Two-color narrowband photon pair source with high brightness based on clustering in a monolithic waveguide resonator

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The future of quantum communication relies on sophisticated sources of single photon pairs which feature high brightness, narrow spectrum and excellent purity. For practical realizations, stable, miniaturized, low-cost devices are required, especially for addressing the absorption line of the storage medium in a quantum memory with one photon and transmit the second over a fiber network.

One promising approach to generate such narrowband pairs is to use resonance enhancement of parametric down-conversion (PDC) within a cavity. Here we report on an integrated non-degenerate narrowband photon pair source via type II PDC in a Ti-indiffused periodically poled lithium niobate (Ti:PPLN) waveguide with high-reflective dielectric mirrors deposited on the waveguide end faces [1]. In the doubly resonant waveguide, the material dispersion results in different free spectral ranges for signal and idler. As maximum enhancement is only obtained if both signal and idler are resonant simultaneously, PDC is generated only in certain regions of the spectrum, so called ‘clusters’, shown as Fig. 1.

The conversion spectrum in single-photon level consists of three clusters and only 3 to 4 longitudinal modes with about 150 MHz bandwidth in each cluster. The high conversion efficiency in the waveguide, together with the spectral clustering in the double resonator, leads to a high brightness of $3 \times 10^{3}$ pairs/(s·mW·MHz), typically 2 to 3 orders of magnitude more efficient than in bulk crystals. The compact and rugged monolithic design makes the source a versatile device for various applications in quantum communication.

![Figure 1: (a) An integrated doubly resonant waveguide with poling period of $\Lambda = 4.44 \, \mu m$. (b) The actual device compared to a one cent euro coin (16.25 mm diameter). (c) Clustering effect. Photon pair generation by PDC obeying energy conservation and phase-matching (green dashed curve) occurs only if signal and idler are resonant simultaneously. Thus, the product of the two frequency combs (red and blue) and the phase-matching determines the spectrum of the resonant PDC source.](image-url)