Spontaneous parametric down-conversion using a pulse train

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The exponential faster speed of quantum computers over their classical counterparts has motivated several research areas in quantum computation and quantum information processing (QIP) in recent years. The key to success for QIP is the entangled states. Usually spontaneous parametric down-conversion process (SPDC) in second-order nonlinear crystal is used for generating entangled states. SPDC has been extensively studied for the case of continuous wave pump as well as single pump pulse. In this work we study the effect of a train of pump pulses on degenerate collinear type-II SPDC and degenerate collinear type-I SPDC processes. We assume that signal and idler photons are degenerate, having the same central frequency. In the type-II case, the pair of photons produced is orthogonally polarized but we will study the case of collinearly produced pairs.

The down-conversion process can be described by the following interaction Hamiltonian [1]

\[ H_{\text{INT}} = \frac{2}{3} \epsilon_0 \int dV \chi E_s E_i E_p, \]

in which \( \chi \) is the nonlinear susceptibility tensor and the integral is over the volume of the sample. The signal (\( E_s \)) and idler (\( E_i \)) fields are considered to be quantized while pump field (\( E_p \)) is classical and linearly polarized propagating in the \( z \)-direction. The electric field \( E_p \) for the pulse train with repetition rate \( T_R \) and central frequency \( \Omega \) used for the pump is given by [2]

\[ E_p = \sum E(t - NT_R)e^{iN\Delta \Psi} = [ \sum E(t - NT_R)e^{iN\Phi}]e^{i\Omega t} = \epsilon_{T}(t)e^{i\Omega t}. \]

The effects of number of combs on the coincidence probability (\( R_C \)) of detecting signal and idler photons, plotted in Figs. 1 and 2 for type-II and type-I SPDC, respectively, are given below. This work will provide guidelines for the SPDC process in experiments.

![Graph showing coincidence counting rate as a function of τ/DL for different numbers of comb tooth (M) in type-II SPDC.](attachment:image1.png)

**Fig. 1** Plot of coincidence counting rate (\( R_C \)) as a function of \( \tau/D_L \) for different numbers of comb tooth (M) in the pulse train for type-II SPDC. Curves A, B, C, and D, are for \( M = 0, 1, 2 \), and 3, respectively [2].

![Graph showing coincidence counting rate as a function of τ²/D"L for different numbers of comb tooth (M) in type-I SPDC.](attachment:image2.png)

**Fig. 2** Plot of coincidence counting rate (\( R_C \)) as a function of \( \tau^2/D''L \) for different numbers of comb tooth (M) in A, B, C, and D, are for \( M = 0, 1, 2 \), and 3, respectively [2].

References: