Fiber Optic Stability Experiments: Part 1

Experience from recent deployments of the MOBY systems in the ocean environment has shown that there are significant day-to-day changes in the irradiance profiles of the incoming light on the system detector. This instability is concisely illustrated in Figure 1, which shows the irradiance profile of Channel 9 of Spectrometer BS04. The image shows an irradiance profile that is U-shaped (day 05), tilted (day07), or some combination of the two (day08). This write-up describes experiments that that seek to identify the cause of this instability and possible optical design strategies to mitigate the problem.

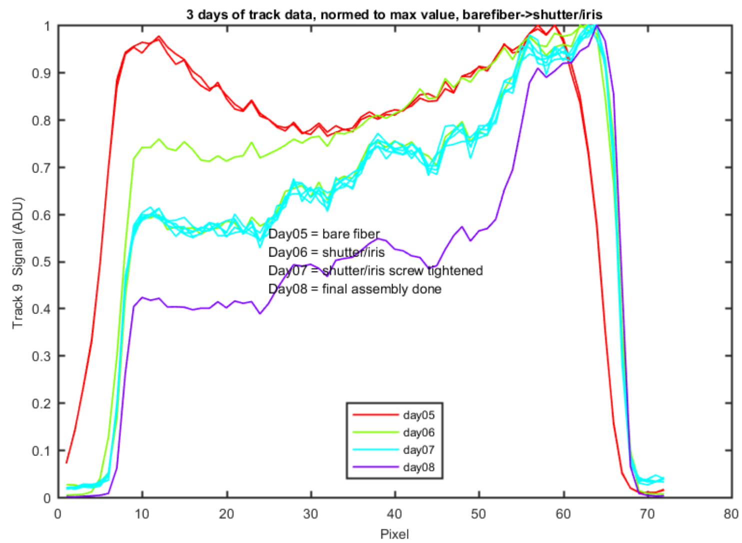

Figure 1. Irradiance profiles of Channel 9 of Spectrometer BS04. Image comes from MOBY Report L267-BS04 9.01.

The basic experiment setup is illustrated in Figure 2. This figure shows a 600 um diameter fiber optic strand with its input end coupled to an integrating sphere. Ideally, the integrating sphere would be illuminated with a narrow band source such as an LED. A broadband source introduces chromatic aberration into the mix, which only obscures the underlying issues of interest. Fiber optic strand is shown bent into a coil. The purpose of the experiment is to demonstrate the effect of this bending on the output from the fiber.

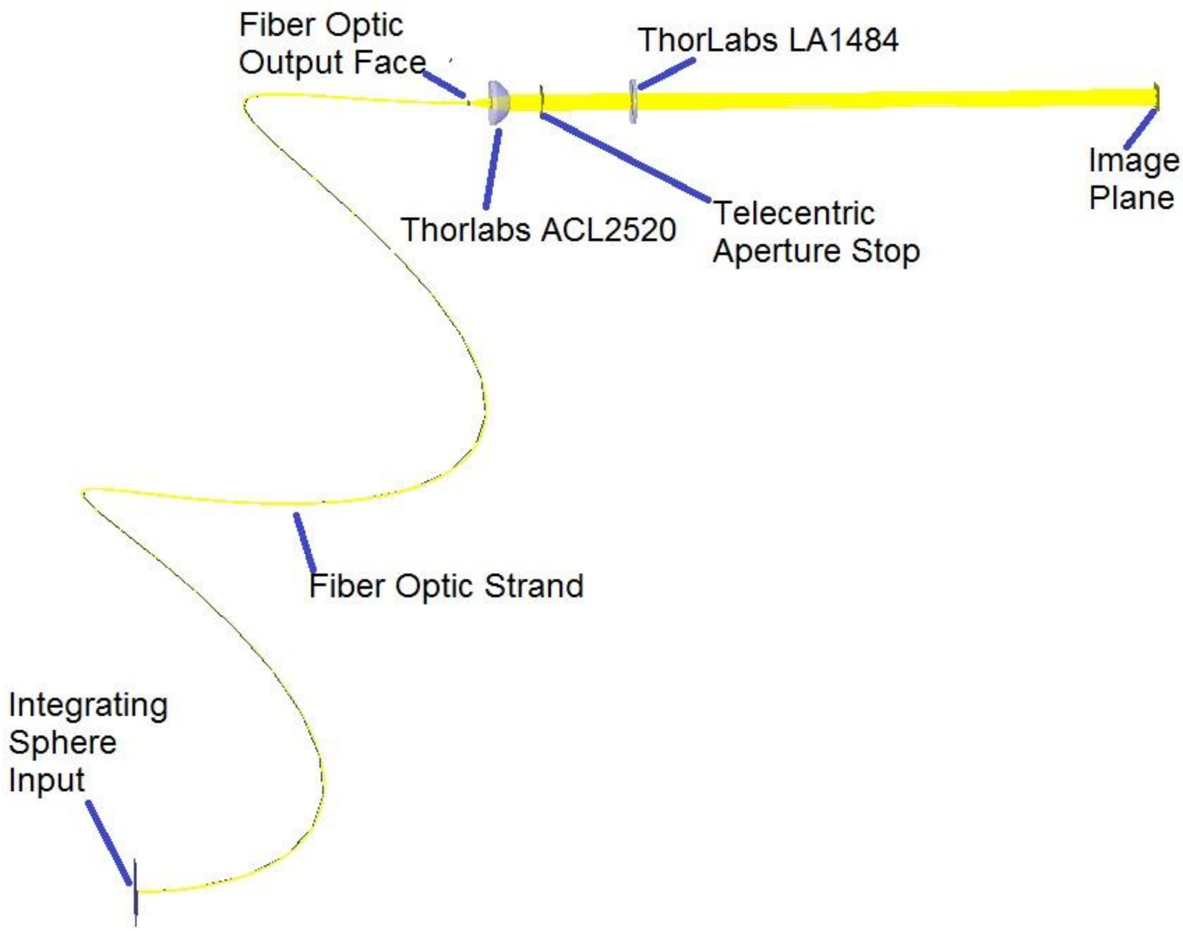

Figure 2. Experimental Setup Overview.

Light enters into the fiber from the integrating sphere. It passes through the fiber and out the back end. From this end, the light expands and is brought to collimation via a Thorlabs condenser lens with a 20 mm focal length. After collimation, the light crosses a hypothetical plane labeled “Telecentric Aperture Stop” in the figure. This plane is a geometric location rather than a physical aperture. Its importance is discussed further below. After travelling a few inches from the condenser lens, the light passes through a 300 mm Thorlabs lens which serves to focus the beam down to an image on a plane about 300 mm behind the last lens.

Based on FRED modelling, the distribution of any cross section of light varies depending on where the detector is placed. At the output face of the fiber strand, the irradiance profile should look like it does in Figure 3. A tilt in the irradiance profile is clearly evident. Since the fiber is placed in an integrating sphere that fully fills the front face of the fiber, any variation in profile at the output face must be caused by bending of the fiber itself.

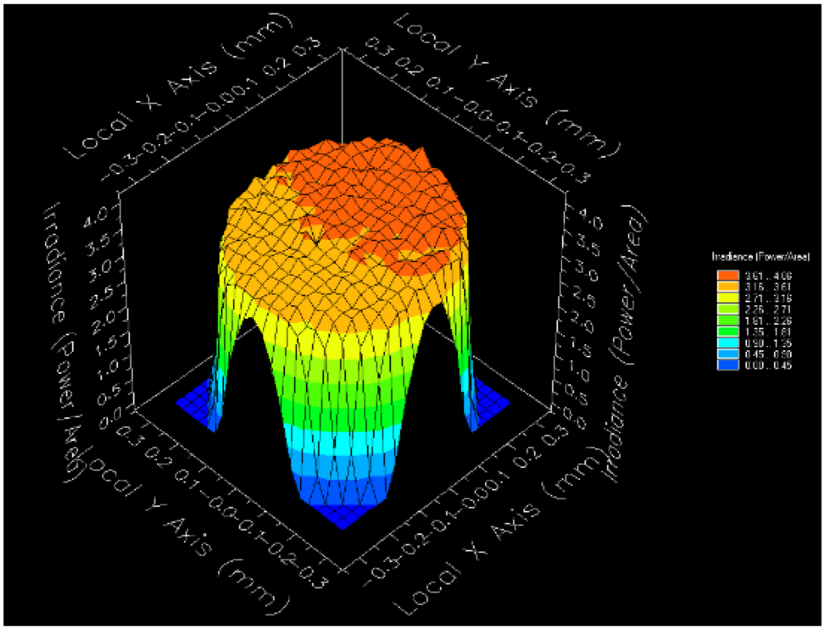

Figure 3. Irradiance profile at output face of the fiber optic.

At the point labeled “Telecentric Aperture Stop” in Figure 2, the light from the output face of the fiber strand is collimated. The irradiance profile at this point is illustrated in Figure 4. Note that the irradiance profile has a flat, top hat shape. There is no evidence of the tilted profile shown in Figure 3. This is because we are at the telecentric aperture stop position of the Thorlabs ACL2520 lens. At this one position, variation in the irradiance profile will occur only if the twist in the fiber changes the angular profile of the beam. The irradiance profile of Figure 4 indicates that this is not the case.

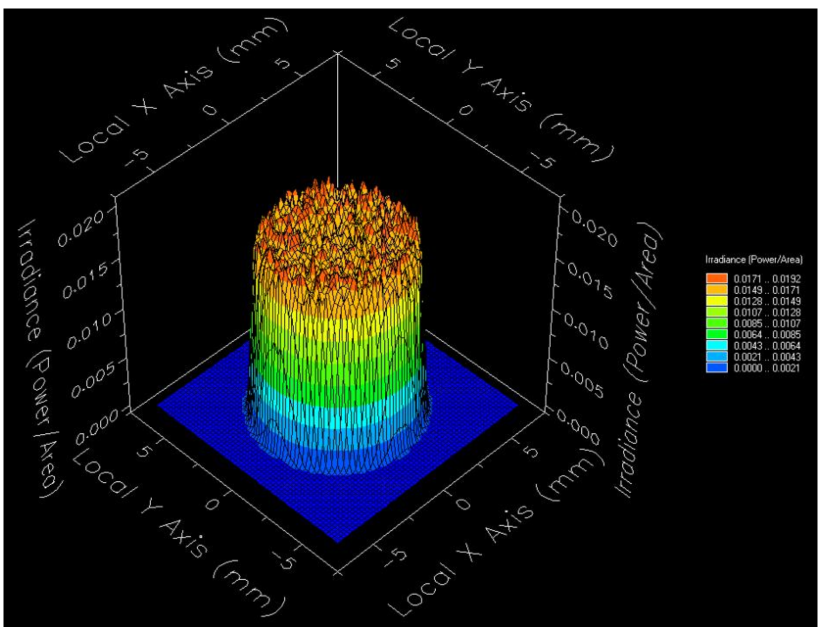

Figure 4. Irradiance profile of the beam at the telecentric aperture stop position.

Finally, at the point labeled "Image Plane" the irradiance profile has the shape show in Figure 5.Once again, a tilt in the irradiance profile is clearly evident.

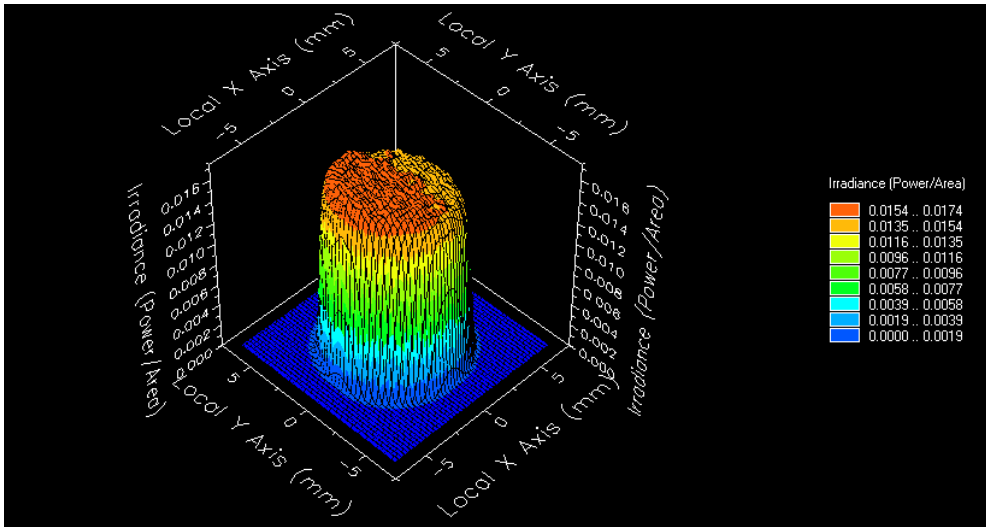

Figure 5. Irradiance profile at the image plane of Figure 2.

The above models indicate that change in the way that the fiber optics are bent will change the shape of the irradiance profile on the output face of a fiber bundle. Since the imaging spectrometer in effect images the output face of a fiber bundle, it also will display variation in the signal as a result of shifts in the position of the fiber optics. A means of confronting this problem would be to couple the light from the output face of the upstream fiber bundle to the succeeding fiber bundle at the telecentric aperture stop position. This is not something I have done before, however, and I don't think it has been done much by anyone. It would require careful experimental verification before ordering parts in volume.

The first step is to verify the above FRED modelling conclusions in a laboratory setting. This can be done on an optics table using the low cost optical components identified above together with an Andor CCD. First, the camera should be placed with its image plane at the "Image Plane" position shown in Figure 2. If the above modelling is done correctly, the irradiance profile on the CCD should be a circle about 10 mm in diameter. The irradiance profile is expected to vary in shape in response to bending of the input fiber. Second, the 300 mm lens should be removed so that the image plane of the camera can be placed at the "Telecentric Aperture Stop" position. In this case, the irradiance profile also should be a circle about 10 mm in diameter. In this case, however, the profile should not change as the fiber is bent, provided that the output face of the fiber bundle is securely attached to the table.

Once these results are confirmed or negated in the lab, we can proceed to the next step, which would be a more sophisticated and costly lab setup or a return to the drawing board, depending on the experimental outcome.