INTRODUCTION: The following data represents experiments and tests for the use of the LuxeonZ LED in the ATLAS alignment network. Specifically, the LuxeonZ was tested to determine if it was a viable substitute to the EZ500 LED for the fiber-optic alignment network of the New Small Wheel.

DATA:

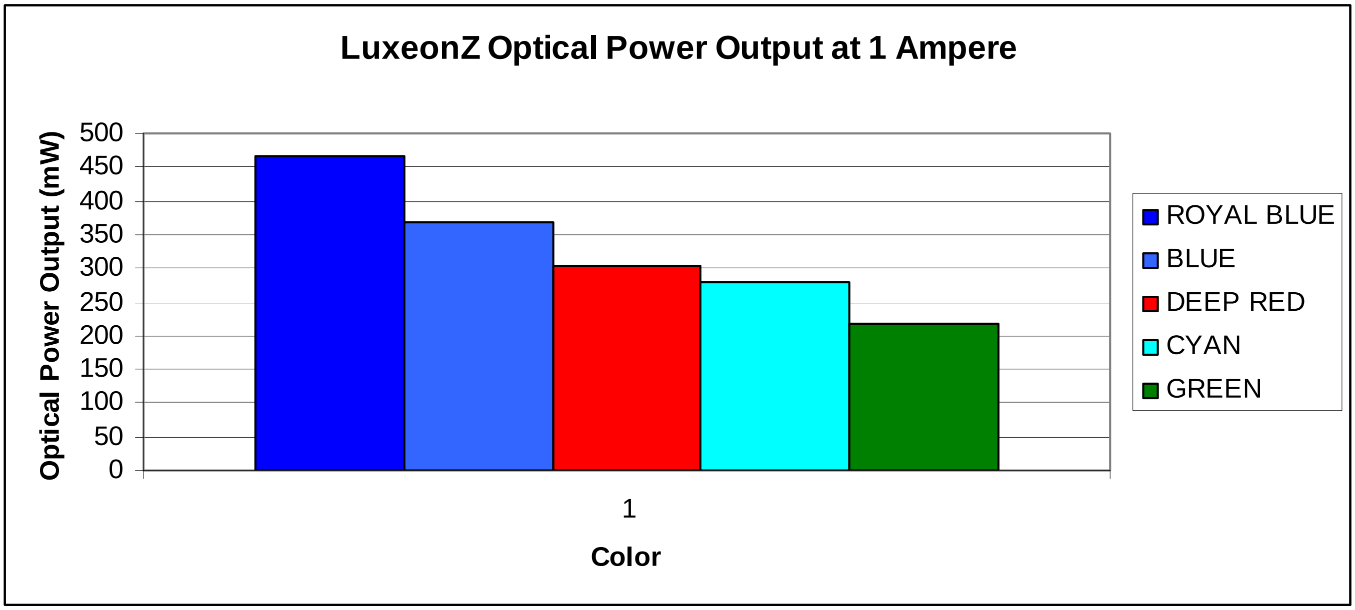

Figure 1: Optical Power Output at 1000mA versus Color. Power measured with a SD445 Photodiode, 15V reverse bias, and 100Ohm Resistor. Datasheet for the SD445 can be found at [1].

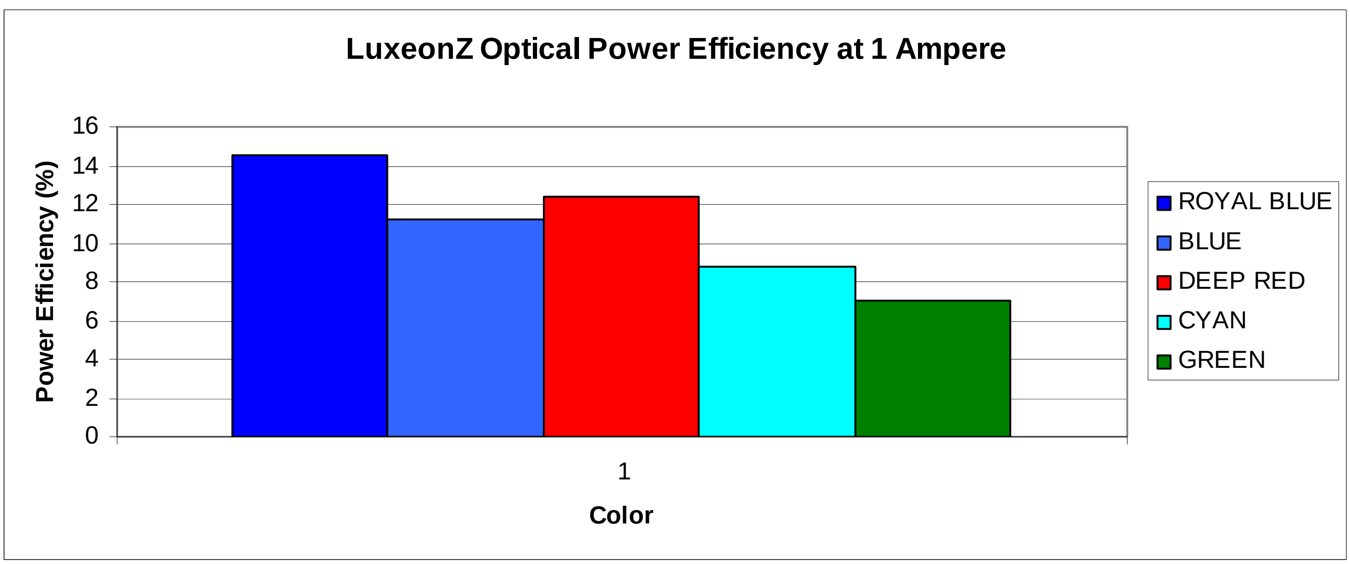

Figure 2: Optical Output Power divided by Electrical Power input vs. Color.

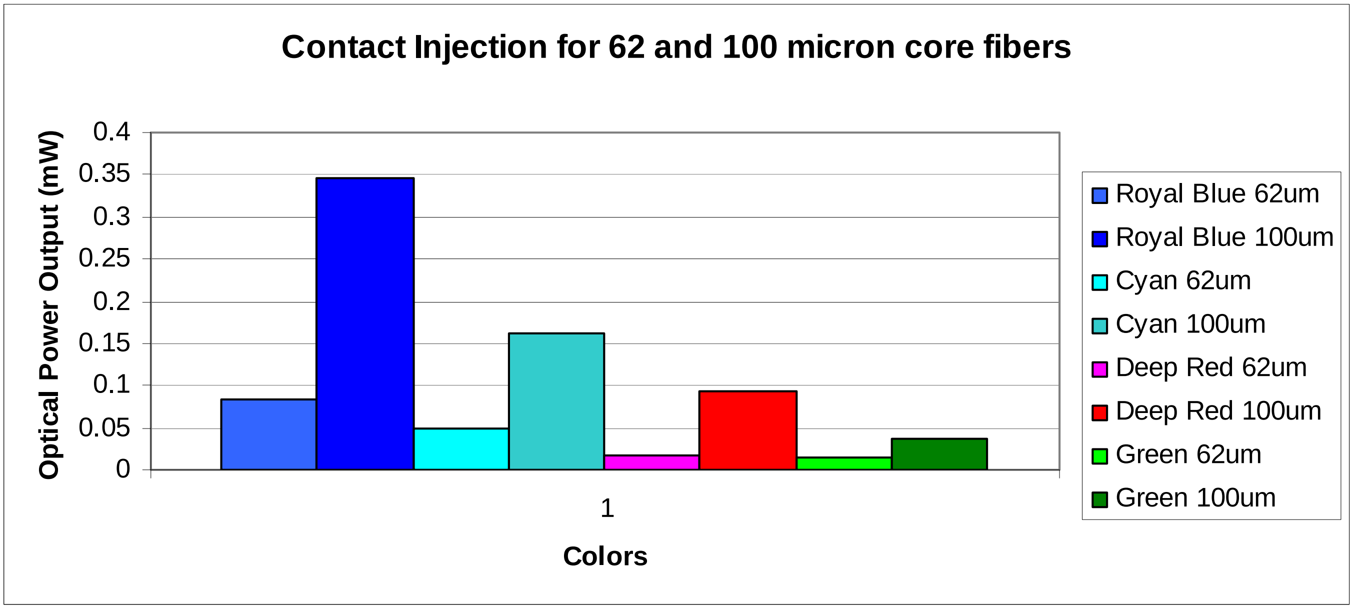

Figure 3: Optical Power Output through fiber vs. Color & fiber core diameter.

For this test, a 1000mA forward current was sent through each color of the LuxeonZ LEDs. From there, the optical power output through fiber optic cables of two different diameters (62um and 100um) was measured. The light was transferred from each LED via contact injection. The calculation for determining the expected power output is:

$$P_{cable} = [D_f^2 * \pi/4] * 0.5[1-\cos(2*\theta)] * P_{optical}$$

P_{cable} is the output power expected through the fiber.
D_f is the diameter of the fiber used (either 62 or 100 microns)
θ = arcsin(Numerical Aperture)
$P_{optical}$ = the total power output without going through a fiber

The first term explains the power lost due to the size of the fiber itself. As the diameter is much smaller than the total area of light emission, this term shows the total power that enters the fiber. The second term determines how much of the light that enters the fiber will stay in the fiber. This calculation requires knowing the numerical aperture of the fibers used. For these tests, both fibers have a numerical aperture of 0.22. By multiplying these two terms together and then again with the total optical power output without a fiber, the total optical power output through the fiber can be estimated.

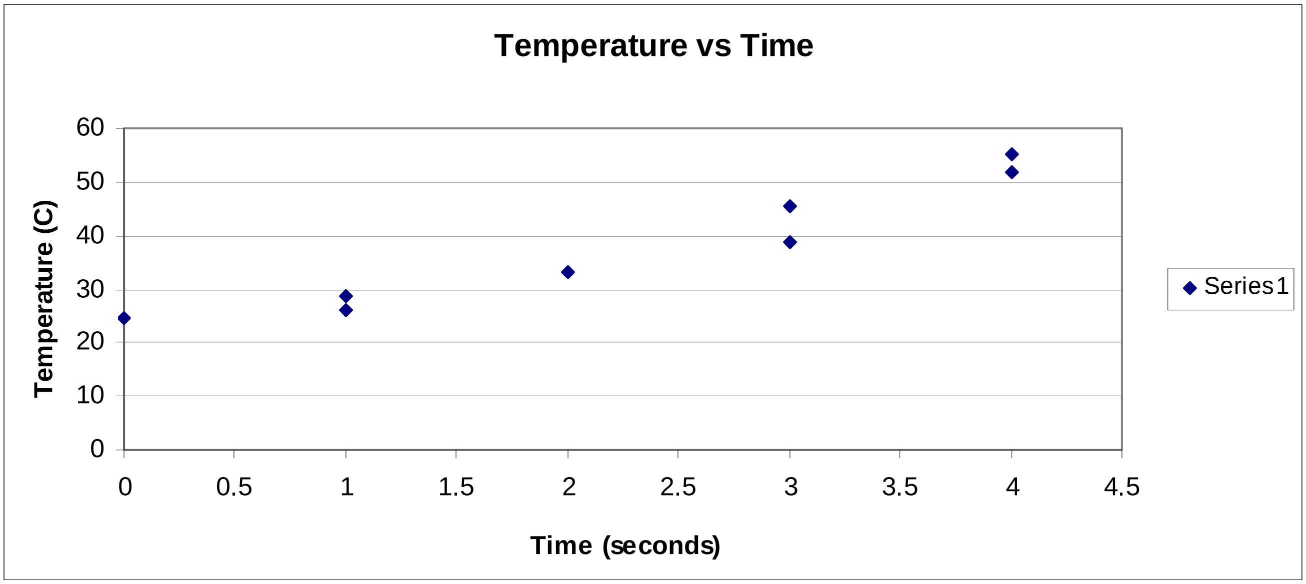

Figure 4: Temperature (C) vs. time. Temperature sensor saturated at 55 degrees C.

The date from figure four was obtained by placing an Resistive Temperature Device (RTD) next to the LuxeonZ LED such that the RTD is in thermal contact with the LED. The temperature was measured through the Resistive Sensor Head A2053 LWDAQ device [2]. This graph gives an idea of how quickly the LuxeonZ LEDs heat up. Our setup during this test was not prepared to handle the high temperatures that the LuxeonZ LED can reach (over 200 degrees C). The importance of this graph is solely to show that the LEDs will heat up for any 'on-time' over 1000ms.

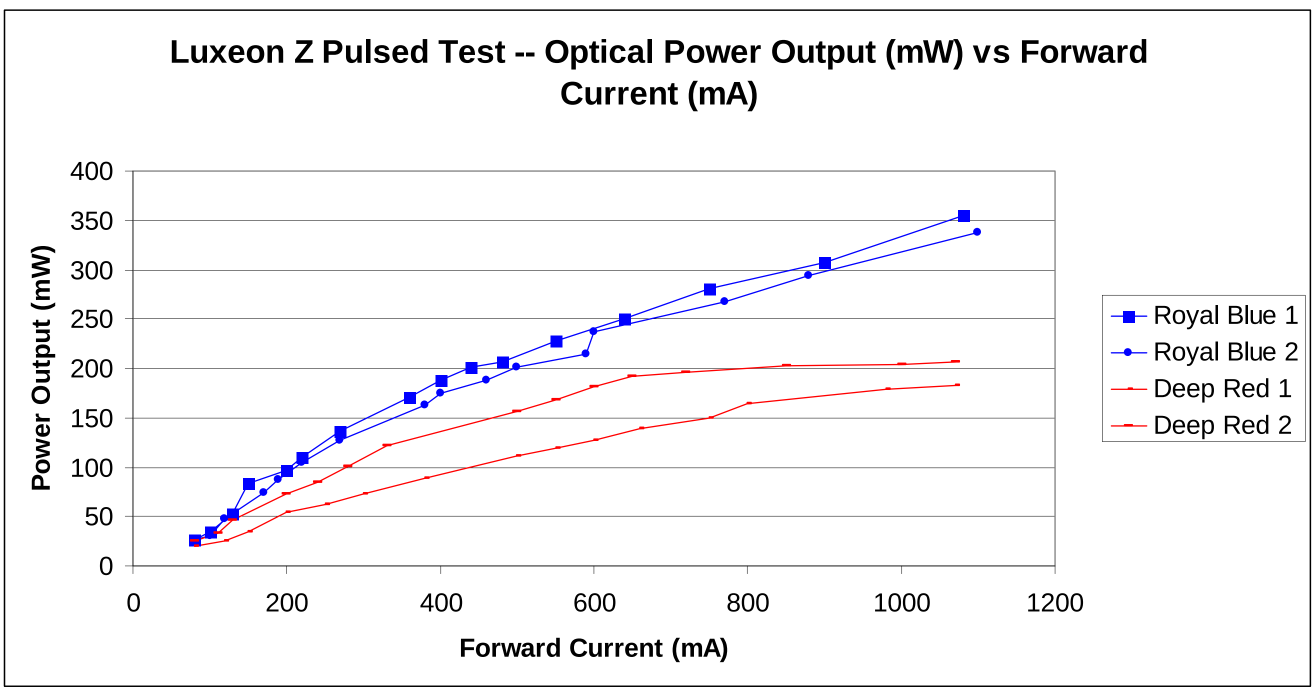

Figure 5: Optical Power Output vs Forward Current.

In order to accurately measure the power output of the LuxeonZ LEDs, a circuit was made to pulse the LED. This allowed the LED to remain cool while still allowing for data collection. The pulse for this test lasted approximately 6ms and repeated with a period of 115ms.

DISCUSSION:

The LuxeonZ LED offers much more flexibility within the alignment system. The LED package itself is more durable, contains no open bond-wires, and is very easily placed on a circuit. Moreover, the large light-emission area would allow for consistent and easy contact injection into the fiber-optic cables proposed in the New Small Wheel Upgrade. These tests help re-affirm that the LuxeonZ is an ideal LED to be used. Specifically, the Royal Blue color (448nm) and the Deep Red (655nm) offer the highest efficiency out of any color tested.

Experiments have shown that the LuxeonZ can handle a full one ampere of forward current when pulsed, deliver a satisfactory optical power output, and is suitable for contact injection. There are however two potential roadblocks involved in using the LuxeonZ.

The first is heat dissipation. The LuxeonZ heats up for any pulse time over 1000ms. As such, we determined that the maximum constant forward current for each color such that the temperature does not go above the datasheet-recommended limit. For Deep Red, the maximum forward current is about 650mA, and 250mA for Royal Blue. These LEDs will reach their recommended maximum temperatures of 135 and 150 degrees centigrade respectively. Looking back to figure 5, it is observed that the optical power output of the Deep Red LED at 650mA is higher than that of the Royal Blue at 250mA. This suggests that the Deep Red LED may in fact be a more viable option.

The second problem is that of radiation. The alignment system of the New Small Wheel must be resistant to radiation. Thus if the LEDs themselves cannot function well at the radiation levels expected, the LuxeonZ is no longer a potential candidate. It is generally seen that rad-hardness is proportional to the band-gap of the LED. Since Royal Blue has a higher band-gap than Deep Red, it is possible that the Royal Blue LED may be the better choice for ATLAS.

Unfortunately, radiation testing of the LuxeonZ has yet to be performed. At this point then, if the it can be shown to have sufficient resistance to radiation, it is recommended that the Deep Red LED be integrated into the ATLAS alignment upgrade. This conclusion has been made by considering the heat produced by the LED, the forward voltage drop required for higher currents, and that none of the current BCAMs [3] installed at ATLAS would have to be altered to account for a different frequency of light.

FOOTNOTES:

[1] http://alignment.hep.brandeis.edu/Electronics/Data/SD445.pdf
[2] http://alignment.hep.brandeis.edu/Electronics/A2053/M2053.html
[3] http://alignment.hep.brandeis.edu/Devices/BCAM/