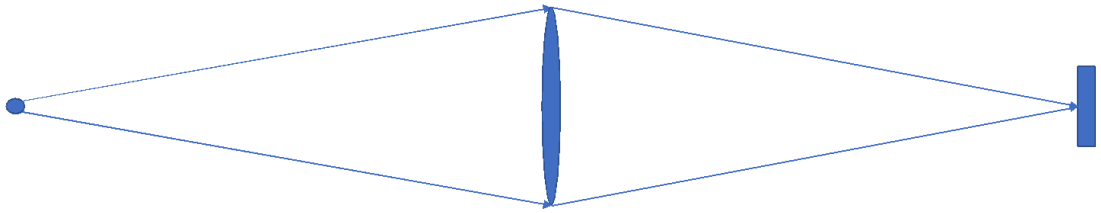
Design and Engineering of Modern Beam Diagnostics

Matlab Transverse Profile Lab

1. Optical stuff



A. Resolution

a) Diffraction

A point source is no longer a point after traversing an optical system (or any measurement system for that matter). The non-point image is the impulse response function or point spread function (PSF) in optical systems. It defines the resolution of the system. The diffraction limit is an example of a point spread function. It is the sinc function in one dimension (line source) and the Airy function in 2 dimensions (point source).

MATLAB: Point source Airy function after lens

b) Convolutions for resolution

Adding a resolution to a signal is a convolution of the signal with the PSF.

MATLAB: Convolve a gaussian signal image with the PSF from above

What are the initial FWHM/2? What's the final FWHM/2? What are the initial FWHM/2 added in quadrature?

Since the convolution of a gaussian with another gaussian is a gaussian with a variance that is the sum of the original variances, it is often sufficient to treat the PSF as a gaussian and avoid the actual convolving. Often the PSF contains several effects which when combined produce a gaussian-like distribution even if the originals were not.

c) Chromatic Aberrations

MATLAB: Change wavelength of original signal

What's the FWHM/2 of the new PSF?

MATLAB: Change the image distance by a small amount

What happens?

B. MTF vs. Resolution

1951 USAF Target



MTF stands for Modulation Transfer Function. A transfer function of some input is the convolution of that input with the impulse response function, or PSF in the case of optics. Thus, the MTF is the convolution of the PSF with a series of modulations which are usually alternating black and white lines as seen above in the infamous 1951 Air Force Target. The dimensions of the lines are usually specified as the number of line pairs per mm, i.e. how many black/white pairs in 1 mm.

We discuss this, since many optical equipment manufacturers specify their resolutions as MTFs. The problem we encounter is in the manufacturers' interpretation of what a resolution of some number of line pairs / mm means. Can they not see them anymore? Can they just barely see them? Without a specification of the contrast it is not possible to interpret.

MATLAB: Convolve various line pairs with the PSF from above

Measure the contrast for each line pair (contrast is (dark-light)/(dark+light).

MATLAB: Use the provided conversion function to convert lp to resolution

Convert your measured line pairs / contrast number to an equivalent gaussian resolution using the provided OpticalResolutions() function.

2. OTR angular distribution

OTR angular distribution in the presence of finite beam size

MATLAB: Generate OTR distribution

Generate OTR angular distribution for 200 MeV electrons. Notice the long non-gaussian tails.

Convolve with finite beam size of 0.001 (this in theta units).

Measure contrast at 0 degrees to determine beam size.

Add 10% random noise to the convolved distribution and measure contrasts for 10 samples.

3. More on Diffraction

Effect of tails on diffraction; difference between synchrotron and transition radiation.

Use Initial wavefront and run the gaussian and profile sections on it before propagating through the lens and to the image.

MATLAB: Gaussian wavefront with sigma of 1/8 the lens radius

What's the FWHM/2

MATLAB: 1/(1+x^2) wavefront with FWHM/2 of 1/8 the lens radius

What's the FWHM/2