

Procedure for testing the power output of A2080 36-way light injectors
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1. Setup: This section covers the preliminary (uncalibrated) physical test stand setup and communication with LWDAQ. Our lab's test stand is shown below.



Figure 1 - Our lab's test stand setup

- Select a working NBCAM and tape a 1% neutral density filter over the lens, without obstructing the lens (see below). The filter was sent in the box which also contains two optical fibers and the machined injector holding piece (which I will refer to as the 'holder').



Figure 2 - Taping the neutral density filter over the NBCAM lens

- Place an injector in the holder. You may wish to clip the injector to the holder at the top, as shown.

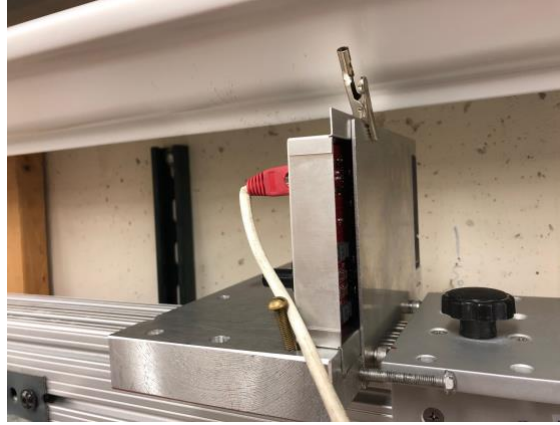


Figure 3 - Clipping the top of the injector to the holder

- Place the NBCAM and holder + injector at a distance of 1.7 ± 0.2 m from NBCAM lens to injector face, with the NBCAM facing the injector face.
- Attach cables from the NBCAM and injector to a driver which you can access conveniently from a computer. Make sure the cable does not obstruct any LEDs on the injector.
 - You may wish to put a weight on top of the NBCAM to prevent movement due to cable tension.
- In LWDAQ, open the BCAM instrument and load the file 'A2080_check.tcl' with File>Load Settings> A2080_check.tcl
 - You will have to enter your own values for 'daq_ip_addr', 'daq_driver_socket' and 'daq_source_driver_socket' as appropriate for your cabling, network, and driver ID.
- Acquire on the BCAM instrument. It should return an image similar to the one shown below, with all 36 LED lights visible and identified by the analysis feature, as well as a list of the 36 intensities.
 - If not all 36 injector LEDs are visible and identified, you may have to adjust the holder or NBCAM closer or further apart and repeat the acquisition until they are. Note that the distance of 1.7 ± 0.2 m mentioned above is chosen to fulfill this guideline of being able to see all LEDs.
 - The 1% neutral density filter should block out nearly all ambient room lighting.

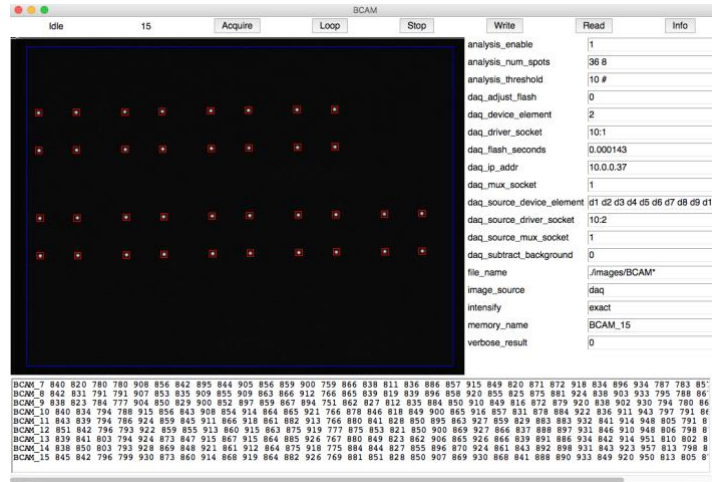


Figure 4 - Sample BCAM acquisition with all 36 LEDs clearly visible, no background lighting, and 36 returned intensity values.

2. Calibration: This section covers the calibration of the test stand. We will begin by measuring the power outputs for a few injectors, then anchoring the physical test stand setup, and finally calculating a conversion factor from power outputs in uW to LWDAQ intensity count values.
 - Select three injectors at random.
 - Cable an injector to a driver connected to a computer and confirm that you can access the injector with the LWDAQ diagnostic tool.
 - Get one of the short fiber-optic cables and the photodiode and associated power output display.
 - For each LED on the injector, perform the following procedure:
 - Plug one end of the fiber-optic cable all the way into the injector LED port.
 - Using the diagnostic instrument, turn on the LED.
 - Press the other end of the fiber-optic cable against the photodiode, and be sure to cover the rest of the photodiode with a blackout cloth.
 - **Make sure that, when no fiber is present and the cloth covers the photodiode, the power output is <1uW.**
 - The LED power output values measured by the photodiode should be in the range of 25-45uW. The spread of values across a single injector should be small (standard deviation <2.5uW). Using this procedure on each LED on 30 injectors, we found an average output of 35uW with a standard deviation of 1.5uW.
 - The values may fluctuate slightly as the LED stays on. This is of no concern unless they drop significantly out of this range.
 - Record the resulting power output for each LED in the 'injector_led_output_report' spreadsheet in the 'Photodiode Power Outputs' sheet.
 - All cells highlighted green are unprotected and can be edited.
 - Perform this procedure for all 3 injectors.

It is important that the NBCAM face is as near-parallel as possible to the injector face (within 3°). We outline a strategy to achieve this here. We will also introduce a Toolmaker tool.

- Place one of the three measured injectors in the holder, facing the NBCAM, all arranged as detailed in part 1 (Setup).
 - Acquire on the LWDAQ BCAM instrument to confirm once more that all 36 LEDs can be seen.
- Open Tool>Toolmaker and then press ‘load’ in the Toolmaker window to load the file ‘Injector Tester [version]’, and then press ‘execute’ in Toolmaker.
 - This should bring up a Toolmaker tool which looks like this:

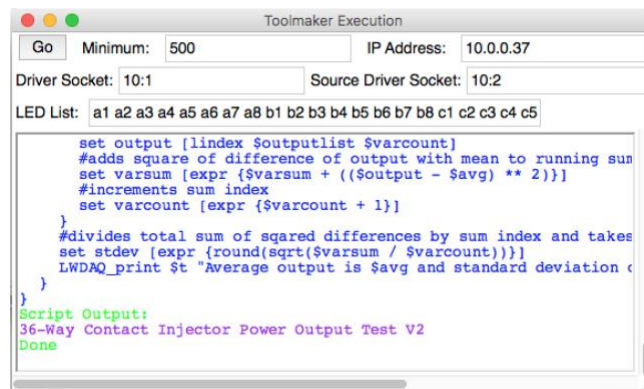


Figure 5 - The Injector Tester Toolmaker tool, upon loading

- Set the ‘Minimum’ value to 0 for now. Enter the appropriate values for the IP address, driver socket, and source driver socket. ‘All’ should be entered in the LED List entry box.
- Press go. All LEDs should list upon pressing go. The acquisition takes ~2 minutes.
 - The result should look as seen below with LED outputs listed as they are acquired, and an average and standard deviation calculation at the end.

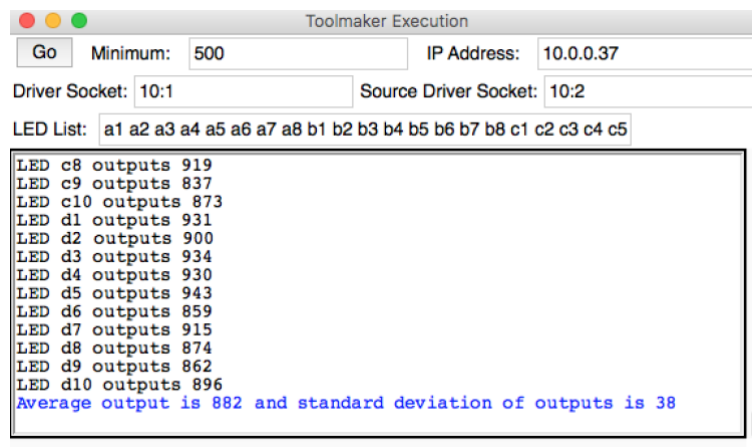


Figure 6 - The Injector Tester Toolmaker tool returning a 36-LED acquisition

The goal now is to minimize the standard deviation in the intensity values by setting the NBCAM face and injector face nearly parallel, such that each LED is seen straight-on by the NBCAM. Experimentally, we have found that rotation of the injector from parallel has a significantly detrimental effect on the reliability of measurements taken with this test stand.

- When the injector was not rotated from parallel, we had an average of 880 intensity counts and a standard deviation of 38.
 - The average optical power output for this injector, measured with a photodiode, was $\approx 35\text{uW}$, with a standard deviation of 1.5uW . $\frac{880}{35} \approx \frac{38}{1.5} \approx 25 \frac{\text{counts}}{\text{uW}}$, and by the closeness of these ratios (compared to the values seen for an 8° rotation), we are reasonably confident that this injector face is nearly parallel to the NBCAM face.
- When the injector was rotated 8° from parallel, we had an average of 678 intensity counts and a standard deviation of 196.
 - Doing the same calculation as before, $\frac{638}{35} \approx 18 \frac{\text{counts}}{\text{uW}}$; $\frac{196}{1.5} \approx 130 \frac{\text{counts}}{\text{uW}}$, and by the discrepancy in these ratios, we conclude that the injector face is not nearly parallel to the NBCAM face.
- Rotate the holder and injector and take acquisitions. You already know the optical power outputs calculated with the photodiode. For each acquisition, compute the two ratios $\frac{\text{Average Intensity Counts}}{\text{Average Photodiode Power Output}}$ and $\frac{\text{StDev of Intensity Counts}}{\text{StDev of Photodiode Power Output}}$ as demonstrated above.
 - The spreadsheet titled 'injector_led_output_report' includes a sheet 'Ratio Calculator' which will calculate these ratios once the values are entered. **Repeat the procedure until the two ratios are nearly the same (ratio of ratios is ~ 1).**
 - Experimentally, we had some variation here – for some injectors we could bring this ratio of ratios to 0.99; on others only to 0.75. This is due to error in the measurements and is not of concern – simply try to bring the value as close to 1 as possible.
- At this point, you must find a way to anchor down the NBCAM and holder, or otherwise establish markers such that you can reliably make hundreds of measurements while switching out injectors, throughout which the tested injector and NBCAM maintain their relative positions.
 - To be sure that the test stand is anchored effectively and to confirm that the NBCAM and injector faces are nearly parallel, perform the above procedure and calculate the ratio of ratios for the two other injectors you have tested with the photodiode. **If the test stand is well-aligned, the ratio of ratios should be as close to 1 as possible for each injector.**
- The physical test stand is now complete in its arrangement.
- Average the three values acquired for $\frac{\text{Average Intensity Counts}}{\text{Average Photodiode Power Output}}$. This will serve as the conversion factor between intensity counts and uW.

- Use this value to determine the minimum acceptable intensity count threshold based on your photodiode power output values.
 - $\text{Minimum} = \text{Conversion factor} * 25\mu\text{W}$

3. Testing injectors: This section details a method to efficiently test the power output of many injectors using a well-calibrated test stand.

- Place and cable a new injector in the well-anchored, calibrated holder. Again, you may want to clip the top of the injector to the top of the holder to keep it upright.
- On the computer used with the test stand, open LWDAQ and load the settings 'A2080_check.tcl' by File>Load> A2080_check.tcl
 - You may have to enter your own values for 'daq_ip_addr', 'daq_driver_socket' and 'daq_source_driver_socket' as appropriate for your cabling, network, and driver ID.
- Open Tool>Toolmaker and then press 'load' in the Toolmaker window to load the file 'Injector Tester [version]', and then press 'execute' in Toolmaker.
 - Set the minimum value to the value established during the calibration procedure.
 - Enter the appropriate values for the IP Address, Driver Socket, and Source Driver Socket. 'All' should be entered in the LED List entry box.
- Press 'Go' in the Toolmaker tool. The acquisition will take about 2 minutes. You should receive a list of 36 LEDs and their corresponding intensity counts, followed by an average and standard deviation value for the list.
 - For LEDs with intensity counts below the minimum value, the entry in the list will return in **red**, with a corresponding message that the value is too low.
 - These LEDs should be catalogued as their power output has been deemed too low. The spreadsheet titled 'injector_led_output_report' includes a sheet (Injector LED Tracker) in which to enter these values. This sheet will also convert the values to uW once the conversion factor is entered.
- Carefully remove the injector from the holder and repeat the procedure with a new injector.
- If desired, sets of individual LEDs can be tested with the Toolmaker tool by typing them into the Led List directly. The phrase 'all' is a shortcut to list all LEDs, rather than having to type them out.