The analysis of photon pair source at telecom wavelength based on the BBO crystal

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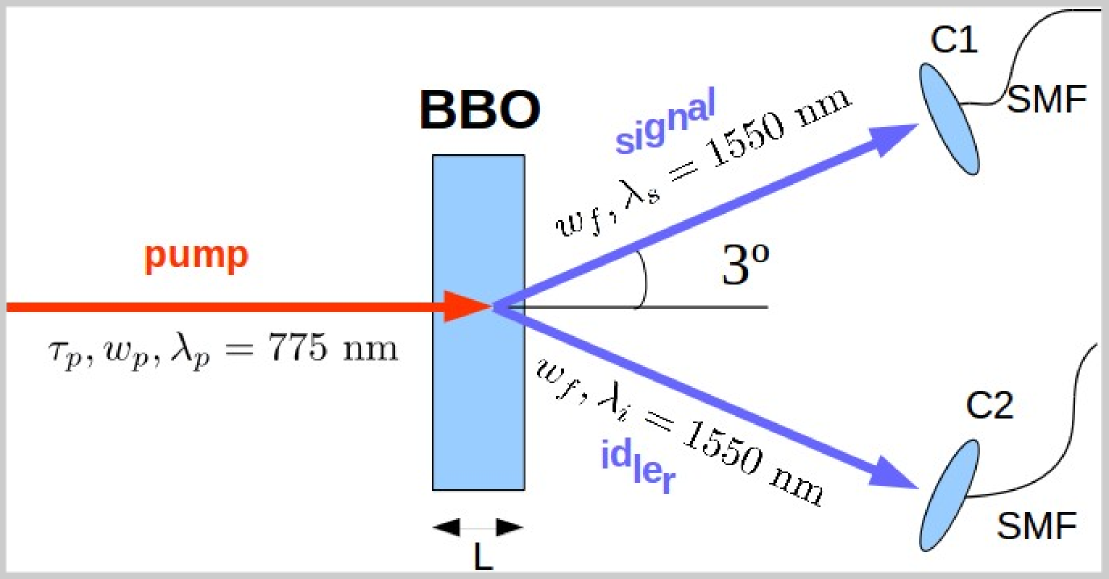
The aim of research (numerical simulation).

Our research was conducted in order to provide quantum optics researchers with „recipe" of how to design fiber coupled single pair photon source based on β-barium borate (BBO) which will match their experimental needs i.e high **coupling efficiency** for long distance quantum communication, **spectrally uncorrelated** photon pairs for quantum optics, or **positively correlated** photon pairs for reduction of **chromatic dispersion** effect[1,2]. We also provide insight into physics behind fiber coupled SPDC sources.



Experimental setup

A single photon source is based on a BBO crystal of thickness L cut for type II phase matching at frequencies 755nm 1550nm + 1550nm and half cone opening angle 3 deg. A pump pulse of **τp** duration is centered around 775nm and its transverse spatial mode is assumed to be a Gaussian function with a characteristic diameter 2**wp**. The photon pairs are coupled into single mode fibers (SMF), which together with coupling stages (C1,C2) define a collected transverse spatial modes, which are assumed to be a Gaussian functions of diameters 2**wf**.

Source Description

We describe our source with three parameters.

- Pair production rate Rc (brightness)

$$R_c = \int d\omega_s d\omega_i \, |\Psi(\omega_s, \omega_i)|^2.$$

- Coupling efficiency η

$$\eta = R_c/\sqrt{R_s R_i}.$$

- Spectral correlation (described by Pearson parameter)

$$r = \frac{\langle(\omega_s - \omega_0)(\omega_i - \omega_0)\rangle}{\sqrt{\langle(\omega_s - \omega_0)^2\rangle\langle(\omega_i - \omega_0)^2\rangle}}.$$

Analytical model

The biphoton wave function of such a source is a product of an effective phase matching function Θ(ωs,ωi) and a temporal pump function [3]:

$$\Psi(\omega_s, \omega_i) = A_p^{\text{temp}}(\omega_s + \omega_i)\Theta(\omega_s, \omega_i).$$

Effective phase matching function cannot be evaluated analytically due to its complicated form. It depends on length of crystal (L) and spatial modes diameters of pumping beam (2wp) and collective optics (2wf), where pump function only on pulse time duration (**τp).**

Numerical simulation

Numerical calculations were performed for 2.5, 5 ,7.5 mm long crystals, and for 50, 100, 150 fs long pumping pulse. For each combination of crystal length and pulse duration full analysis (in range 20 to 500 μm.) of influence on source performance of pumping beam diameters and collective beam diameters was performed.

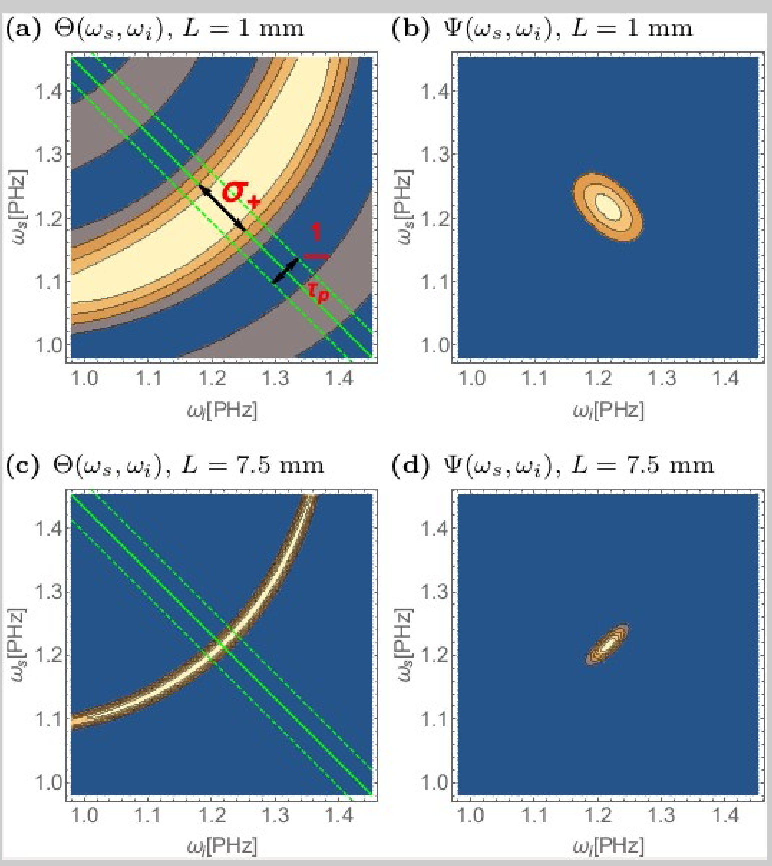
RESULTS

Spectral correlation

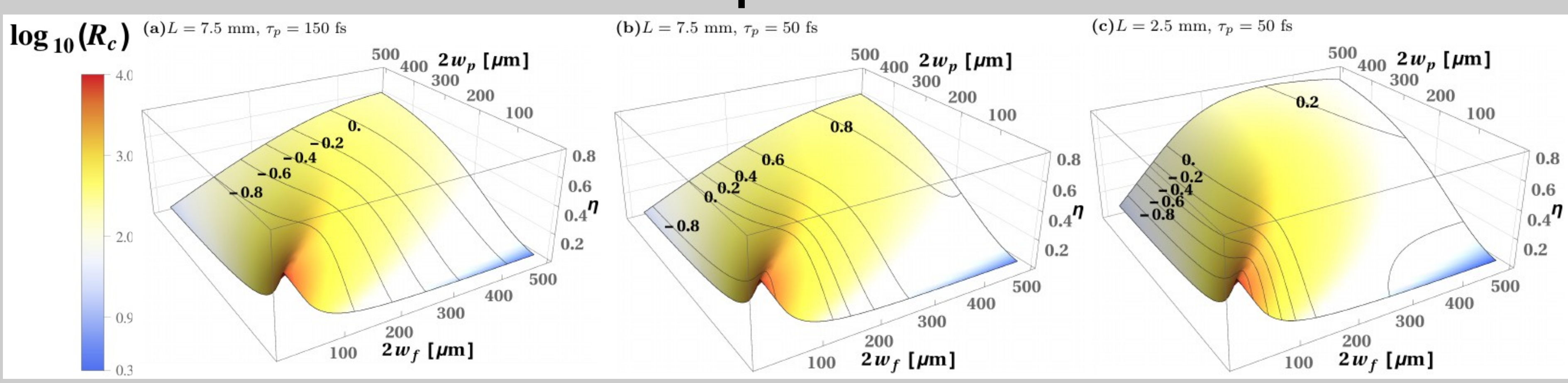
Simplified analytical formula for correlation parameter:

$$r = \frac{1 - \tau_p^2\sigma_+^2}{1 + \tau_p^2\sigma_+^2}, \sigma_+^2 = \frac{1}{\beta^2}\left(\frac{2d_x^2}{w_f^2} + \frac{5}{L^2}\right).$$

Ilustration of negative and positive correlation



Source performance



Each of the graphs represent possible characteristics of source based on BBO crystal of a given length and time pulse duration (50fs and 150fs for 7.5mm crystal, and 50fs for 2.5mm crystal).

- **Coloring: brightness(Rc)**
- **Contours: spectral correlation (r)**
- **Height: coupling efficiency (η)**

Bibliography

[1] T. Lutz, P. Kolenderski and T. Jennewein, Opt. Lett., 38(5), 697 (2013)

[2]T. Lutz, P. Kolenderski and T. Jennewein Opt. Lett., 39(6), 1481 (2014)

[3]P. Kolenderski, W. Wasilewski, K. Banaszek,Phys. Rev. A, 80(1), 013811 (2009)

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