Calculating Power Density – A Shortcut

It is often necessary to calculate the power density (Power/Area) of a laser beam (for example, when trying to determine whether a beam will damage an optic or detector). Usually power density is expressed in terms of W/cm^2. However, laser beam diameters are usually expressed in millimeters. Performing this calculation can be tedious, so you may find the following formula useful as a shortcut.

$$\text{Power Density } (W/cm^2) = \frac{250}{d^2} \times \text{Power}$$

where d is the diameter of the laser beam *in millimeters*.

For those interested in knowing the origin of this formula, please read on. Otherwise, just enjoy using the formula!

To derive this formula, we start with the easily verifiable fact that the reciprocal of the area of a 1 mm diameter beam is 127 cm^{-2}.

$$1/A = 127 \text{ cm}^{-2} \quad \text{(1 mm diameter beam)}$$

To get the power density of a 1 mm diameter beam one must simply multiply the power (in Watts) by 127 cm^{-2} to get power density (in W/cm^2). Or,

$$\underset{\text{(of 1 mm beam)}}{\text{Power Density}} = 127 \times Power$$

If the beam diameter is 2 mm instead of 1 mm, then the power density will drop by 2^2 or 4. So divide 127 by 4, then multiply by power. If the beam diameter is .5 mm, then the power density will increase by 4, so multiply 127 x 4, then multiply by power. So, for an arbitrary size beam, the following formula holds:

$$\text{Power Density} = \frac{127}{d^2} \times Power$$

This tacitly assumes that the beam profile is uniform. If the beam has a Gaussian profile, then multiply by 2 and the formula at the top of this page results. (The multiplication value is actually closer to 255, not 250, but this difference is trivial, introducing only ~2% error. We use 250 simply because it's easier to remember and perform mental calculations than 255!)