Polling period and temperature dependence of lithium niobate on tunability of biphoton generation

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***Abstract*—Biphoton generation with spontaneous parametric down conversion (SPDC) process has applications in quantum imaging and sensing. Simulations have been done on periodically poled lithium niobate (PPLN) crystals with varying polled period. The poled period has been varied from 20.6 μm to 23.3 μm. The pump wavelengths have been selected in the range of 750 to 850 nm. The variations in temperature and the poled grating facilitate the generation of tunable entangled photon pairs from 1100 nm to 3200 nm.**

SUMMARY

The down-conversion efficiency of periodically poled lithium niobate (PPLN) crystal is reported to be higher than that of a single crystal. The Sellmeier equation shown in Eq. (1) can be used for temperature-dependent refractive index simulations [1], [2].

$$n_e^2 = a_1 + b_1 f + \frac{(a_2 + b_2 f)}{\lambda^2 - (a_3 + b_3 f)^2} + \frac{(a_4 + b_4 f)}{(\lambda^2 - a_5^2)} - a_6 \lambda^2, \quad (1)$$

Here $a_1, a_2, a_3, a_4, a_5, a_6, b_1, b_2, b_3$ and b_4 are constants and f is the temperature dependent parameter given by $f = (T - 24.5^o C)(T + 570.82)$. These constants have been determined in [1]. The quasi phase matching (QPM) condition for the PPLN crystal is achieved by satisfying the following equation:

$$\frac{(n_e(\lambda_p, T))}{\lambda_p} - \frac{(n_e(\lambda_s, T))}{\lambda_s} - \frac{(n_e(\lambda_i, T))}{\lambda_i} - \frac{1}{\Lambda} = 0, \quad (2)$$

where Λ represents the PPLN period lengths, p, s, and i stand for the pump, signal, and idler, respectively, and n_e is the extraordinary polarized wave's refractive index.

The plots in fig. 1 show the observed variation of the signal and idler wavelengths as a function of the polling-period of PPLN. The wavelength of the signal varied from 1100 nm to 1600 nm and that of the idler from 1600 nm to 3200 nm. The entangled photons in the telecom wavelength range, which is typically around 1550 nm, are suitable for applications in quantum communication such as quantum key distribution (QKD) [3]. For an 800 nm pump, degenerate signal and idler photons occur at a grating length of 20.37 μm at 300K and 20.24 μm at 330K.

The temperature of PPLN can be adjusted (see fig. 1) to alter the phase-matching conditions, periodicity of the grating in the crystal, and the wavelength of the down-converted photons. This also helps vary the range of photon wavelength. The pump wavelength of 800-nm is suitable for PPLN in spontaneous parametric down-conversion (SPDC) as it maximizes the nonlinear efficiency.

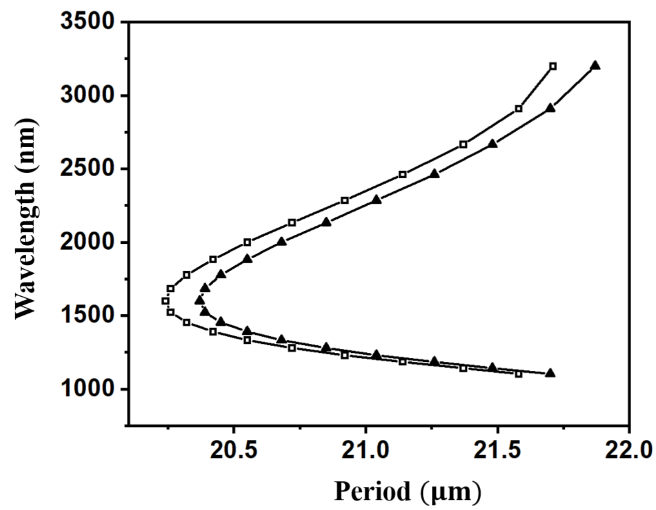

Fig. 1. SPDC wavelength tuning curves for PPLN at 300 K (filled delta) and 330 K (open squares) using an 800 nm pump wavelength

From Table 1, we see that at 20.37 μm, the signal and idler are degenerate at 1600 nm, wavelength suitable for variety of applications such as quantum imaging, quantum sensing and quantum teleportation [4].

TABLE I
TYPICAL WAVELENGTHS OF TWIN PHOTONS AND PERIOD LENGTH OF PPLN FOR 800 NM PUMP AT T = 300K.

Signal wavelength (nm)	*Idler wavelength (nm)*	*Period (μm)*
1067	3200	21.87
1333	2000	20.68
1600	1600	20.37
1523	1684	20.39
1454	1777	20.45
1391	1882	20.55

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