Comment on "Measurements of Higher Order Photon Bunching of Light Beams"

Qu, Singh, and Cantrell [1] describe a two-photon detection scheme used to measure three and four photon correlations in a light beam and claim the superiority of this technique over earlier ones [2,3] used for exploring the structure of intensity correlation function of the laser near threshold. We point out limitations of the technique which dilute their claims. Since the field under consideration has been laser near threshold, we define our quantities in the following manner.

From the Fokker-Planck equation for the laser field in the steady state, the joint probability density $p_3(v_1, t; v_2, t + \tau; v_3, t + \tau')$ for the field to have complex amplitudes v_1 at t, v_2 at $t + \tau$, and v_3 at $t + \tau'$ is given by

$$p_3(v_1, t; v_2, t + \tau; v_3, t + \tau') = p_1(v_1) G(v_2, v_1, \tau) \times G(v_3, v_2, \tau' - \tau),$$

where $p_1(v)$ is the probability density for the field at any time and $G(v_1, v_2, \tau)$ is Green's function for the process.

Following [2], we get

$$p_3(t, t+\tau, t+\tau') dt\, dt\, d\tau' = \alpha c S \langle I(t) I(t+\tau) \times I(t+\tau') \rangle dt\, d\tau\, d\tau',$$

where α is the quantum efficiency of the detector and S its illuminated surface area. It is therefore clear that by repeated recording a pair of time intervals τ, τ' we can obtain a complete third order intensity correlation function $k(\tau, \tau')$. This was the basis for the correlator mentioned in Ref. [3].

However, Ref. [1] describes a scheme that involves the measurement of auto correlation and cross correlation function of second harmonic (SH) and its fundamental field in order to measure third and fourth order correlation functions, viz.,

$$C(\tau) = \frac{\langle I_2(t) I(t + \tau) \rangle}{\langle I_2(t) \rangle \langle I \rangle} = \frac{\langle I^2(t) I(t + \tau) \rangle}{\langle I \rangle^2 \langle I \rangle}$$

and $G(\tau) = \langle I_2(t) I_2(t + \tau) \rangle / \langle I_2 \rangle^2$, since SH intensity $I_2 = \text{const} \times I^2(t)$.

To explore complete dynamics in a system one needs to measure $k(\tau, \tau')$ and not $C(\tau) \equiv k(0, \tau')$ which provides only a partial measurement of third order intensity correlation function. Even for the laser system Cantrell, Lax, and Smith [4] have calculated theoretically $\lambda(\tau, \tau')$ the third order intensity correlation function for its operation near threshold. Therefore $C(\tau)$ provides us with incomplete dynamics of the system and only partial structure of the third order function and similarly for the fourth order intensity correlation function. This is because in SH signal two photons arrive simultaneously and it is only the third photon which provides the functional delay. There is no way in this technique where the dynamics of the first two photons can be studied with respect to the third, therefore giving rise to incomplete correlation function, or, in broader terms, it becomes a special case of earlier measurements. The advantage which this technique provides is a considerable reduction of dead time only in the detection of the first two photons which have to arrive almost simultaneously for the SH signal, but then the signal is reduced considerably.

This technique of SH cannot be used for the measurement of second order intensity correlation function which is most widely measured in experiments with fluctuating signals. There are hardly any known systems apart from laser near threshold where third or fourth order intensity correlation function measurements have been carried out.

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