Influence of fibre homogeneity on Four Wave Mixing pairs generation

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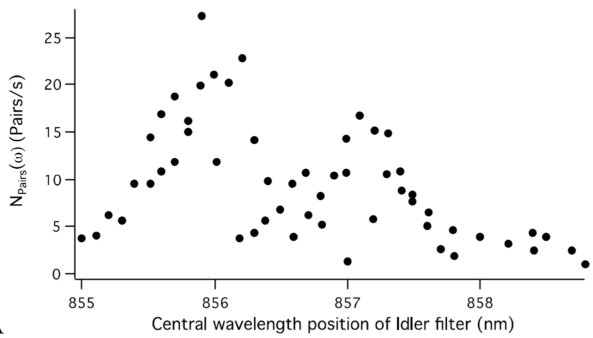
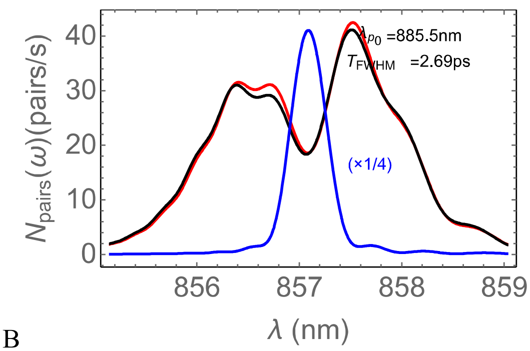
Optical fibre (either classical or microstructured) is a preferential media for realization of sources of entangled photons for quantum communications. Indeed the photon pairs are generated through spontaneous Four Wave Mixing (FWM) directly in the fibre core and can thus be connected easily and without loss to the optical telecommunication network.

The quality of the emitted pairs of photon is thus a crucial point for the realization of such sources. One major drawback of the source realized with silica core fibres is the concomitant emission of uncorrelated Raman photons with the desired pairs. This problem can be solved using a new fibre architecture based on hollow core photonic crystal fibres (HC-PCF) filled with a nonlinear liquid or a gas [1]. This architecture benefits from the fact that the liquids, contrarily to amorphous solids such as silica, present a narrow Raman line spectrum, allowing to easily separate the parametric FWM emitted photons from a majority of Raman lines.

We have realized such a source and characterized its performances. Yet, recent measurements showed a photon pair generation rate lower than expected. Further characterization showed, as it can be seen in Fig. 1A, a widened pair spectrum and a diminution of the generation rate compared to the prediction of our model (Fig. 1B) [2]. Such features can be explained by taking in account the intrinsic inhomogeneity of the fibre, i.e. the core and cladding dimensions fluctuation along the fibre. Indeed, a small variation of the fibre diameter implies a slightly different dispersion, hence shifted photon pair frequencies. To depict these uniformities, we extended our model through a similar approach than in Ref. [3], considering the fibre as an assembly of homogeneous sections, each one with its own length and phase mismatch. Consequently, the joint spectral intensity of pairs describing their generation probability for a given couple of frequencies will be more complex. In Fig. 1B, we show the result of our numerical simulation for a purely uniform fibre with parameters corresponding to our source [1,2], and in the case of a linear variation of the zero dispersion wavelength along the fibre. In this specific case, a new analytical solution that will be presented, can be derived from our model, and is also shown in Fig. 1B as a comparison.



A



B

Fig. 1 (A) Experimental measurement of the generation rate of pairs of photons emitted by a HC-PCF filled with acetone-d6 used in [1]. (B) Calculation of the generation rate of emitted pairs in a fibre exhibiting a linear variation of the zero dispersion wavelength of -1nm between the input and output, using the analytical model (red curve) and the piece-wise integration for 50 steps (black curve). The result for a uniform fibre (divided by a factor 4) is shown for comparison (blue curve).

This study suggests that photon pair generation can be highly dependent on local variation of fibre dimension, as a fluctuation of the cladding pitch as low as 0,1% causes a significant broadening of the emission peak and a reduction of emitted pairs number.

Beyond the case of the fibre we have studied experimentally, we will present the different models (numerical and analytical) that may be used to describe the influence of various type of inhomogeneity (random or deterministic) in different kind of waveguide structures (fibre or planar waveguide) used for photon pair generation.

References

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