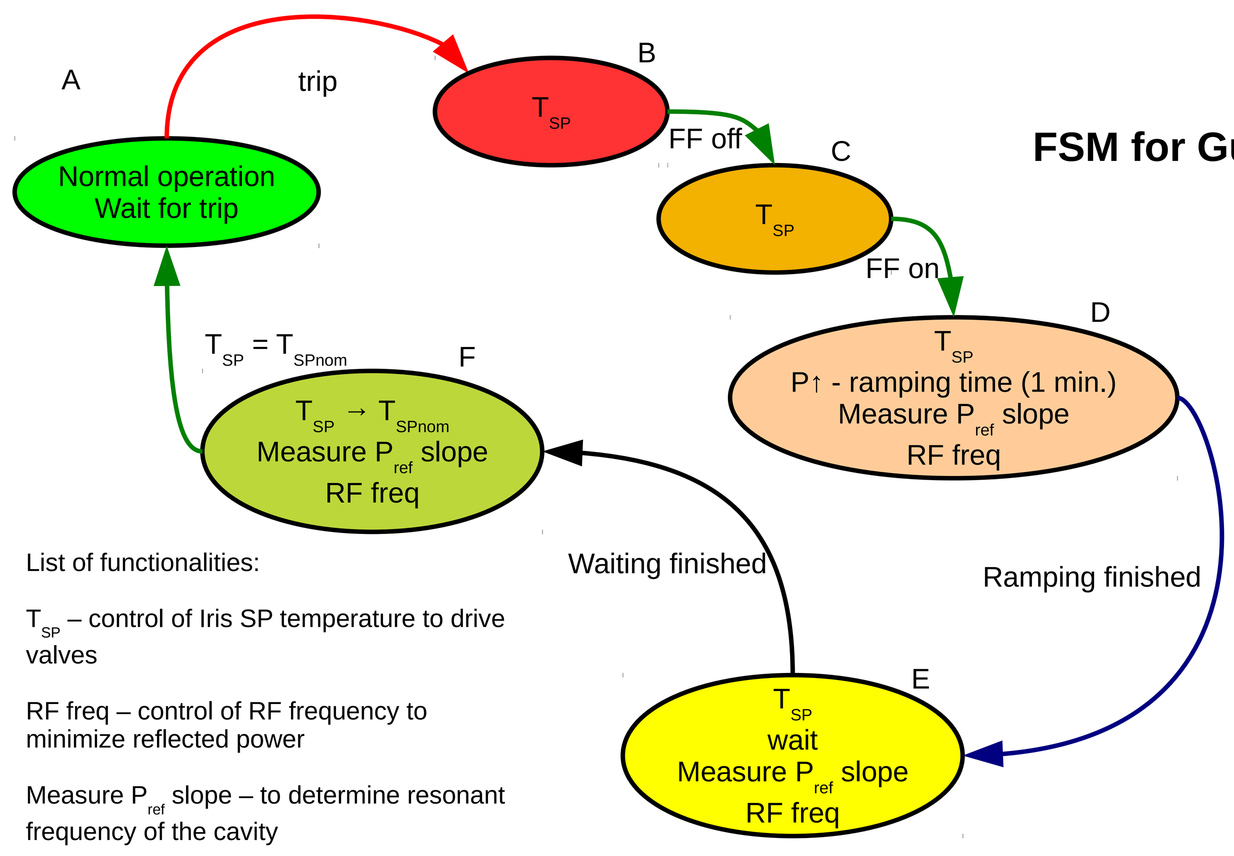


The only problem then is to start the Gun when it is heavily detuned. It can be done if the RF frequency is modulated and follows resonant frequency of the cavity. The whole procedure requires simultaneous measurements and control of few parameters.

The resonant frequency of the cavity can be determined and followed looking at the shape of reflected power pulse.

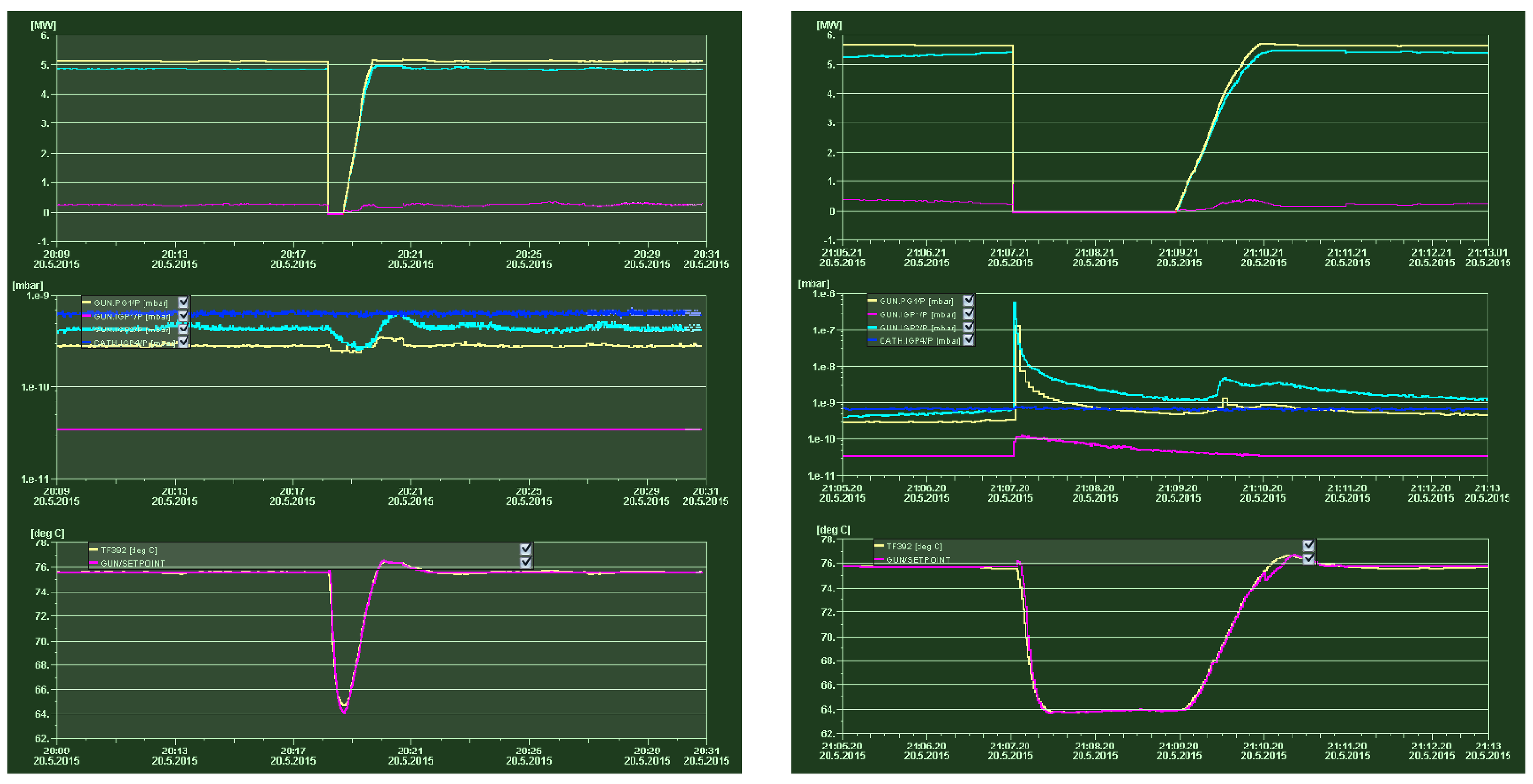






FSM for Gun trip recovery

Examples (experiments performed ad PITZ)



Simulated trip (recovery time ~3 min.)

Recovery from real trip

Conclusion

The procedure is fully automatized and does not require operator intervention. It keeps the reflected power minimized during ramp-up and not exceeds the nominal reflected power level during normal operation. This prevents standing wave at the waveguides and RF window. The start up of the Gun after trip is reduced to just a few minutes (~1 minute to full power and some more time to temperature stabilization). Currently it is implemented as a Matlab script. The DOOCS server implementation is ongoing.