5th North American Particle Accel. Conf. NAPAC2022, Albuquerque, NM, USA JACoW Publishing
ISBN: 978-3-95450-232-5 ISSN: 2673-7000 doi:10.18429/JACoW-NAPAC2022-TUPA52

INITIAL RESULTS OF THE 201.25 MHz COAXIAL WINDOW TEST STAND

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Abstract

We have recently commissioned an RF window test stand for the Drift Tube Linear Accelerator (DTL) portion of the Los Alamos Neutron Science Center (LANSCE). The window test stand (WTS) consists of two RF windows that create a vacuum chamber which allows the windows to be tested to the peak power levels used in the DTL. Initial results clearly indicated multipactoring due to the increase of pressure at specific regions of peak forward power levels. Temperature measured at various azimuthal locations on both windows showed increased multipactor heating on the downstream window versus the upstream window. We present the effect of the titanium nitride coating that is presently applied to windows on both multipactor and window temperature. These results are discussed with respect to their impact on the LANSCE DTL performance.

INTRODUCTION

RF vacuum windows are a necessary component of the transmission lines that deliver RF power to accelerator tanks. These windows have multiple requirements including maintaining vacuum, withstanding mechanical and thermal stresses, and transmission of RF power. At LANSCE, the DTL coaxial windows have experienced periods of frequent failures [1].

The frequent window failures were attributed to electron charging effects. The windows were coated with TiN to mitigate electron charging of the windows, but this also introduced additional issues such as excessive heating. Multipactor is an electron phenomenon that is also of concern. This is when an electrons emitted from surfaces experience a resonant interaction with RF fields to generate an avalanching electron population, as described in numerous publications [1-4]. The titanium coating suppresses this effect and prevents chare accumulation [1, 5]. To test the performance of these coatings, the window test stand was built by Mega Industries in collaboration with electrical and mechanical engineers from LANSCE.

The window test stand has allowed us to investigate the unknowns of window performance. The vacuum level and window temperatures were of particular interest as they give key information about the window performance. The pressure can indicate the occurrence of multipactor, and the window temperatures are indicative of heating in the DTL.

EXPERIMENTAL SET-UP

RF power is delivered to the WTS by a Diacrode® amplifier, and the power is transmitted through the test stand into a load. Two windows are used to create a vacuum chamber, and a data acquisition (DAQ) system captures important information about the window performance. Figure 1 shows the WTS installed and connected to the amplifier and the load.

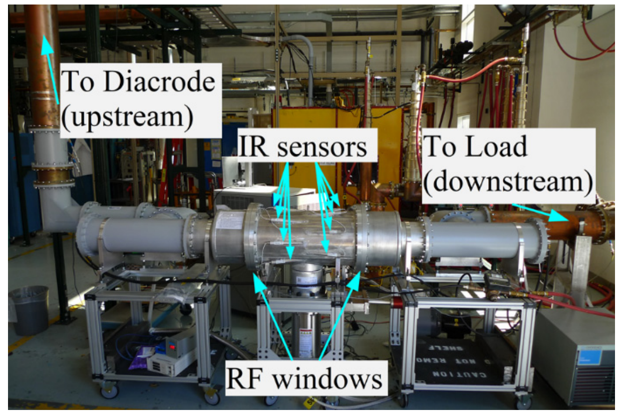

Figure 1: The window test stand in place for testing.

The WTS amplifier delivers similar power to what the windows experience in the DTL. The amplifier operates up to 2.5 MW peak power, and the RF is pulsed at a maximum of 120 Hz repetition rate and 1000 µs pulse width. The load was only able to dissipate about 200 kW of average power. This gets the same peak voltage as in the DTL, but the average power is a less than the 310 kW in the DTL. This allows the same multipactor conditions that occur in the DTL to be tested in the WTS, but the windows being tested cannot experience the same RF heating as in the DTL. The windows are cooled via water that run into quarter wavelength stubs at the ends of the WTS, and the vacuum is pumped via a CTI-Cryogenics cryopump during testing.

There are several data that are collected via the DAQ system. The vacuum chamber has multiple ports for Micro-Epsilon IR temperature probes to measure the window temperature at various azimuthal locations of both windows. The pressure of the vacuum chamber is measured by a Granville-Philips gauge, and the RF power is measured by an in-house power detector that use the ADL 5511. The DAQ system is a National Instruments cDAQ chassis that communicates data via a LabView program, and this reads the data via voltage outputs from the measurement devices. This data is logged automatically at user-definable time intervals, and the power waveforms of a large number of pulses can also be recorded as requested.

RESULTS

The initial tests were done on three window configurations. Each test requires two windows, and for all three configurations, the upstream window was kept the same. The first configuration used two Rexolite® (crosslinked polystyrene) windows that did not have the TiN coating to establish a baseline measurement of multipactor. Next, a

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TiN Rexolite® coated window was placed in the downstream position, and the final configuration replaced the coated window with a third uncoated window in order to see the effect of conditioning the upstream window and vacuum chamber.

Multipactor

The presence of multipactor was obvious in the response of the vacuum pressure to the peak power that was input into the WTS. Multipactor is well known to occur at certain power levels for a set geometry and RF frequency, and the vacuum pressure will steeply rise in response to multipactor [6]. This meant that as the peak forward power was changed, the voltage in the coaxial line be at the right values for multipactor to occur. This resulted in a correlation between specific peak forward power levels and high vacuum levels. The average power (i.e. increasing the duty factor of the pulsing) would have an effect on the overall pressure as well, but if the peak power is not in region of multipactor, the duty factor has less impact on pressure.

The effect of multipactor and the importance of conditioning are shown in the plot of vacuum pressure versus peak forward power into the WTS in Fig. 2. There are clear trends where the vacuum increases and decreases across the full range of forward power levels, although an increase in pressure from the baseline pressure without RF (~10^{-7} Torr) is present for nearly every power level. There are two causes to this increase in pressure with RF. First, RF will heat the surfaces, and this heating leads to the outgassing from the surfaces under vacuum. Secondly, the multipactor can affect a broad range of power levels such that the results in Fig. 2 resemble the simulation results of other coaxial lines [7].

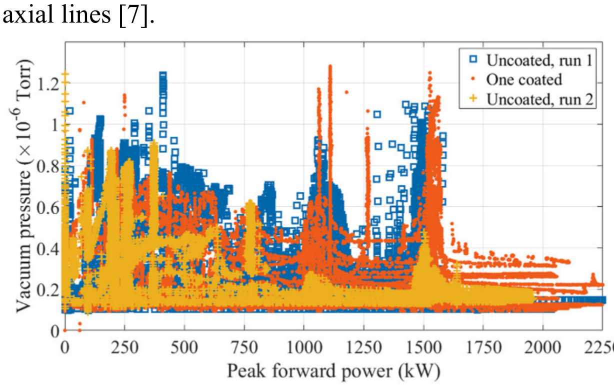

Figure 2: Vacuum pressure vs the peak forward power into the WTS for all three window configurations.

The other important result shown in Fig. 2 is the effect of conditioning on multipactor. The results from the three window configurations are shown in the order in which they were run, and each subsequent run generally had a reduction in the vacuum response to RF. This was also observed in each window configuration over multiple days of testing, where each day that the windows were tested experienced a reduction in vacuum response to RF. These reductions are attributed to a conditioning of the WTS, where multipactor is gradually reduced by allowing it to run at low duty factors so that there is no damage.

Window Heating

The window temperatures were also tracked throughout testing. There are a large number of factors that affect the window temperatures, including the ambient temperature, the average RF power delivered, multipactor, and another phenomenon called ion bombardment [6]. The balance between these various factors can be difficult to account for, but general trends were noticed that provide useful information.

The effect of multipactor on window heating was apparent when compared to the vacuum pressure. An example of this is shown in Fig. 3. The data in these figures were taken with a constant RF pulse duty factor (30 Hz, 385µs), and while the forward power was constantly increased, the window temperatures fluctuated. Additionally, the greatest predictor here was the pressure, which itself varied with the peak forward power in discrete multipactor bands. This shows that these temperature changes were due to multipactor and not RF heating.

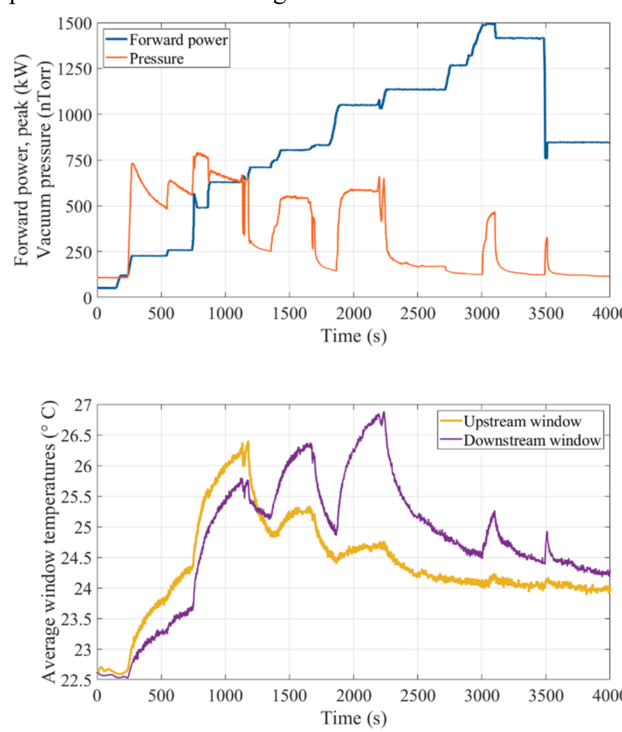

Figure 3: Peak forward power into the WTS and the vacuum pressure vs time (top), and the upstream and downstream window temperatures averaged over all IR sensors (bottom).

The limitation of this observation is that the power levels where multipactor occurred were only run at low duty factor. This was done because increasing the duty factor of the RF pulses during multipactor does significantly increase the pressure, and this practice is also how the DTL tanks are conditioned. The observation of multipactor heating is useful in considering the process of multipactor in the WTS, however. Generally, electrons generated by multipactor can be expected to drift in the direction of RF power flow in the transmission line [1], so we would expect the down-

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stream window to be bombarded by electrons from multipactor, and thus experience greater heating. This was the case when the peak forward power was above ~600kW, as can be seen in Fig. 3. Below 600 kW, the drifting effect is not strong enough to influence the heating.

The most significant heating observed was due to the RF fields. Once the windows were sufficiently conditioned through multipactor, they were brought to a high average power to observe the terminal temperature. A summary of these temperatures is in Table 1. The first line in Table 1 is the terminal temperature reached for the first run of the uncoated windows, and the coated windows had two heat runs (#2-3 in Table 1). The last line in Table 1 (#4) is the second run of the two uncoated windows, although RF turned off before the temperature reached a steady state value.

Table 1: Window Temperatures Due to RF Heating

#	Upstream Temperature (°C)	Downstream Temperature (°C)	Average RF Power (kW)
1	39.0	40.4	180
2	45.2	66.3	150
3	46.0	61.9	210
4	37.3	39.6	200

Generally, the windows experienced > 20°C temperature increase throughout testing. The non-coated windows all ran around 40 °C after several hours of testing, and for all tests the ambient temperature stayed at nearly 22°C. The coated windows were significantly hotter. This result was expected as the TiN coating is conductive and subsequently has higher losses. The two coated window runs also had a more significant pressure increase (~1.6e-7 torr) from the starting pressure without RF than the two uncoated window runs (<1e-7 torr). This could be indicative of some additional heating sources such as ion bombardment, but the pressure was stable, ruling out multipactor as the heating source.

CONCLUSION

The multipactor observed in the test stand indicates how the windows installed in the DTL might perform. Generally, multipactor in the WTS was highest at power levels below 800 kW. This is below the peak power that is run in the DTL modules (2-2.5 MW), but when the cavities are being conditioned after downtime or being vented, their conditioning will run through these power levels. Multipactor is observed at these values, and at higher power levels there are often very narrow regions of power where multipactor occurs, similar to the observations at 1100 kW and 1500 kW in Fig. 2. This strongly indicates that multipactor is occurring in the transmission line as the phenomenon is geometry dependent.

The upstream and downstream window differences in the test stand data also demonstrate how the DTL windows will be stressed. The upstream window experienced less heating when there was multipactor, which is consistent with expectations of electrons migrating away from it. The DTL windows generally have power, and thus electrons, flowing away from it in a similar manner. However, the DTL is more complicated due to power reflected from the cavity that were not present in the test stand.

The coated windows only allowed for mixed conclusions. As far as multipactor was concerned, there was a significant amount of it over several days of testing, and the second run of the two uncoated windows had less multipactor than the coated window. This showed that the coating did not reduce multipactor in the entirety of the test stand, but there were many surfaces for electrons to impact and generate the phenomenon besides the coated window. Overall, this was inconclusive. The heating of the TiN coated window was very clear, however, and indicated that there was a significant enhancement in temperature. This will be even more pronounced in the DTL where the average RF power can reach up to 310 kW. Interestingly, the temperature of the IR sensors themselves only ever reached about 2°C hotter than ambient. These give a measurement similar to the window temperatures recorded in the DTL by RTDs placed on the outside of the coaxial line. This indicates that the DTL windows can be running significantly hotter than indicated.

FUTURE WORK

There are several items to be done in future window testing. First, the duty factor can be increased at power levels where multipactor is observed. This is opposed to increasing the peak power first as had been done in this work, and would better indicate how much multipactor affects the window temperature. Second, multipactor could be measured directly by collecting the electrons generated by the phenomenon at various locations to remove ambiguity in the window coating performance. Third, RGA analysis of the vacuum would be very useful as well.

Simulations will also be examined to compare the actual to theoretical performance. The multipactor simulations have slightly different profiles from those in Fig. 2, but those simulations didn't have the small reflections or two window configurations actually present. Additionally, thermal simulations of the WTS will be run, and those can be extended to simulations of the DTL windows as well.

ACKNOWLEDGMENTS

The authors would like to thank the following for their hard work and contributions: Gabe Roybal, Gilbert Sandoval, Daniel Sandoval, and John Bernal.

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