

TECHNICAL NOTE TN-08

Problem	What is the size of image line on the target? What is spatial resolution? What is spectral resolution?	Date	8th of July 2015
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1. Introduction

Imaging spectrograph is a line scan (push-broom imaging) device. The slit selects a narrow line from the scene (object space) and this line is dispersed to spatial / spectral image on the CCD. The width of the slit defines the width of the line on the target surface. The slit width also affects the spectral resolution. Sometimes a compromise is needed between these two parameters.

2. Size of imaged line

Length (L_i) and width (W_i) of the scene line imaged at a time is determined by the slit length (L_s) and width (W_s), lens focal length (f) and distance between target and lens (D):

$$\begin{aligned} L_i &= \frac{L_s \cdot D}{f} \\ W_i &= \frac{W_s \cdot D}{f} \end{aligned} \quad (1)$$

In standard ImSpector maximum slit length is 9.8 mm and slit widths of 25 µm, 50 µm, 80 µm and 150 µm are readily available. The ImSpector Enhanced series slit length is 14.3 mm and possible slit widths are 13 µm, 18 µm, 30 µm, 50 µm, 80 µm and 150 µm.

NOTE: Magnification of the spectrograph optics is 1. Thus, if the CCD size is smaller than the slit length, the CCD spatial dimension instead of the slit length determines the length of imaged line.

Example:

In an application 23 mm focal length lens is used with 2/3" CCD camera (detector size 6.6 x 8.8 mm where 8.8 mm is the spatial axis). The spectrograph has 30 µm input slit width and measurement distance from the surface is 1000 mm. What are the dimensions of the target line?

Using equations (1) we get

$$\begin{aligned} L_i &= \frac{8.8 \cdot 1000}{23} \text{ mm} = 383 \text{ mm} \\ W_i &= \frac{0.03 \cdot 1000}{23} \text{ mm} = 1.3 \text{ mm} \end{aligned}$$

The dimension of the measured line is: length 383 mm and width 1.3 mm.

Table 1. Scene line length (L_i) and width (W_i) and field of view (θ) with different lens focal lengths (f) and distances between target and lens (D). 2/3" (8.8 mm) detector and 80 μ m slit (with other slits, W_i is directly proportional to slit width).

	f = 24mm		f = 16mm		f = 8mm	
D (m)	L_i (mm)	W_i (mm)	L_i (mm)	W_i (mm)	L_i (mm)	W_i (mm)
0.3	110	1.0	165	1.5	330	3
0.5	183	1.7	275	2.5	550	5
1.0	367	3.3	550	5.0	1100	10
	$\theta = \pm 10$ degrees		$\theta = \pm 15$ degrees		$\theta = \pm 29$ degrees	

3. Spatial resolution

Spatial resolution along the image line is determined by the camera pixel size and point spread size of the optics. Rms spot radius <30 μ m in the standard ImSpector, corresponding to MTF of 15 lp/mm. RMS spot radius of E-series is <20 μ m corresponding to 25 lp/mm. With a 2/3" detector, having 8.8 mm dimension, the point spread size limited resolution is 8800/30 $\approx$ 300 points. The number of pixels always determines spatial sampling.

Many customers do not follow these rules due to several reasons:

- Input slit also defines the along-track resolution on the target (width of the measurement line). If one needs high ground resolution a narrow slit should be used. This is not a problem in regards to sampling but one loses some energy.
- In low light level applications many customers use wide slit to gain as much energy as possible. This of course reduces spectral resolution.

4. Spectral resolution

Spectral resolution is determined either by slit width or sampling whichever is higher.

The relatively simple argument is that we convolve the point spread function (due to optics) with the slit to get the spectral broadening seen by the pixels. Then to actually resolve two peaks separated by this resolution, we need THREE pixels: one at the center of each peak and one in the middle. If we don't have the one in the middle, there's no way we can tell if we are measuring a single peak that is straddling two adjacent pixels, or two distinct peaks.