FORMULAS

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The effect of 2PA can be quantified by 2PA cross section δ , which is defined by using the following form of the propagation equation for a beam of wavelength λ and angular frequency w incident on a 2PA material:

$$\frac{d\phi}{dz} = -\sigma N_g \phi - \delta N_g \phi^2 \longrightarrow \phi = \frac{I}{E_{ph}}$$

$$\frac{dI}{dz} = -\sigma N_g I - \frac{\delta}{E_{ph}} N_g I^2$$

SPDC - Chirp
Entangled photon pairs produced in a non linear crystal of length L, pumped by an intense laser pulse with tunable spectral properties has a quantum state

$$|\Phi\rangle = -\frac{i}{\bar{h}} \int_0^L dz\ \hat{G}(z)\,|vac\rangle \rightarrow \hat{G}(z) = 4\epsilon_0 A \int_\infty^{-\infty} dt\ \chi^{(2)} \varepsilon_p^{(+)}(z,t)\ \hat{E}_s^{(-)}(z,t)$$

The pump electric field amplitude is given $\varepsilon_p^{(+)}(z,t)$:

$$\varepsilon_p^{(+)}(z,t) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} dw_p e_p(w_p) e^{-i(w_p t - k_p z)}$$

And the pump spectrum $e_p(w_p)$ is characterized by the chirp ξ_p:

Entangled photons in a twin beam are described by the filed operator:

$$\hat{E}_j^{(+)}(z,t) = \int dw_j \sqrt{\frac{\bar{h}w}{2\pi c A_q n_j}}\, \hat{a}_j(z,w_j) e^{-i(w_j t - k_j z)} \rightarrow j = s,i$$

$$\hat{H}_I(t) = \hat{\mu}(t)E^{(+)}(t) \rightarrow E^{(+)}(t) = E_s^{(+)}(t+\tau) + E_i^{(+)}(t)$$

TPA

We assume that the medium is in ground state $|g\rangle \rightarrow \epsilon_g$ and is exited to the state $|f\rangle \rightarrow \epsilon_f$ by TPA process. Then the probability the medium is exited to this final state is:

$$P_{g\rightarrow f} = \int_{-\infty}^{\infty} dt_2 \int_{-\infty}^{t_2} dt_1 \int_{-\infty}^{\infty} dt_2' \int_{-\infty}^{dt_2'} dt_1' M^*(t_1,t_2)\ G^{(2)}(t_2,t_1:t_2',t_1')\ M(t_1,t_2)$$

$$G^{(2)}(t_2,t_1:t_2',t_1') = \langle \hat{E}^{(-)}(t_2)\ \hat{E}^{(-)}(t_1) \times \hat{E}^{(+)}(t_2')\ \hat{E}^{(+)}(t_1')\rangle$$

$M(t_1,t_2)$ describes the response of the medium to the applied fields:

$$M(t_1,t_2) = \sum_j \frac{\mu_{fj}\mu_{jg}}{\hbar}\ exp[\ i(\epsilon_f - \epsilon_j)t_2 + i(\epsilon_j - \epsilon_g)t_1\ ]$$

where μ_{fj} , μ_{jg} are the transition matrix elements of the dipole-moment operator between the states specifide in the subscript.

96. $\left[\dfrac{x^{10}}{10y^3z^4}\right] =$