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LETTER TO THE EDITOR

Comment on the letter by Jakeman *et al* 'Correlation of scaled photon-counting fluctuations'

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Recently Jakeman *et al* (1972) and Koppel and Schaefer (1973) have presented a method for measuring the full photocount correlation function which might be called single channel scaling (SCS). The advantage of SCS is that it can be used in conjunction with a clipped correlator (see review by Pike 1972) to measure directly the full photocount correlation rather than the clipped correlation function.

By its definition the full photocount correlation function can be represented as an infinite sum over all the separate clipped photocount correlation functions in the following way:

$$\langle n(t_1)n(t_2)\rangle = \sum_{k=0}^{\infty} \langle n^{(k)}(t_1)n(t_2)\rangle. \tag{1}$$

In practice, however, if $\langle n\rangle$ is not too large the clipped correlation functions with larger k values contribute only very small corrections to the infinite sum in (1). For instance, when $\langle n\rangle = 1$ a finite sum over all the clipping levels $k \leqslant 6$ will represent the true correlation function within an accuracy of 1% for gaussian light. Such a finite summing can be achieved experimentally by uniformly and randomly clipping with k values chosen in a pseudo-random fashion between 0 and l as noted by Jakeman *et al* (1972). While it is not hard electronically to implement the pseudo-random clipping, a simpler but an approximate way of achieving the same end is to use the SCS as was shown by Jakeman *et al* (1972).

In this letter we wish to point out an equally simple way of performing the same measurement and finite sum by uniformly and sequentially clipping (USC) incoming photocounts. With this method one simply clips sequentially from some maximum clipping level $k = l$ during each of $l+1$ sampling periods, then starts over again at $k = l$. In this way the uniformity of the sampling is automatically ensured and can therefore be used as a technique to test experimentally the clipping uniformity of SCS. We performed an extensive set of measurements using both SCS and USC over a wide range of scaling and sequential clipping levels and found both methods lead to exactly equivalent results.

Denoting N as the total number of samplings made during the measurement we can then give the content of the channel corresponding to the delay time τ as:

$$\langle G\rangle = \frac{N}{l+1}\sum_{k=0}^{l} \langle n^{(k)}(0)n(\tau)\rangle \simeq \frac{N}{l+1} \langle n(0)n(\tau)\rangle. \tag{2}$$

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For sufficiently large l the higher order terms $\Sigma_{k=l+1}^{\infty}\langle n^{(k)}(0)n(\tau)\rangle$ will be negligible. For gaussian light this condition is met when $(\langle n\rangle/1+\langle n\rangle)^{l+1} \ll 1$.

We have constructed a variable length (up to $l = 15$) USC gate using a presettable four-bit binary counter and the associated sequential presetting circuits (the circuit is available upon request). Using this USC gate and a similarly made variable length scaler, we ran an experiment in which we measured light scattered by 1 μm polystyrene spheres in methanol at an angle of 40°. We performed measurements at maximum clipping levels $l = 1, 5, 10$ and 15 for USC and at the corresponding scaling values $s = 2, 6, 11$ and 16 for SCS. The fitted linewidths in all cases agree to within 1% of the value $\Gamma = 60\ s^{-1}$. Moreover, since in this case we were dealing with a gaussian light it was possible to evaluate the correction to the measured correlation function. The corrected correlation functions were found to agree to a high degree of accuracy with the full correlation function in both cases (see equation (9) of Jakeman *et al* 1972).

In conclusion, we have demonstrated that the incorporation of a USC gate in a clipped photocount correlator allows one to measure the full photocount correlation function. The circuit is as simple as the scaling circuit and the 'uniformity' condition required in (1) is automatically satisfied without requiring any theoretical justification. Furthermore, the experimental results show that for the case of gaussian light USC is fully equivalent to the scheme of scaling.

References

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Authors' reply

We agree with the above comment on our paper that choice of clipping levels in a regular sawtooth fashion (USC) provides a uniform distribution, and hence partially satisfies the requirement for achieving full correlation of an optical signal with one-bit processing. We had, in fact, considered such a simple scheme ourselves, but had discarded it since synchronization of a signal frequency with the sawtooth frequency can occur, with distorted output as a result. Since neither scaling nor uniform sequential clipping is particularly hard to implement, it seemed to us that scaling, which does not have a deficiency with respect to synchronous signals, was the best approach. The comments of Tartaglia *et al* have not changed our views on this matter. In fact, their experimental results, showing no advantage for USC over SCS for nonperiodic signals, strengthen the claim that SCS is the more useful method for general application.

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