1 Background

Broadband sources are light sources that contain a spectrum of wavelengths, and the total power of the source is distributed among the wavelengths. The distribution of power is called the "power spectrum", and is most conveniently specified as function of wavelength. Let $p(\lambda)$ be the power spectrum for some broadband spectrum. The total power P in the emitter is

$$P = \int_0^\infty p(\lambda) d\lambda \tag{1}$$

The dimensions of p must be power over length. If the wavelength is measured in nm and power is measured in W, the units on p will be $\mathrm{W\,nm^{-1}}$. These units are important for correctly simulating a broadband exposure.

2 Modeling a Broadband Source

A broadband source can be modeled as a collection of laser sources. We can essentially just think of the broadband source as a bunch of lasers with different wavelengths, each emitting some power. However, it is important to correctly determine the power of each laser.

Consider a collection of N single wavelength lasers with wavelength λ_i and power P_i. Together they approximate a broadband source, and the more lasers we use, the better the approximation will be. The total power in the collection of lasers will be

$$P = \sum_{i=1}^{N} P_i \tag{2}$$

When we model a broadband source as a collection of laser sources, the total power in the collection of lasers should match the total power in the broadband source. The error in the approximation will then be how the power is distributed among the wavelengths. If the absorption coefficient did not depend on the wavelength, then there would be no error in the energy absorbed, but since the absorption coefficient does depend on the wavelength, the approximation will lead to an error in the power that is absorbed.

So, we need to find the powers P_i, such that

$$\sum_i P_i = P = \int_0^\infty p(\lambda) d\lambda \tag{3}$$

and

$$\lim_{N \to \infty} P_i = p(\lambda_i) \tag{4}$$

Let's assume that we have a collection of N lasers, each with a wavelength λ_i, that are uniformly separated: $\lambda_{i+1} - \lambda_i = \Delta\lambda$. Now, break the integral 1 into pieces, with each piece a length $\Delta\lambda$ long and centered about a λ_i

$$P = \sum_{i=1}^{N} \int_{\lambda_i - \Delta\lambda/2}^{\lambda_i + \Delta\lambda/2} p(\lambda) d\lambda \tag{5}$$

Comparing to 2 gives

$$P_i = \int_{\lambda_i - \Delta\lambda/2}^{\lambda_i + \Delta\lambda/2} p(\lambda) d\lambda \tag{6}$$

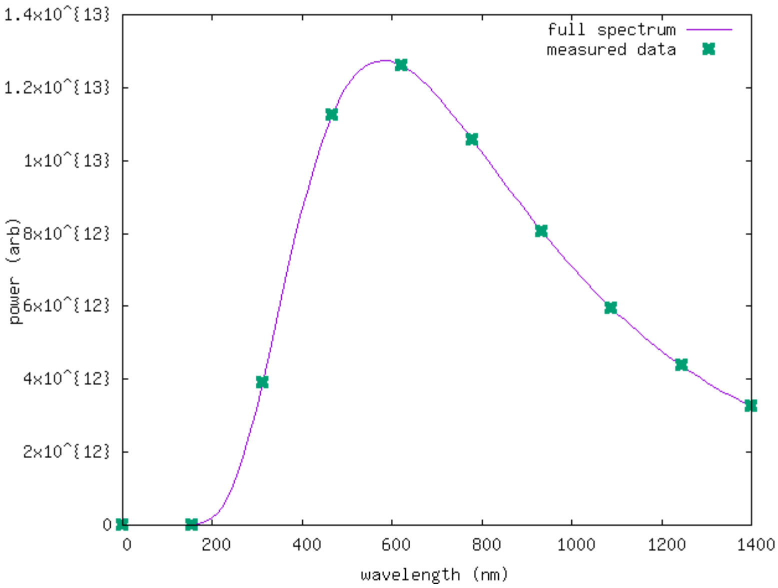

Figure 1: An example of a measured power spectrum with the underlying full spectrum that is being measured

3 Using measured data

There is nothing about 6 that is particularly difficult to understand, however it is important to keep in mind that the power of each laser in our approximation should correspond to an integral of the power spectrum over some range. It becomes a less clear how to deal with a measured power spectrum. It is important to understand how the measured data relates to the underlying power spectrum so that the source can be modeled correctly.

One way to "measure" the spectrum of a broadband source would be to place a filter that blocks all but one wavelength in front of a power meter and measure the power transmitted through the filter. This would be a direct measurement of the power contained in the wavelength transmitted by the filter. This measurement will be a direct estimate of the power spectrum, $p(\lambda)$, at the transmitted wavelength, not the powers P_i. Figure 1 illustrates how the measured data is related to the true underlying spectrum of the source. It is important to understand this in order to correctly determine the total power in the source. For a set of measurements, the total power in the source will not just be the sum of the measured powers, but is instead the integral of the power spectrum that underlies the data. The total power can be estimated from the measured data, but this must be done with numerical integration.

Assume that we have a set of M measured powers, P'_j at discrete wavelengths λ_j which are uniformly separated, $\lambda_{j+1} - \lambda_j = \Delta\lambda$. We want to model this source with as a collection of single wavelength lasers, and we want to just use one laser for each measured data point $M = N$ (rather than using the data to approximate $p(\lambda)$ via interpolation or curve fitting). What power should each laser in the collection have? The answer is that they should have the same total power as the true broadband source.

Let's use a Riemann sum approximation for the total power based on the measured data,

$$P = \int_0^\infty p(\lambda) d\lambda \approx \sum_j P'_j(\lambda_{j+1} - \lambda_j) \tag{7}$$

Therefore, the power we use for each laser in our model should be the measured power times distance between wavelengths: $P_i = P'_i \Delta\lambda$.