Application Note

Industrial Laser Monitoring System

Introduction

The Industrial Laser Monitoring System (ILMS) combines a reimaging LensPlate2 assembly with a high power Polarization Preserving Beam Sampler (PPBS) to monitor the focus of high power industrial lasers with a WinCamD-LCM imaging profiler. This system is designed to magnify a beam waist while sampling a small percentage of its energy. Magnification allows full 2D measurements of beam spots as small as a few microns.

Theory of Operation

The beam waist is directed towards the input lens and located at a distance such that the lens images the waist to infinity, collimating the beam into the PPBS. The PPBS samples the reflections from two orthogonal wedge windows to safely reduce the power while preserving the original polarization of the input beam and eliminating the interference effects of multiple reflections from each air-glass interface. The collimated beam exits the PPBS and is refocused to a beam waist with another lens. Optionally, additional ND filters can be placed before the output lens. The ratio of the input/output lens effective focal lengths determines the magnification.

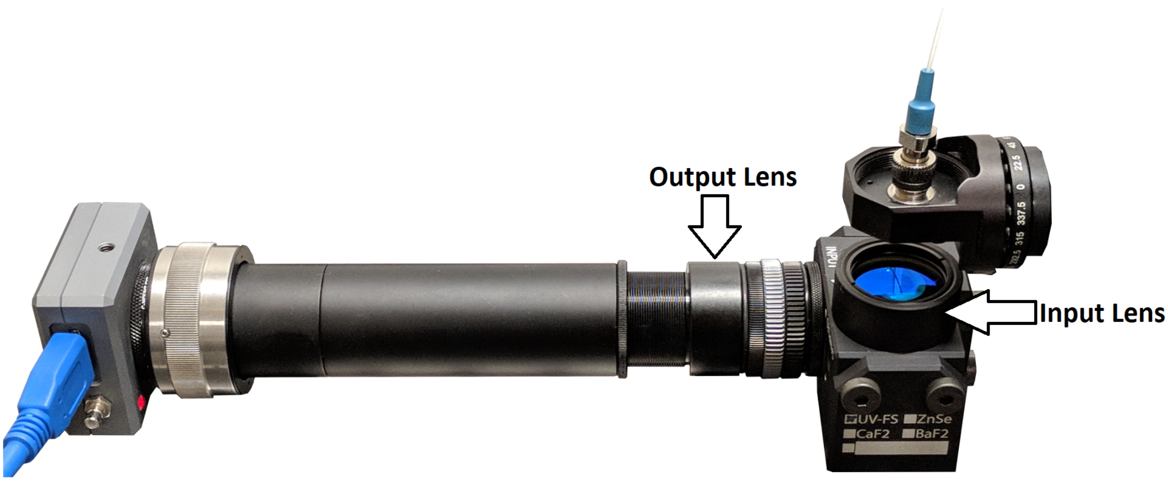

Figure 1: The ILMS uses beam sampling and magnification optics to monitor a high power fiber output or beam focus with the WinCamD-LCM imaging profiler.

Safety

Always follow proper laser safety protocol when working with lasers of any power, refer to ANSI Z136.1. Be sure to understand the light's path, including every reflection/transmission through glass surfaces. The PPBS will have three apertures releasing laser radiation: Residual 1, Residual 2, and Output. The majority of the power will exit the Residual 1 face. **Expect up to 99% of the beam's power to exit Residual 1**. Residual 2 may output less than 1% or up to 50% depending on the material, wavelength, and input polarization. Be cautious and assume that the beam trap or any other element absorbing energy will be hot.

The damage threshold of the 650 - 1050 nm coated lens is 1000 W/cm (1064 nm, Ø0.025 mm) and 5.0 J/cm^2 (810 nm, 10 ns Pulse, 10 Hz, Ø0.155 mm)

Calibration

The system is calibrated in-house using a reference well-collimated beam of similar wavelength to the end-user application. The input lens at the **Input** aperture of the PPBS is removed and the well-collimated beam is directed through the **Input** aperture. The collimated beam is reflected through the PPBS and exits the PPBS **Sampled** face to be focused by the second lens. An adjustable tube separates the beam profiler from the second lens. The distance between the measurement plane of the beam profiler and the second lens is adjusted until the beam waist created by this lens coincides with the measurement plane–this occurs when the measured beam size is minimized. The measurement plane of the beam profiler is now located at the back focal plane of the output lens. The adjustable lens tube is now locked in place; it is calibrated for this specific beam profiler and should *not* be adjusted.

The input lens is now reattached to the **Input** aperture and the device is now ready to reimage a beam waist to the beam profiler. A test beam waist is aligned to the input lens at the *Input* aperture (as shown in Figure 1), and the distance of the beam waist from the input lens is adjusted until the reimaged spot on the beam profiler is minimized. The magnification is determined by using a micrometer to move the beam waist in X/Y and compare the distance the reimaged beam centroid moves on the beam profiler.

System Setup

Hardware Setup

The following parts will be included with the Industrial Laser Monitoring System (ILMS). The ILMS is delivered assembled and calibrated for a specific camera, unless otherwise specified by the customer.

Parts List

- ILMS (in order from input beam)
  - Input Lens
  - PPBS
    - (2) Wedged windows of one of the following materials:
      - UV Fused Silica (190 nm – 2100 nm)
      - Barium Flouride (0.2 μm – 11 μm)
      - Calcium Flouride (0.2 μm – 8 μm)
      - Zinc Selenide (0.5 μm – 16 μm)
  - ND filter(s)
  - Output Lens
  - Adjustable lens tube (locked to a specific calibration)
  - SM1 to C-mount adapter
  - DataRay beam profiling camera
- Optional BeamTrap (*Depending on power handling requirements*)

Pixel Multiplication Factor

In the software, the Pixel Multiplication Factor must be set correctly so that the software can automatically accommodate for the ILMS magnification. The Pixel Multiplication Factor (PMF) must be set to the *inverse* of the magnification. For example, a 5X Industrial Laser Monitoring System with model ILMS-5X-LCM would require a PMF value of 0.2 as shown in Figure 2. **All measured values are displayed in accordance with the PMF value; it is not necessary to manually calculate the corrected values when the PMF is set correctly.**

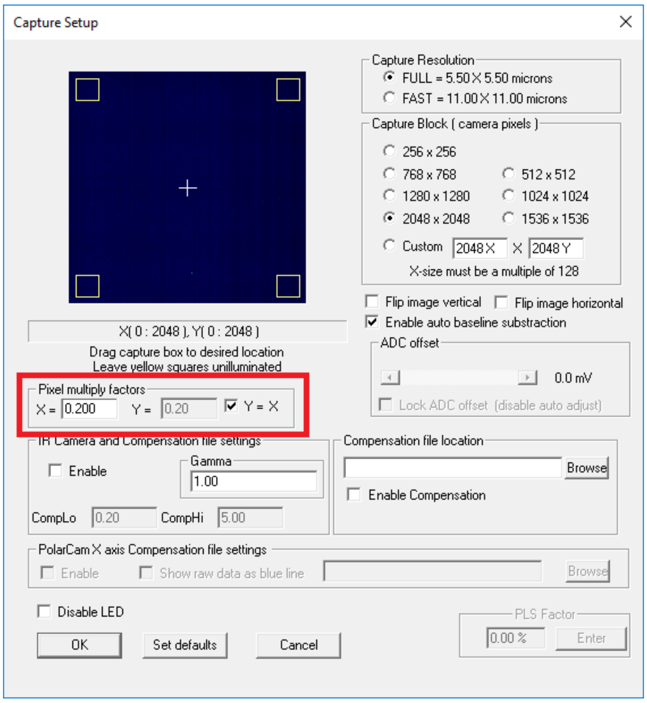

Figure 2: The PMF value must be set to the inverse of the ILMS magnification.

Assembly and Use

1. The beam profiling camera is pre-attached during the in-house calibration. If the customer chooses to order without an included camera, they must attach their camera to the end of the lens tube on the output face of the PPBS using the SM1 to C-mount adapter. *Be advised that adjusting the lens tube or swapping cameras can affect the calibration which placed the measurement plane at a specific distance from the output lens.*

2. Mount the assembly such that the laser enters normal to the center of the Input lens.

   - Proper alignment requires 5 degrees of freedom–X, Y, Z, pitch, and yaw.

3. Mount a beam trap or other power handling tool behind 1st residual face to absorb energy. **The included Residual 1 & 2 covers are *not* intended to handle high power.**

   - Consider whether a beam trap is necessary for the Residual 2 output

4. Adjust the distance between the input beam waist and the input lens until the spot size measured on the beam profiler is minimized.

   Do not adjust the calibrated LensPlate2 output tube that connects the beam profiler to the PPBS. The only variable the user must control is the alignment and distance of the beam waist to the input lens.

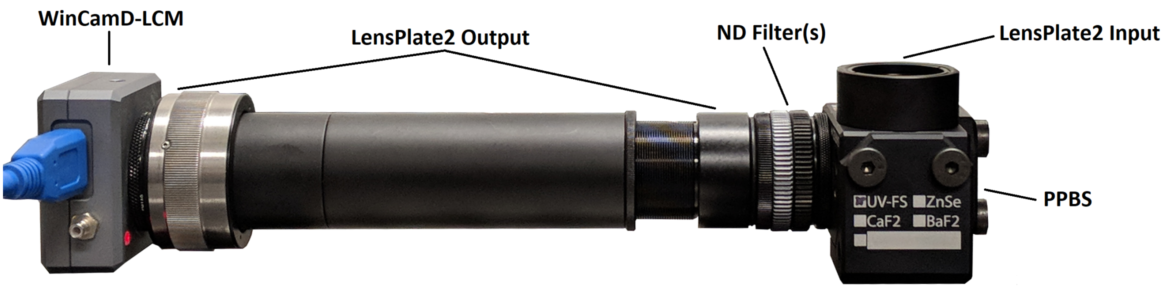

Figure 3: Industrial Laser Monitoring System.

Attenuation

Because the sampled beam is the result of the reflections from the first surface in each glass wedge, the attenuation is calculated according to Fresnel reflection equations. The reflected intensity of the laser for each wedge surface depends on the wavelength, polarization, index of refraction, and incident angle. Since the two reflections are orthogonal, the net effect from polarization is canceled out. The beam is assumed to have normal incidence to the input face of the PPBS, so the sampled beam output percentage depends only on the laser's wavelength and the material of the wedge. Figure 4 shows the sampled percentage for four different PPBS wedge options. If additional ND filters are used between the PPBS output and the second lens, this provides additional attenuation. The Attenuation Calculator spreadsheet can calculate combined attenuation of PPBS and ND filters for given beam parameters.

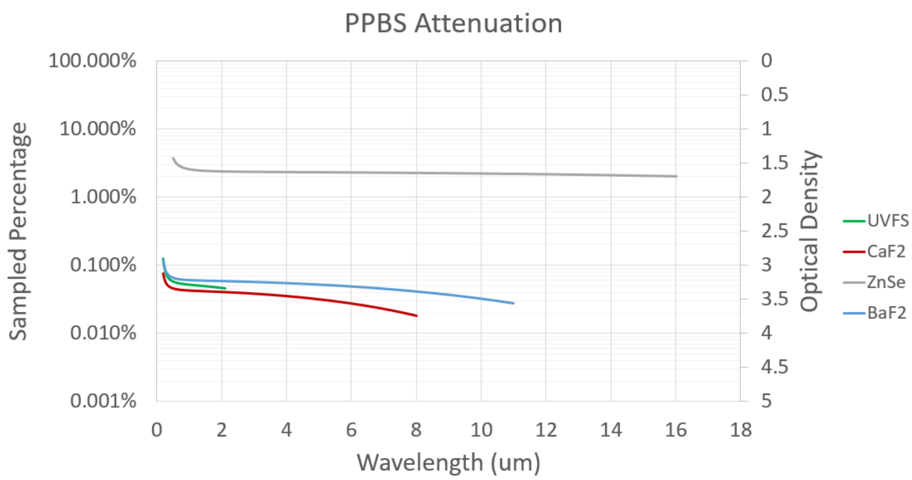

Figure 4: Sampled Percentage of the beam for each PPBS wedge material option

Alignment

The input beam should be aligned through the center of the input lens with minimized pointing error. The distance from the input beam waist to the input lens is very important because the system is calibrated assuming a collimated beam between the lenses. The input waist location must be adjusted until the spot size seen by the beam profiler is minimized. The figures below show a simplified, unfolded optical path to demonstrate how the input waist position will affect the output waist location.

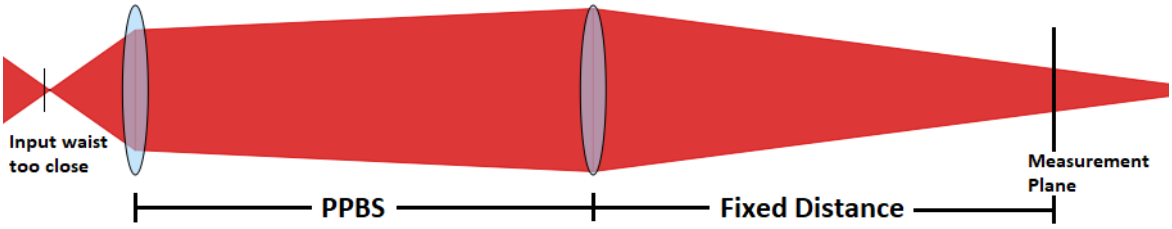

Figure 5: The input beam waist is too close to the input lens. **This is *not* aligned correctly.**

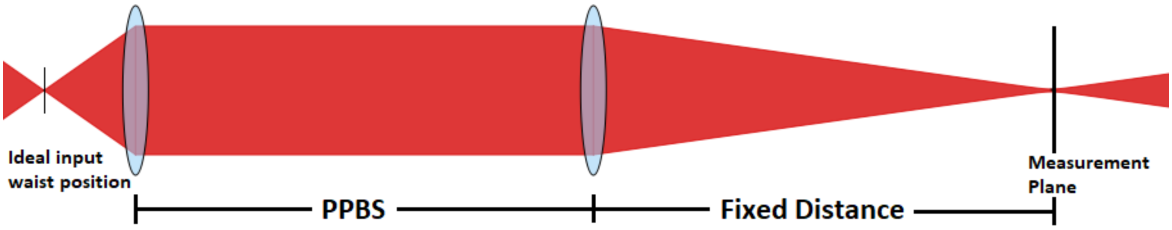

Figure 6: The input beam waist is positioned properly to minimize the spot size at the measurement plane.
This is correctly alligned!

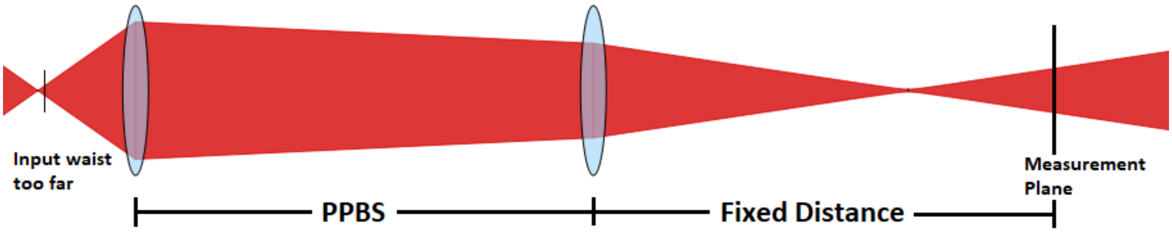

Figure 7: The input beam waist is too far from the input lens. **This is *not* aligned correctly.**

Lens Design

Each lens in the LensPlate2 is designed for best performance at an infinite conjugate ratio for beams close to on-axis. For lasers, this means that the beam on one side of each lens should be collimated for best performance as shown in Figure 8. The LensPlate2 is calibrated such that the focus of the output lens will coincide with the WinCamD imaging sensor when the beam incident the output lens is collimated thus satisfying the infinite conjugate ratio requirement for best optical performance.

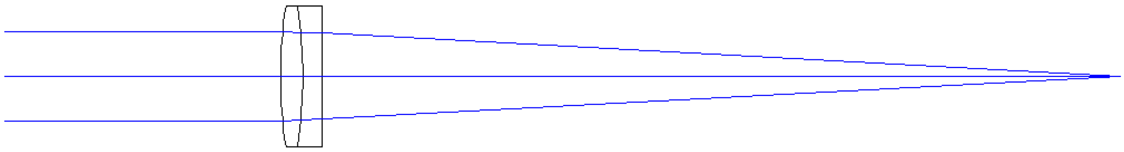

Figure 8: Infinite conjugate ratio example.

Off-Axis Performance

Our LensPlates are typically designed for on-axis measurements using achromatic or aspheric lenses, which covers most laser measurement applications. Applications that require better off-axis imaging will usually need an input objective corrected for off-axis imaging. Such objectives can be purchased from a third-party and are sold as infinity-corrected microscope objectives. DataRay can assist in choosing the proper infinity-corrected objective to use as the input lens.