Transient Microphonic Effects In Superconducting Cavities*

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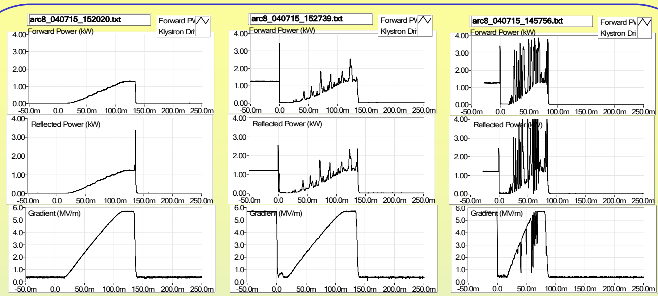


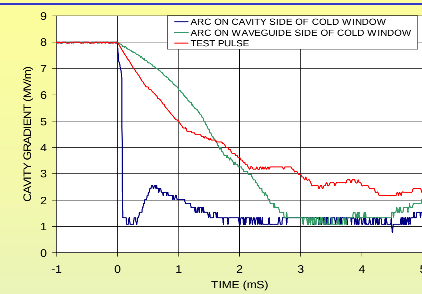
Test Pulse   Arc on Waveguide Side of Cold Window   Arc on Cavity Side of Cold Window

INITIAL CLOSED GRADIENT LOOP RESULTS

The system was set up with a closed gradient loop for the secondary pulse. The initial gradient was 8 MV/m. The secondary pulse was set to 8 MV/m. Secondary arcs frequently occurred when the initial event was an arc on the cavity side of the cold window

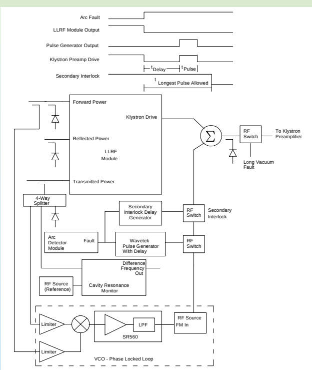
ABSTRACT

A number of experiments were performed on an installed and operational 5-cell CEBAF cavity to determine the minimum time required to reestablish stable gradient after a cavity window arc trip. Once it was determined that gradient could be reestablished within 10 ms by applying a constant power RF signal using a voltage controlled Oscillator-phase locked loop based system (VCO-PLL), a second experiment was performed to determine if stable gradient could be reestablished using a fixed frequency RF system with a simple gradient based closed loop control system. During this test, instabilities were observed in the cavity forward power signal, which were determined to be microphonic in nature. These microphonic effects were quantified using a cavity resonance monitor and a VCO-PLL RF system. Two types of microphonic effects were observed depending on the type of arc event. If the arc occurred in the vacuum space between the warm and cold windows, the transient frequency shift was about 75 Hz peak-to-peak. If the arc occurred on the cavity side of the cold window the transient frequency shift was about 400 Hz peak-to-peak. The background microphonics level for the tested cavity was approximately 30 Hz peak-to-peak. Experimental results indicate that the transient vibrations produced when there is an arc on the cavity side of the cold window take approximately 0.75 seconds to decay to the level twice that of the background microphonics

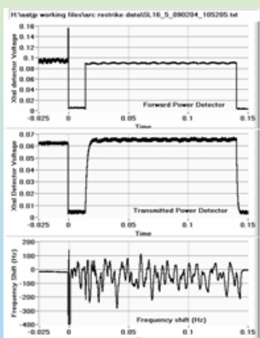


TYPICAL DECAY TIMES FOR TWO TYPES OF ARC AND A TEST PULSE

Note the rapid decay on the order of 50 µs that is associated with an arc on the cavity side of the cold window. These types of events have an associated intense burst of gamma radiation that lasts for about 200 ns. The theory is that gas which is released from the surface is ionized by the cavity's electric field and the electrons are accelerated by the cavity and reduce the stored energy. The hypothesis is that the sudden decrease in the Lorentz force during this rapid loss of stored energy excites the vibrational modes of the cavity.

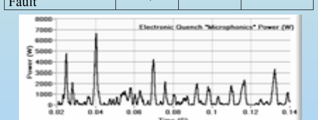


Setup for VCO-PLL control of frequency on secondary pulse as well as to make microphonic measurements



Typical plots of the crystal detector signals for the transmitted; forward power and frequency shift waveforms during a secondary pulse following an arc on the cavity side of the cold window.

Event Type	Gradient Decay Time	Gradient Fill Time	Pk-Pk Frequency Shift
Background Microphonics	NA	NA	30 Hz
VCO-VCO test pulse	1 ms	3 ms	56 Hz
LLRF –VCO test pulse	1.1 ms	3 ms	45 Hz
Waveguide Vacuum Fault	1.9 ms	3 ms	75 Hz
Electronic Quench Fault	80 µs	3 ms	400 Hz

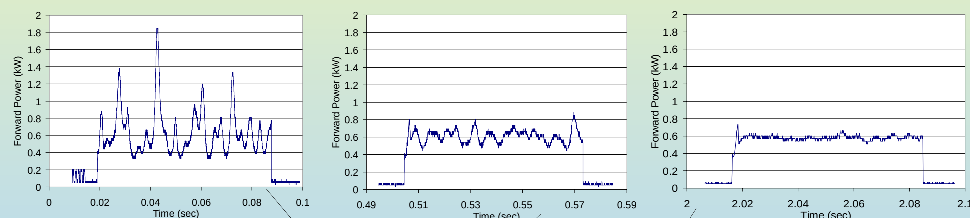


Calculated additional klystron power required to maintain stable gradient during the secondary pulse for the figure to the left.

MICROPHONICS MEASUREMENTS

A cavity resonance monitor was used in conjunction with a VCO-PLL to quantify the microphonic effects associated with the different events. The above figure shows the cavity's frequency shift as a function of time after an arc occurred on the cavity side of the cold window. In this test the cavity was operated at 8 MV/m both before the event and during the secondary pulse. The formula given below was used to determine that the forward power transients observed during the secondary pulses were consistent with this effect. It should be noted that this formula is only valid for values of $\delta f/f \ll 1$. In this formula f is the frequency of the applied RF power, δf is the difference between f and the cavity frequency, Q_L is the loaded Q of the cavity, E is the gradient and $(r/Q)/L$ is the shunt impedance in Ω/m.

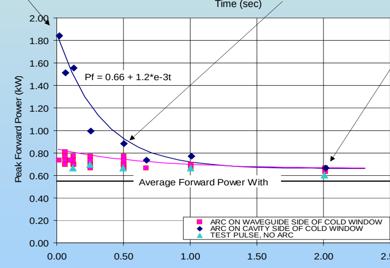
$$P_{Klystron} = \frac{1}{4} * Q_L * E^2 * \left[\left(\frac{1}{Q_L} \right)^2 + \left(2 \frac{\delta f}{f} \right)^2 \right] * \frac{L}{(r/Q)}$$

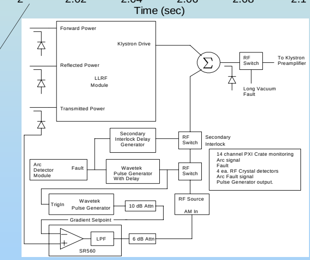


DECAY OF INDUCED MICROPHONICS

The system was set up with a closed gradient loop for the secondary pulse. The initial gradient was 8 MV/m. The secondary pulse was set to 3.3 MV/m in order to avoid saturating the klystron or initiating a secondary arc.

The upper waveforms show the forward power signals for several different events. The time is the delay time from the initial event in the waveguide. They correspond to the indicated points on the summary graph. All of the time domain plots show the microphonic effects after arcs which occurred on the cavity side of the cold window.





Setup for closed loop control of gradient on secondary pulse

SUMMARY

There are microphonic vibration mode that, coupled with beam loaded klystron power margins, limit the recovery of CEBAF cavities after arc event. The most likely source of the excitation function is the dynamic Lorentz force detuning which occurs when the cavity gradient is rapidly reduced by the event. This effect is substantially worse for an arc which occurs on the cavity side of the cold window where the gradient decays in less than 100µs. Using the existing low level RF system one would probably have to wait for at least 0.5 seconds prior to applying RF and about 1.5 seconds prior to loading the system with beam.

*Work supported by the U.S. Department of Energy, contract DE-AC05-84ER401050