Beam Attenuation: Key to Successful Beam Profiling

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Beam profiling characterizes the size, shape, quality, and focal position of a laser beam. Whether the application is a few milliWatts in power or several kWatts, beam profiling is used to test optical designs, verify laser performance, or monitor the performance of laser systems.

Sensors used in most beam profiling instrumentation are very sensitive, saturating at power levels of ~1 microWatt per cm^2, much lower than the irradiance of even the lowest power lasers. Thus, beam profiling is a lot about carefully attenuating the power level so the beam can be analyzed. This is critical because lasers designed for cutting sheet steel will also have no trouble cutting through a beam profiler if the beam power isn't attenuated!

The good news is there are reliable methods to reduce the beam power to levels required while preserving the beam profile integrity. What is required is some understanding about the optics involved and some back-of-the-envelope calculations.

Avoiding Thermal Lensing

Neutral density filters are commonly used to attenuate the beam in profiling applications. But at high enough powers, they can thermally lens, distorting the beam profile. Thermal lensing occurs when local heating of the absorptive neutral density filter changes the local index of refraction of the material. The temperature induced change of the index of refraction creates a thermal lens which makes the beam appear larger than it true size. This effect occurs with the beam power per unit area is 5 Watts per cm^2 or larger.

To avoid thermal lensing, a reflective rather than an absorptive attenuator must be used. Typical reflective attenuators involve a beam splitter or using the front surface reflection from a wedge optic, which reflects 4% from the front surface. Lower percentages of reflection are achieved with anti-reflection coatings. Laser grade optics should be used in reflective beam attenuation schemes to maintain the profile integrity.

When using front surface reflections to attenuate the beam, usually two reflective optics are used, mounted so the beam strikes the surfaces at opposing right angles to preserve the beam polarization. Once the beam power is reduced to the point where thermal lensing is no longer an issue, absorptive neutral density filters are then used further down the optical beam path to reduce the beam power even more.

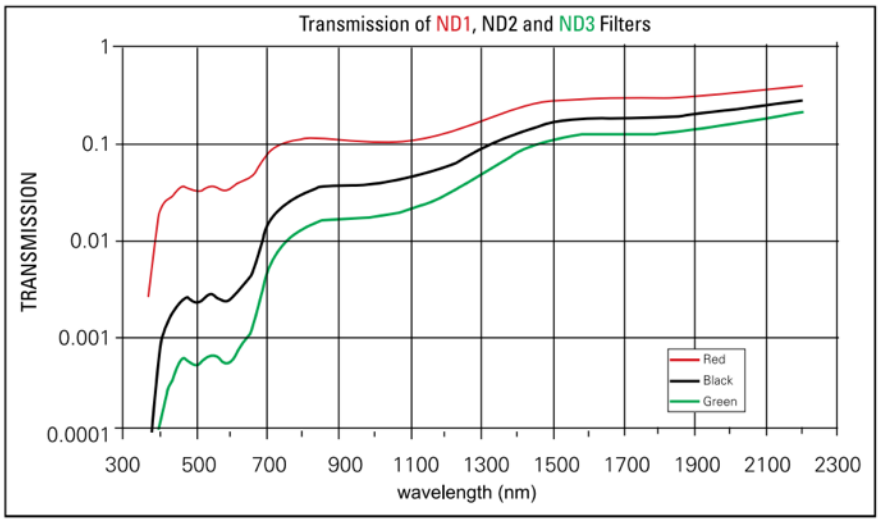

Fig. 1: Typical transmission vs wavelength characteristics of neutral density filters.

Putting it into Practice: Beam Attenuation Example

Suppose you wanted to profile a 100 micron beam at 2 Watts of power at 532 nm. Assuming the beam is Gaussian, the irradiance of the beam is 1 x 10^4 Watts per cm^2. The beam would need to be attenuated by ten orders of magnitude to prevent saturation of the sensor. In addition, since the beam power is well above the thermal lensing limit, a reflective beam attenuation scheme would need to reduce the beam power to the point where absorptive neutral density filters could be used.

Two wedges coated anti-reflective coatings that reflect 1% of the 532 nm light would reduce the beam power four orders of magnitude, to 1 Watt per cm^2. Since this is under the thermal lensing limit, neutral density filters that reduce the beam power six orders of magnitude would bring the beam irradiance down to a level where it can be profiled.

LBS-300 Series Beam Attenuators

Ophir developed the compact LBS-300 series of beam attenuators to provide variable beam attenuation with reflective and absorptive attenuation optics to assist our customers in obtaining reliable beam profiles in a variety of profiling applications.

The Ophir® LBS-300s is a compact, portable laser beam splitter for handling small beam diameters and a wide range of powers. The LBS-300s measures laser beams with diameters up to 15mm and powers from 10mW to 400W. It is designed with a shorter distance from the input surface to the camera array to accommodate finding focus spots with shorter working distances. This makes the LBS-300s ideal for enclosed workstations, such as micromachining, microwelding, and medical device manufacturing. Further information can be found at: LBS-300s.

Fig. 2: The Ophir LBS-300HP-NIR beam splitter reduces extremely high laser power at an unprecedented 15MW/cm^2 at 5kW.

The Ophir® LBS-300HP-NIR beam splitter for high power NIR lasers is a compact device that can deliver extremely high power density attenuation, up to 15MW/cm^2 at 5kW. It reflects less than 0.0001% of the incident NIR beam while transmitting 99.9999%. This enables measurement of beam shape, focal spot, beam waist, and overall power. The patent-pending LBS-300HP-NIR beam splitter is ideal for online beam profiling in a variety of high power military lasers, and Nd:YAG applications in industrial materials processing and R&D. Further information can be found at LBS-300HP-NIR.

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