ESTIMATE OF THE OPTIMUM MEASURING TIME IN
THE SYNCHRONOUS PHOTOMETRY OF OPTICAL
SOURCES*

(Research Note)

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Abstract. The note shows how to estimate accurately the optimum measuring time in the measurement of a periodical optical source by means of a synchronous photometer affected by phase-tracking error.

The procedure used can be easily generalized to sources or signal patterns not considered here.

The optimum number of scans to be averaged results to be typically $N_{opt} \approx 0.5 \tau/\varepsilon$ for an optical source of Lorentzian signal pattern, where $\tau$ is the duty cycle of the pulsed component and $\varepsilon$ the relative truncation error of the local sync to the source period.

1. Introduction

The measurement of a periodical component of an optical source can be made advantageously by means of a synchronous photometer. This machine coherently averages the signal by phase-locking to the source period.

The signal to noise ratio improves as the square root of the number of periods averaged as long as the phase is tracked with negligible error. If an exact tracking cannot be ensured, due to differences between the local sync and the source period, then the maximum signal to noise ratio will be obtained by a finite measuring time.

This note shows how to estimate the optimum measuring time as a function of the main parameters of the source and of the machine.

2. Computation of the Optimum Measuring Time

Let the synchronous photometer be realized by means of a photon counter connected to an $N_c$-channels digital coherent averager. The time range $R$, the single channel

width $\Delta t$ and the number of channels $N_c$ of the averager are related by

$$R = N_c \Delta t.$$  \hspace{1cm} (1)

The averager is locked to a local sync generator of period $T_{sync}$, which approximates the source period $T_0$ with a relative truncation error $\varepsilon$ given by

$$\varepsilon = 1 - \frac{T_{sync}}{T_0}.$$  \hspace{1cm} (2)

Let the signal be a train of pulses of Lorentzian shape superimposed to a constant background, as shown in Figure 1.

Due to the weak dependence of the results on the signal pattern this model is fairly accurate for a variety of sources, while giving, in any case, a first order solution.

The signal $S(t)$ within one period is given by

$$S(t) = S_0/(1 + ((t - t_0)/w)^2) + B_0 \text{ (counts s}^{-1}),$$  \hspace{1cm} (3)

where $S_0$ is the peak signal, background-free, $t_0$ is the phase of the maximum, $w$ is the pulse half-width and $B_0$ is the background. The full signal pattern is then characterized by the duty-cycle $r$ given by

$$r = 2w/T_0.$$  \hspace{1cm} (4)

The peak signal to noise ratio $\varphi_N$ after averaging coherently $N$ periods is given by

$$\varphi_N \approx \max \left( \sum_{k=0}^{N-1} \int_{(j-1)\Delta t}^{j\Delta t} \frac{(S_0/(1 + ((t + kD - t_0)/w)^2)) \text{ dt}}{(2NB_0\Delta t)^{1/2}} \right), \hspace{1cm} (j = 1, N_c)$$  \hspace{1cm} (5)

where $D$ is the phase drift over a single scan of the range $R$ which includes one period, as given by

$$D = 2\varepsilon T_0.$$  \hspace{1cm} (6)

The actual $\varphi_N$ must be normalized to the theoretical, drift-free peak signal to noise.

**Fig. 1.** Model of the signal pattern of an optical source showing a periodical component super-imposed to the background.