Thick-crystal regime in photon pair sources: supplementary material

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Published 18 March 2016

This document provides supplementary information to “Thick-crystal regime in photon pair sources,” <http://dx.doi.org/10.1364/optica.3.000347>. © 2016 Optical Society of America

<http://dx.doi.org/10.1364/optica.3.000347.s001>

A. Losses in the dichroic mirror

The measured transmission spectrum of the dichroic mirror used to split the signal and idler beams (FF801-DiO₂, Semrock, denoted DM2 in Fig. 1) is plotted in Fig. S1. The cut-off is centred at 801 nm and has a width of roughly 15 nm. As our signal and idler spectra are centered on 810 nm and imperfectly separated (Fig. 2b), the finite width causes some of the incident photons to be misdirected. As this effect occurs primarily for shorter wavelengths, we treat this approximately by assuming only signal photons are affected. This enables us to model the element as the combination of a perfect dichroic mirror and a partially reflecting mirror placed in the signal arm (Fig. S2).

Fig. S1. Transmission spectrum of the dichroic mirror (FF801-DiO₂, Semrock). We also plot the simulated joint spectrum for a 5.35 mm BBO crystal with collection over a 0.3° solid angle, with the loss due to misdirected photons indicated.

We denote the system transmission efficiency of the signal and idler photons up to the dichroic mirror as η_s and η_i respectively, and the transmission coefficient of our model's partially reflecting mirror η_d . The corresponding modified values of the coincidence rate C and the single photon rates S_i and S_s are denoted C' , S'_i and S'_s . We also consider a “true rate” of photons

Fig. S2. A model for the effect of the dichroic mirror on the observed single photon rates.

S_T , and identify the single photon rates with

$$S_i = \eta_i S_T; \quad S_s = \eta_s S_T. \quad (\text{S1})$$

Considering the observed coincidences in these terms,

$$C' = \eta_s \eta_d \eta_i S_T, \quad (\text{S2})$$

we can form an expression for the system transmission efficiency η_i and show that it is independent of the value of η_d :

$$\eta'_i = \frac{C'}{S'_i} = \frac{\eta_d C}{\eta_d S_s} = \frac{C}{S_s}. \quad (\text{S3})$$

The observed value of η_s will be affected. While the coincident rate C' is reduced compared to C , the single photon rate S'_i will be boosted by the arrival of misdirected signal photons. These will only trigger an event when the corresponding idler photon is not present, and we ignore the slight increase in detection probability when both are present to write

$$S'_i = S_i + (1 - \eta_d)(1 - \eta_i)\eta_s S_T. \quad (\text{S4})$$

Taking this into account, we arrive at the following expression for η_s

$$\eta_s = \frac{C}{S_i} = \frac{C'}{\eta_d S'_i - (1 - \eta_i)(1 - \eta_d) S'_s}. \quad (\text{S5})$$

By evaluating the magnitude of the misdirected signal as a

fraction of the calculated spectrum (see Fig. S1), we can quantify this effect. With $\eta_d \approx 0.91\%$ and all other parameters measured, we arrive at a revised system efficiency for η_s of 34%. The highest observed value for η_s was $33.6 \pm 0.4\%$, indicating near unit efficiency for the overlap of the signal photons with the fiber collection mode.