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Technical note TN-0008

Problem	**What is the meaning of throughput and transmission? What is the effect of slit width?**	**Date**	21 October 2005
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1. Introduction

To be able to calculate signal levels in critical low light level applications one should know the limiting throughput and the transmission in each component in the system. Following discussion tries to clarify these concepts in practice.

2. Problem solution

Throughput Θ

Throughput is often confused with transmission. However, throughput is strictly a geometric quantity whereas transmission is concerned with the various losses of a system caused by such factors as absorption and reflection.

Much of the value of "throughput" is embodied in the conservation of throughput principle: "the throughput of an optical system can be no greater than the lowest throughput of any aperture in the system". Thus, once we have determined the minimum (or "limiting") throughput of any optical system, we can use this value to estimate performance under various conditions.

In practice the throughput of a spectrograph (or matrix array spectrometer) is limited either by the input slit or the pixel size of the detector used whichever is smaller. To make an example let us assume the standard V10E spectrograph with 30 um wide slit and F/# 2.4. If the detector pixel size is the same as slit width (30 um square) the limiting factor is the slit and we get:

$$\Theta = A*\Omega = (0.003\ \text{cm})^2 * 0.136\ \text{sr} = 1.22 * 10^{(-6)}\ \text{cm}^2\ \text{sr}$$

where A is the area and Ω is the solid angle accepted by the spectrograph input (calculated from the F/#).

If the pixel is smaller than the width of the slit then the area A should be calculated based on this. For example: if the pixel size is 10 um square the throughput is much smaller and has the value 0.14 * 10^(-6) cm^2 sr.

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These values should be compared to other "aperture" points in the system and the smallest one should be used in calculating energy transfer.

Transmission and efficiency

The absolute transmission of a spectrograph is governed by absorption, scattering and reflection losses and the diffraction efficiency of the grating. These all are a function of wavelength so in precise analysis the wavelength dependence should also be taken into account.

In typical spectrograph the grating efficiency is more than 45-50% for most of the specified wavelengths. This is also independent on light polarization (in our transmission grating spectrographs).

Due to AR coatings the reflection losses are typically <0.008% for each individual surface inside the spectrograph. This means that the total losses are less than 15%. Absorption and scattering losses can be neglected in visible and near infrared region. However, absorption may cause 10-50% loss between 2.2-2.4 um mainly due to grating material.

3. Slit width and throughput

Slit affects three things simultaneously: a) the width of the line on the target scene, b) the optical spectral resolution of the spectrograph and c) the acquired energy per pixel. Slit width is typically a trade-off between these three things as follows:

a) If one wants the narrows possible line on the scene (best spatial resolution) then the slit width is the smallest possible and one gets less energy. The spectral resolution is good though.

b) If one wants the best possible S/N -ratio (as much energy as possible to the detector) one must use wider slit but then the spectral resolution is lower (poor) and the spatial resolution perpendicular to the slit length is low. Note that the slit width has only minor effect on the spatial resolution along the slit.

As a basic rule: if one uses twice the slit width the energy/pixel is doubled but also the spectral resolution is doubled. Thus 30 um slit allows only 37.5% of the energy to pass compared to 80 um slit.