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Application Note

Polarization Preserving Beam Sampler

Introduction

The Polarization Preserving Beam Sampler (PPBS) will sample a small percentage of a beam's power for measurement applications where the original beam's power density would otherwise damage the measurement instrument or standard absorptive ND filters. The PPBS samples the reflections from two orthogonal wedge windows to safely reduce the power of high intensity light while preserving the original polarization of the input beam and eliminating the effects of multiple reflections from each air-glass interface.

Theory of Operation

The Polarization Preserving Beam Sampler consists of a pair of glass windows that each transmit a large percentage of the input beam's energy to be discarded or trapped in a BeamTrap, and reflect a small percentage of the input beam's energy at each window surface for measurement. Two reflections occur at each window–one per surface. This results in 4 beams exiting the PPBS from the output face. The beam of interest is the result of the reflections off the first surface of each window. The three other beams exiting the PPBS are displaced due to the wedge design of the windows so that they do not hit the beam profiler's imaging area. When this app note discusses the original, intermediate, and sampled beam, it is referring specifically to the different positions of the beam path formed by reflections at the first surface of each window.

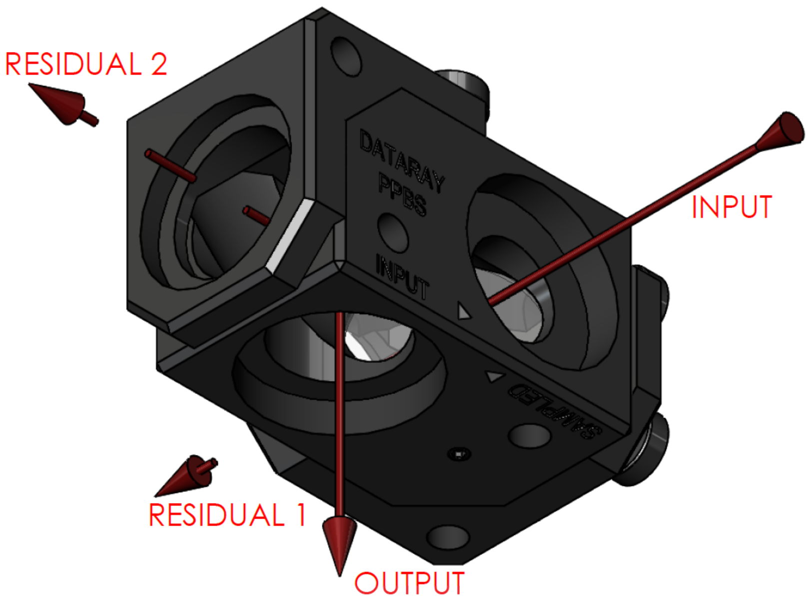

Figure 1: Polarization Preserving Beam Sampler

Warning: Be aware of high power beams exiting this device. Review this entire document before operation.

First Window

The original beam first passes normally through the input face of the PPBS and is incident to the first glass window at a 45-degree angle. Most of the beam's energy is transmitted through this first window and exits the PPBS through the Residual 1 face of the PPBS to be discarded/absorbed by a beam trap. The two surfaces of the glass window each reflect a fraction of the input beam's energy. The front surface, mounted at a 45-degree angle, results in a 90-degree (orthogonal) reflection angle–this is the intermediate beam. Since the window is 3-degree wedged, the rear surface results in a 96-degree reflection angle–this second surface reflection is designed to not reach the measurement area of the beam profiler. The *s*-polarization component of the beam will reflect at a greater percentage than the *p*-polarization component.

Second Window

The intermediate beam between the two windows is reflected again at the first surface of the second window. This second window is oriented in such a way that the polarization effect of the reflection is reversed when compared to the first window's reflection. The polarization component that was reflected at a higher percentage from the first window is now reflected at a lower percentage, and vice versa. The net polarization effect from each of the two windows results in the output beam having the same polarization properties of the original input beam.

Safety

Always follow proper laser safety protocol when working with lasers of any power, refer to ANSI 2135.1. 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.

System Setup

Hardware Setup

The following parts will be included with the PPBS. Follow the assembly steps to mount the LCM camera on the PPBS.

Parts List

- (1) PPBS
  - (2) Wedged windows of one of the following materials:
    * UV Fused Silica (190 nm – 2100 nm)
    * Barium Flouride (0.2 m – 11 m)
    * Calcium Flouride (0.2 m – 8 m)
    * Zinc Selenide (0.5 m – 16 m)
  - (2) Fiber tip set screws
- (2) Brackets with SM1 internal threading
  - (4) Bracket screws
- (1) SM1 to C-mount adapter
- BeamTrap (*Depending on input beam power*)

Assembly

1. Attach camera to the Output face of the PPBS using an SM1 to C-mount adapter
   - The camera may also be mounted farther from the output using an SM1 tube.
2. Mount the assembly such that the laser enters normal to the center of the Input aperture
3. Mount a beam trap behind 1st residual face to absorb energy
   - Consider whether a beam trap is necessary for the Residual 2 output

Figure 2: Polarization Preserving Beam Sampler with a WinCamD-LCM attached to Output and a Beam Trap behind Residual 1

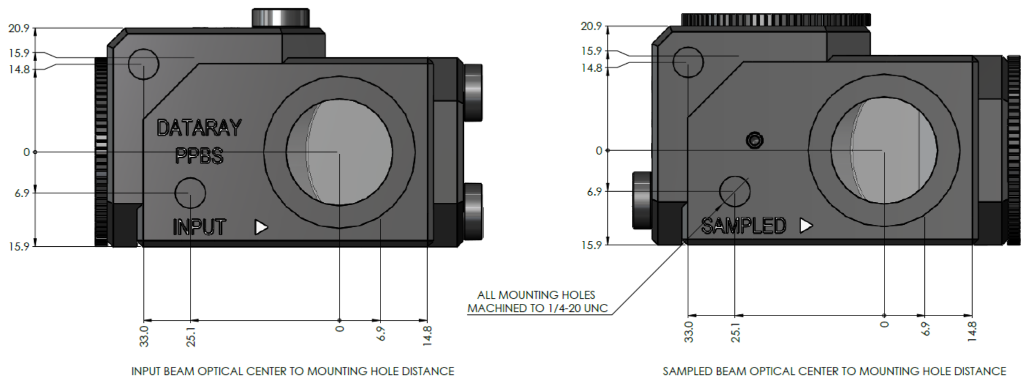

Figure 3: PPBS dimensions for mounting. The optical path length of the PPBS is 50.00 mm 0.5 mm.

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 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 (See Polarization Preservation section). 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 vs wavelength for each available wedge material. The wavelength range of each material is limited by its transmission range. Please refer to PPBS_SampledOutputVsWavelength.xlsx for a spreadsheet to provide attenuation values for specific wavelengths.

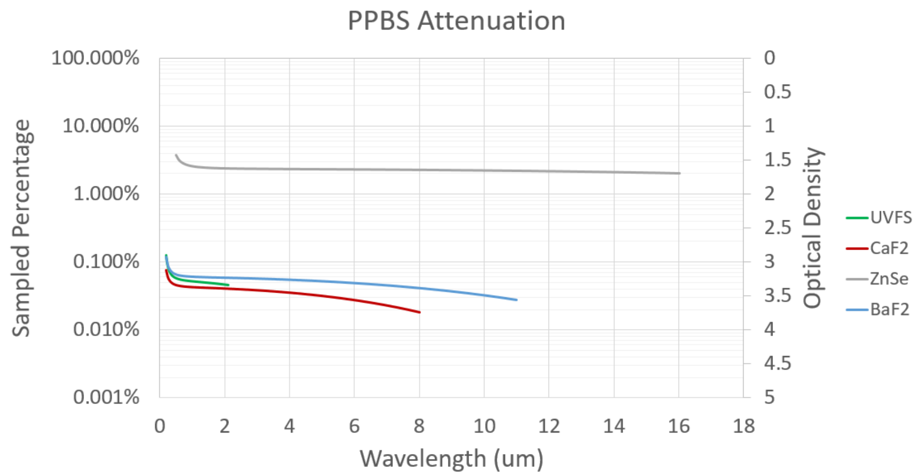

Figure 4: Sampled Percentage of the beam for each PPBS wedge material option

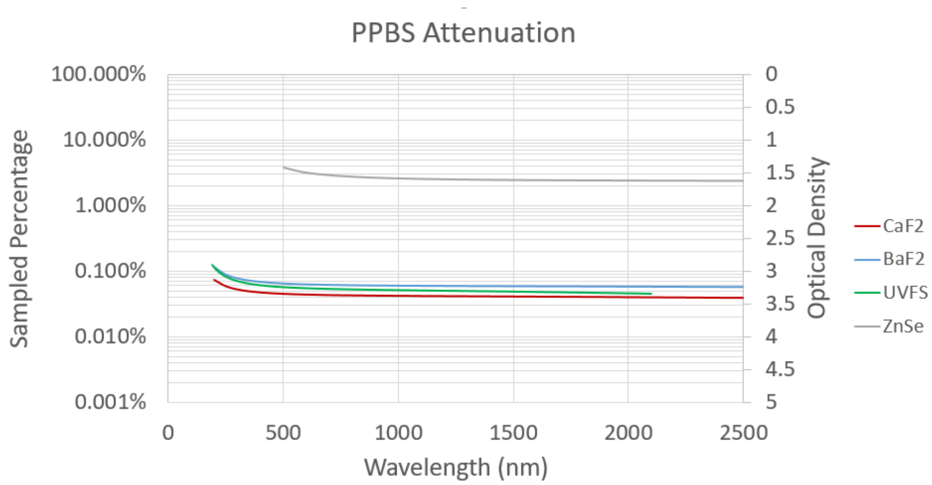

Figure 5: Sampled Percentage of the beam for each PPBS wedge material option (zoomed plot)

Polarization Preservation

The output of a laser is often polarized, and sometimes it is important to preserve this polarization for beam profiling measurements. Polarization defines the the direction in which the electric field oscillates. For simplicity of this explanation, we will consider linearly polarized light in which the electric field is confined to a single plane along the direction of propagation.

s and p polarization

The polarization direction of a beam can be split into two vector components. These are sometimes denoted X and Y components, for example a 100% X-polarized beam would have its electric field oscillating in a horizontal plane. But when considering how the polarization affects a surface reflection, it is convenient to relate the direction of polarization to the plane of incidence.

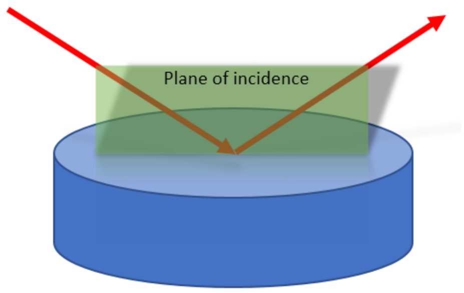

Figure 6: Plane of incidence of a laser reflecting off a reflective surface

The component of the electric field oscillating parallel to the plane of incidence is called the p-polarization component (German word *parallel*). The component of the electric field oscillating perpendicular to the plane of incidence is called the s-polarization component (German word *senkrecht* for perpendicular).

According to Fresnel equations, s-polarized light incident on a surface at an angle will reflect more than p-polarized light. This means that any attenuator that samples a single reflection from a beam will modify the beam's polarization. The PPBS samples two orthogonal reflections which cancels out the polarization modification effect.

Example 1

Input 10 W 350 nm beam that is partially p-polarized to PPBS-UV-FS

- 25% s-polarization component, 75% p-polarization component
- Ratio s/p=0.333

First wedge's front surface

- Reflects 8.64% of the s-polarized light which becomes 0.216 W p-polarized light
- Reflects 0.75% of the p-polarized light which becomes 0.0559 W s-polarized light
- (s and p swap since the plane of incidence changes for the second wedge reflection)

Second wedge's front surface

- Reflects 8.64% of the s-polarized light which becomes 0.0016 W s-polarized light
- Reflects 0.75% of the p-polarized light which becomes 0.0048 W p-polarized light

- Ratio s/p=0.333

The output has the same polarization as the input, but contains only 6.4 mW of the power.

Example 2

Input 10 W 3.5 m beam with equal polarization components to the PPBS-BF

- 50% s-polarization component, 50% p-polarization component
- Ratio s/p=1

First wedge's front surface

- Reflects 8.24% of the s-polarized light which becomes 0.412 W p-polarized light
- Reflects 0.68% of the p-polarized light which becomes 0.034 W s-polarized light
- (s and p swap since the plane of incidence changes for the second wedge reflection)

Second wedge's front surface

- Reflects 8.24% of the s-polarized light which becomes 0.0028 W s-polarized light
- Reflects 0.68% of the p-polarized light which becomes 0.0028 W p-polarized light
- Ratio s/p=1

The output has the same polarization as the input, but contains only 5.6 mW of the power.

Multiple Reflections

The sampled beam from the PPBS is a result of the first surface reflection from each glass wedge. However, since a reflection occurs at *every* air-glass interface, there are actually four beams leaving the output face of the PPBS.

The glass optics in the PPBS are designed with a 3 degree wedge angle, both to eliminate an optical interference etalon effect and to offset the additional reflections from the back surfaces. The larger the wedge angle, the greater the offset and angle between multiple reflections. A 0.5 degree wedge angle will result in additional reflections interfering with the measurement. The PPBS uses a 3-degree wedge angle which offsets the reflections to land outside the sensor area. The camera can also be mounted farther from the PPBS so that the multiple reflections are offset by a greater distance. *Be aware of these stray reflections; they will have roughly the same power as your sampled beam.*