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Beam Diagnostics Report for the Thermal Test conducted on 3/9/2016

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OTR Results

The thermal test OTR data revealed several issues with the beam focus and the target window itself. The oxidation of the target window and the prominence of a scratch across the center of the window makes it impossible to accurately measure the beam profile and size. Fig. 1 below is a picture of the current state of the target window.

Figure 1: Target window image showing severe oxidation and scratch across the middle of the window.

The scratch has a much higher reflectivity than the rest of the window which saturates the camera making it difficult to fit the beam profile for a size measurement. The oxidation itself causes an uneven reflectivity which also potentially affects the OTR intensity profile used to measure beam size. The effects of these two can be seen in the OTR image in Fig. 2. The beam distribution shown in the image was consistent throughout the entire thermal test. The bright spot caused by the scratch can be seen in the center of the image.

The other issue the image in Fig. 2 highlights is the fact that, during the actual thermal test the horizontal beam size appears to extend beyond the target window boundary, and that a non-trivial amount of the beam was deposited onto the sidewall around the target window (this is also further confirmed in the IR images shown in Fig. 7). The profile plot shows the step in intensity from the target window to the sidewall. Fig. 3 is a beam profile taken below the scratch where the window edge and sidewall can be seen more clearly. The intensity is clearly different

on these two surfaces making it impossible to determine just what proportion of the beam is outside of the target window.

Figure 2: OTR image taken during the thermal test. Beneath the image is a profile plot of the region defined by the green rectangle. The intensity gain was increased to better visualize the beam distribution. The intensity of the OTR on the scratch is far greater than the rest of the target window which makes accurately fitting a Gaussian distribution difficult. The reflectivity also appears to be different between the target window and the sidewall.

Figure 3: OTR Beam image profile taken just below the scratch to better show the effects of the window edge. The profile is a plot of the horizontal profile defined by the green rectangle.

The beam shape appeared to be very good during the initial beam tuning that occurred around 11:37 am. Fig. 4 and Fig. 5 show the beam during this time on the sidewall and on the actual target a few seconds later. However the focus got progressively less Gaussian up until the actual testing. Fig. 6 shows the beam focus on the side wall just before the thermal test. The initial beam size was only about 3.5 mm FWHM so the additional changes to the beam focus may have occurred in an effort to increase to the nominal size of 6mm FWHM. The beam in Fig. 6 shows a significant “tail” to the left side of the beam distribution.

Figure 4: Initial beam focus during tune up prior to the thermal test. The beam size was about 3.5 mm FWHM

Figure 5: Early tune up beam on the target window a few seconds after the image in Fig. 4

Figure 6: Beam focus on the side wall 1 second before the start of the thermal test. The shows significant "tail" to the left of the main beam distribution.

IR data

The window temperature was measured at the center of the target window at the hottest point using a 3 X 3 pixel region of interest as done in previous test. The emissivity setting was 0.61 and the transmissivity was set to 0.375. All the measurements of the window temperature were done on the high temperature calibration setting (300 C to 2000 C). The image in Fig. 7 shows the ROI position where the temperature measurements were made and Fig. 8 is plot of the measured window temperature during the thermal test.

Figure 7: IR taken during the thermal test. The ROI labeled “Cursor 1” is located near the center of the target window where the peak intensity was observed. The bright spot to the left of the ROI confirms that a non-trivial amount of beam was striking the wall outside the target window.

Figure 8: Plot of the IR temperature measurements on the target window. The thermal test began about 100 minutes from the time the data started recording. The tune up data was excluded from the plot.

There are two issues that potentially upset the accuracy of the temperature measurement. The first issue is that the camera appears to be out of focus (as shown in Fig. 9) which will diminish the temperature accuracy.

Figure 9: IR image of target window prior to the thermal test. The image show that the window is out of focus.

The second is that the severe oxidation on the surface of the Inconel window might have changed the target emissivity. Changes in the emissivity will affect the accuracy of the temperature reading. We have also found in our previous calibration studies that the loss of temperature accuracy due to small changes in emissivity will be more pronounced on low emissivity surfaces like the target window. The exact degree to which window oxidation affects the emissivity needs to be determined with further study. Even under the best vacuum conditions a target will eventually oxidize to some degree and this could potentially alter the emissivity enough to decalibrate the temperature measurement.

Recommendations for future development

- In order for OTR to be effective, the surface of the target window needs to be uniform. The scratch must be removed or the window replaced and the target window needs to be handled with the same care of any optical surface.

- An effort needs to be made to minimize oxidation. Keeping the target under vacuum continually may reduce the window oxidation, as it is believed to be caused by activation of the target window ionizing air against the window after the irradiation.
- Improve beam focus. Reduce the amount of the beam distribution outside the target window and preserve a Gaussian shape at the desired beam size.
- Devise a test to validate the IR temperature measurements with an actual beam on target. We should design a test target window that allows for the use of thermocouples to measure the temperature along with the IR. Also, we need accurate beam distributions from the test in order to perform accurate numerical modeling. This is difficult with the current set of data due to the beam focus and the issues with the target window. A full test validating the effectiveness of IR temperature measurements is imperative if this diagnostic is to be used for any sort of safety interlock.