Characterization of the Joint SpectrumProduced by a PPKTP Crystal

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Abstract

Efficient generation of correlated photon pairs is essential for the development of technologies in quantum communication and computing. In this work, we investigate the generation of photon pairs via the process of Spontaneous Parametric Down-Conversion (SPDC) using a periodically poled Potassium Titanyl Phosphate (PPKTP) nonlinear crystal. This material was chosen due to its high nonlinear coefficient d_{33}, excellent thermal stability, and its ability to implement quasi-phase matching (QPM) through periodic inversion of its ferroelectric domains. These properties make PPKTP a highly efficient and versatile medium when compared to traditional birefringent crystals like BBO. A theoretical framework based on quantum and semiclassical descriptions of SPDC was developed to analyze how the periodic poling compensates for phase mismatch, allowing for constructive amplification of the generated field. Experimentally, we measured the joint spectrum and the second-order correlation function $g^{(2)}(0)$of the photon pairs emitted by the PPKTP crystal under different temperature conditions. The results show clear frequency correlations consistent with type-0 phase matching and a significant improvement in the pair generation efficiency, in agreement with the expected QPM behavior. These results confirm that PPKTP crystals constitute a bright and tunable source of correlated photons, ideal for applications in entangled two-photon absorption (ETPA) and other quantum optical experiments that require high flux and spectral control.

Theory of Spontaneous Parametric Down-Conversion (SPDC)

Polarization vector

$$\vec{P} = \chi^{(1)}\vec{E} + \chi^{(2)}\vec{E}\vec{E} + \chi^{(3)}\vec{E}\vec{E}\vec{E} + \ldots$$

Interaction Hamiltonian

$$H = \epsilon_0 \int_V d^3r\, \chi^{(2)}_{ijk} E_i E_j E_k$$

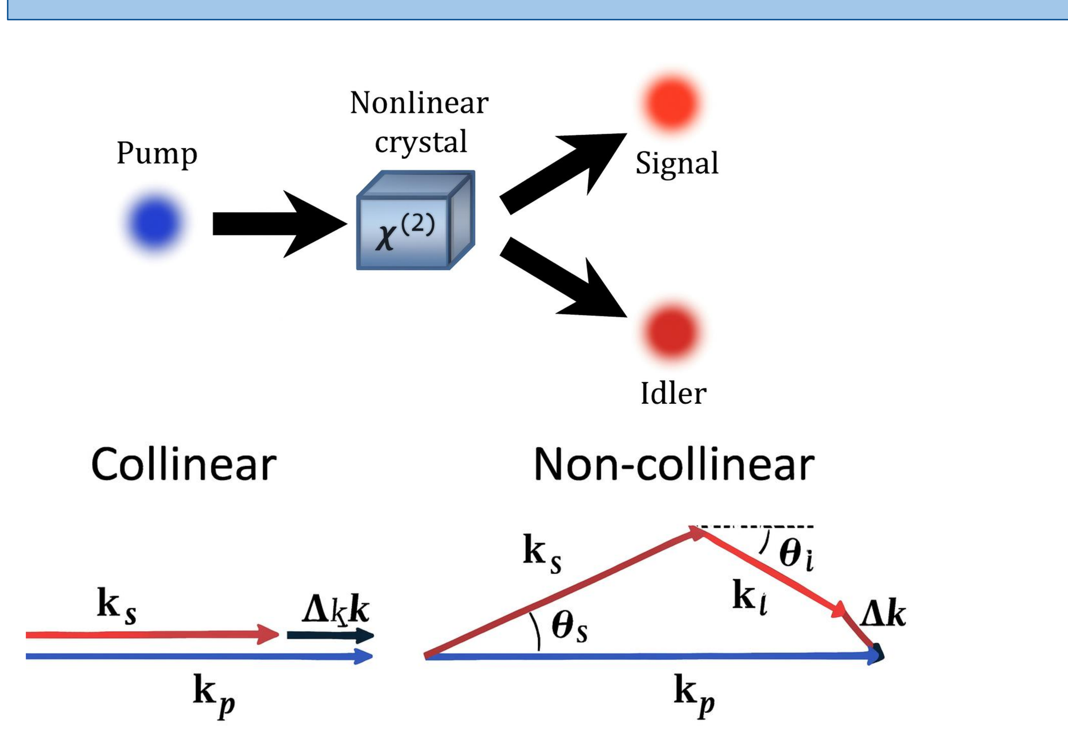
Spectral and angular distribution of the generated pairs

$$\phi(\Delta k_L) = \int_{-L/2}^{L/2} dz\, e^{i\Delta k_L z} = L\,\mathrm{sinc}\left(\frac{\Delta k_L L}{2}\right) e^{i\Delta k_L L/2}$$

Entangled Two-Photon State in SPDCV

$$|\psi\rangle = A_0 \int d^3\vec{k}_s\, d^3\vec{k}_i\, \delta(\omega_s + \omega_i - \omega_p)\, \delta(\vec{k}_s + \vec{k}_i - \vec{k}_p)\, \phi(\Delta k_L)\, \hat{a}^\dagger_{\vec{k}_s}\, \hat{a}^\dagger_{\vec{k}_i}\, |0\rangle$$

Phase Matching and Quasi Phase Matching



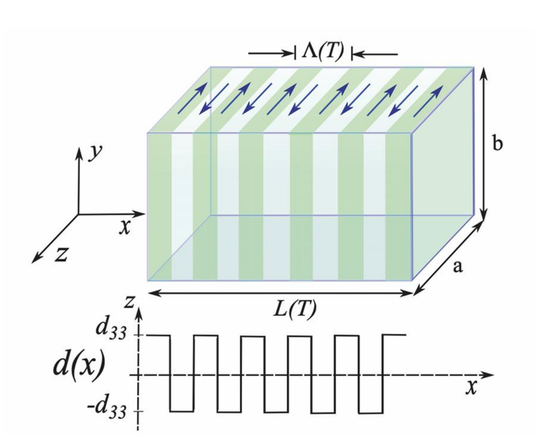
Phase matching condition

$$k_p = k_s + k_i$$

For collinear propagation

$$\frac{n_p(f_s+f_i)}{c} = \frac{n_s f_s}{c} + \frac{n_i f_i}{c}$$

PPKTP: Periodically Poled Potassium Titanyl Phosphate for Efficient Photon Pair Generation

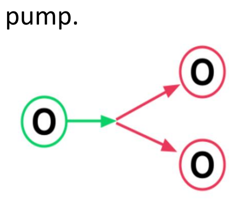


PPKTP is a nonlinear crystal used for efficient photon pair generation in SPDC. Its high d_{33} coefficient and ability to implement quasi-phase matching (QPM) make it ideal for quantum applications.

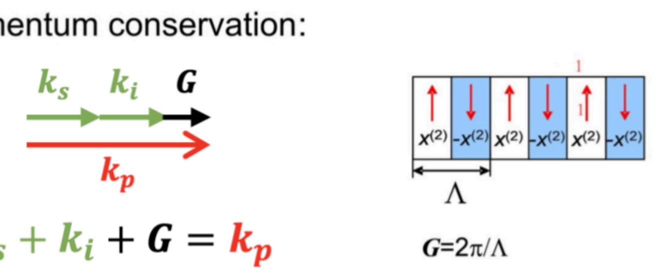
$$L_{\mathrm{coh}} = \frac{\pi}{|\Delta k|}$$

Type 0 SPDC

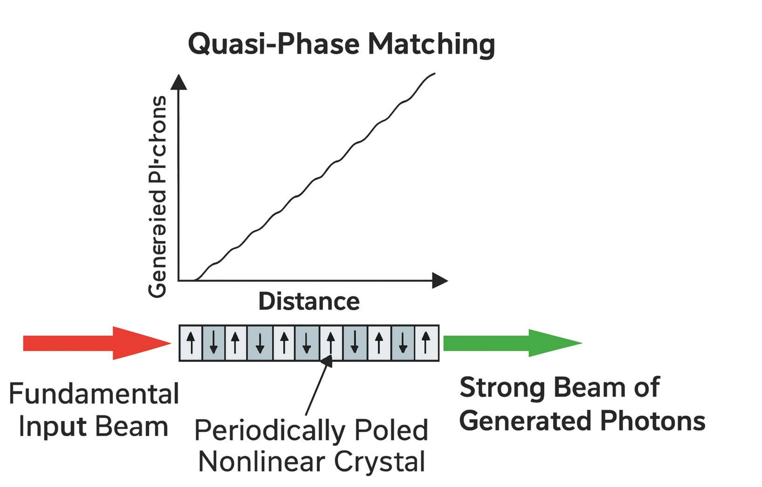
The signal and idler have the same polarization as the pump.



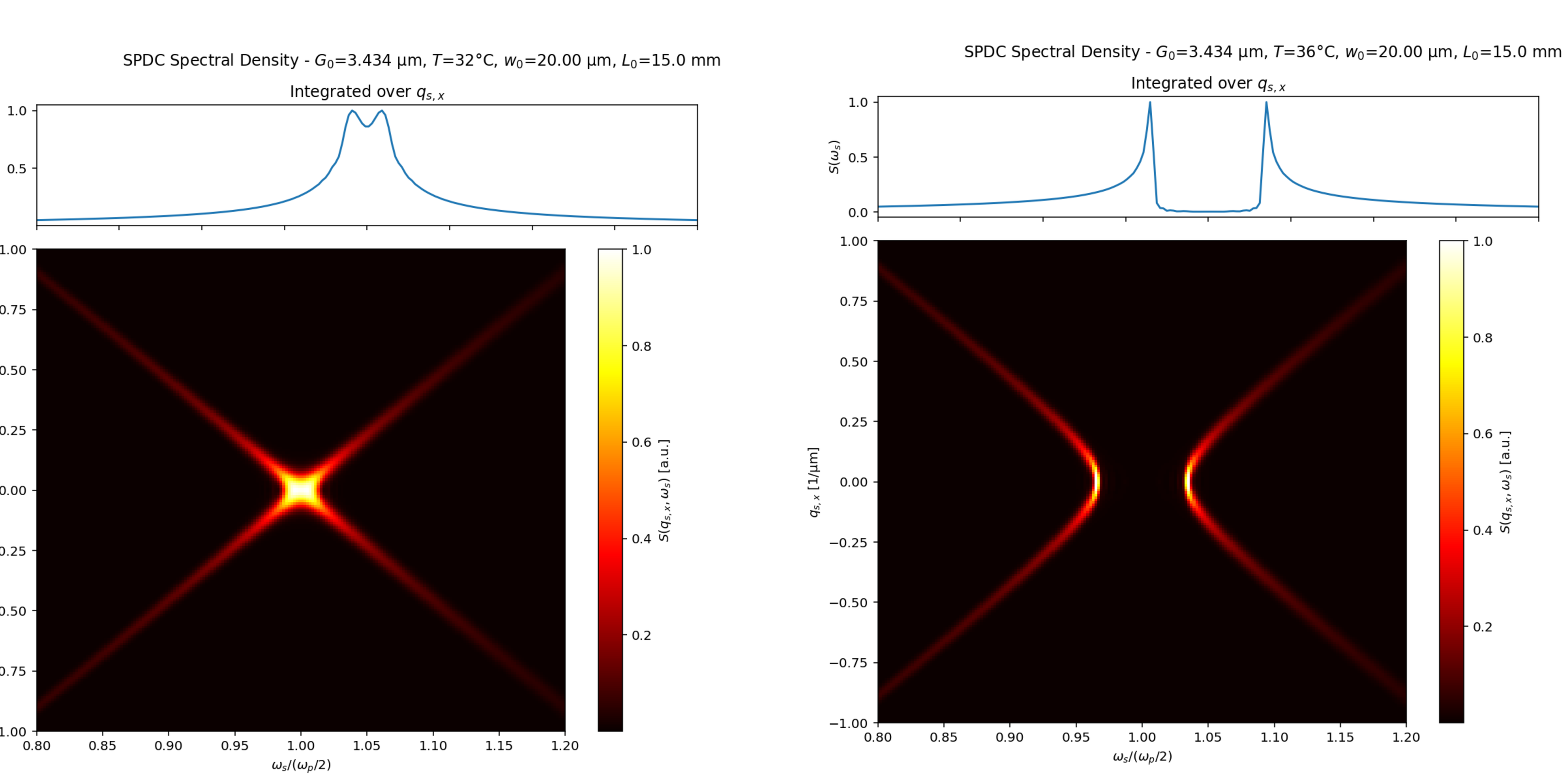
Momentum conservation:



$$k_s + k_i + G = k_p$$

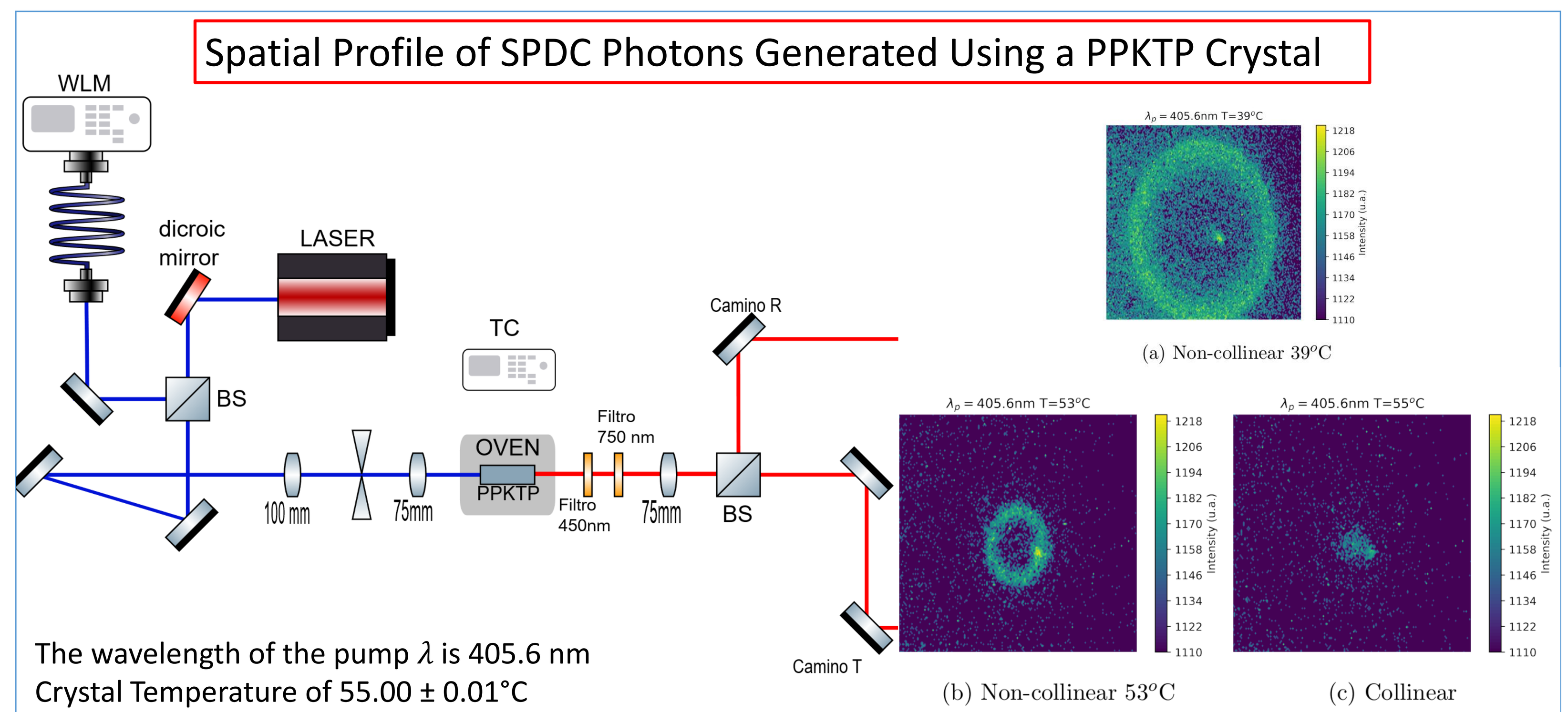


pectral Density Simulation: λ(laser) = 405.1698 ± 0.002 nm



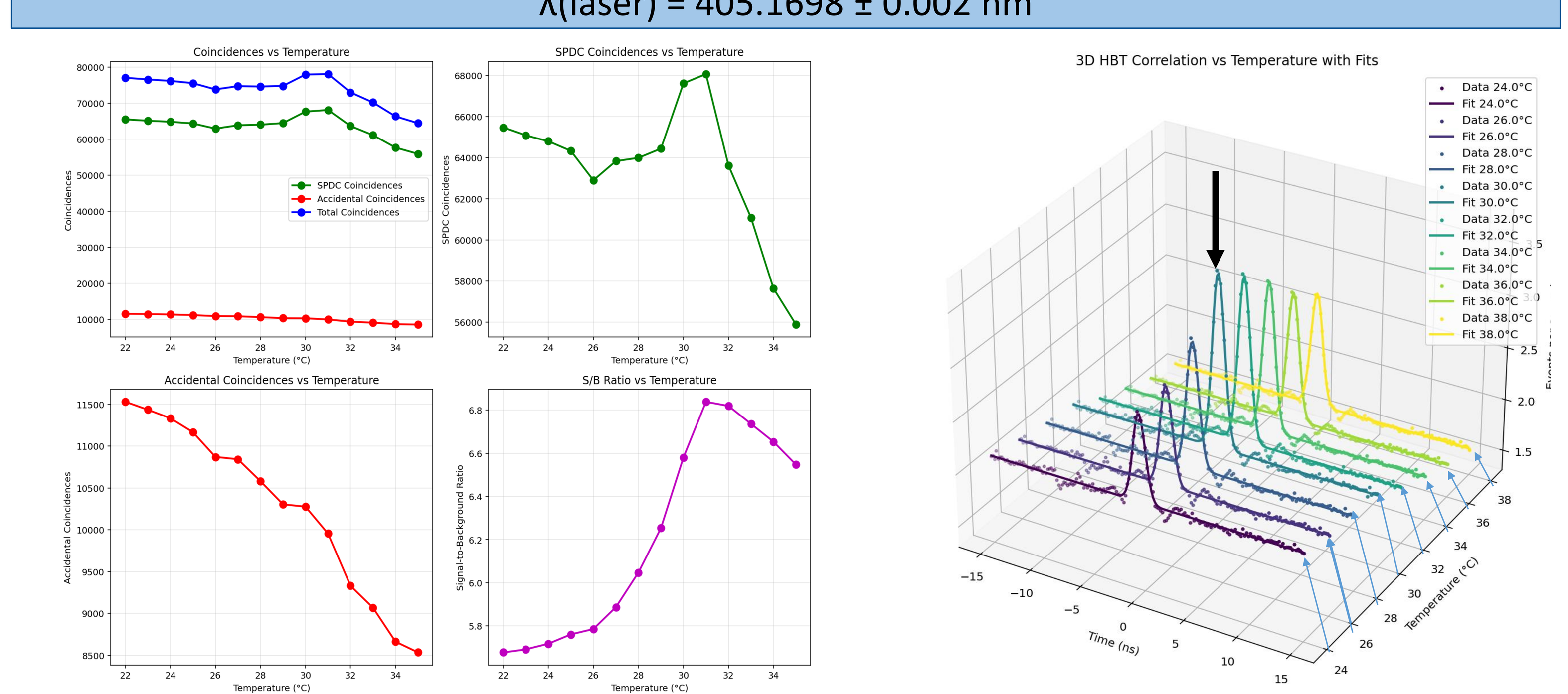
Experimental Setup, Characterization, and Results

Spatial Profile of SPDC Photons Generated Using a PPKTP Crystal

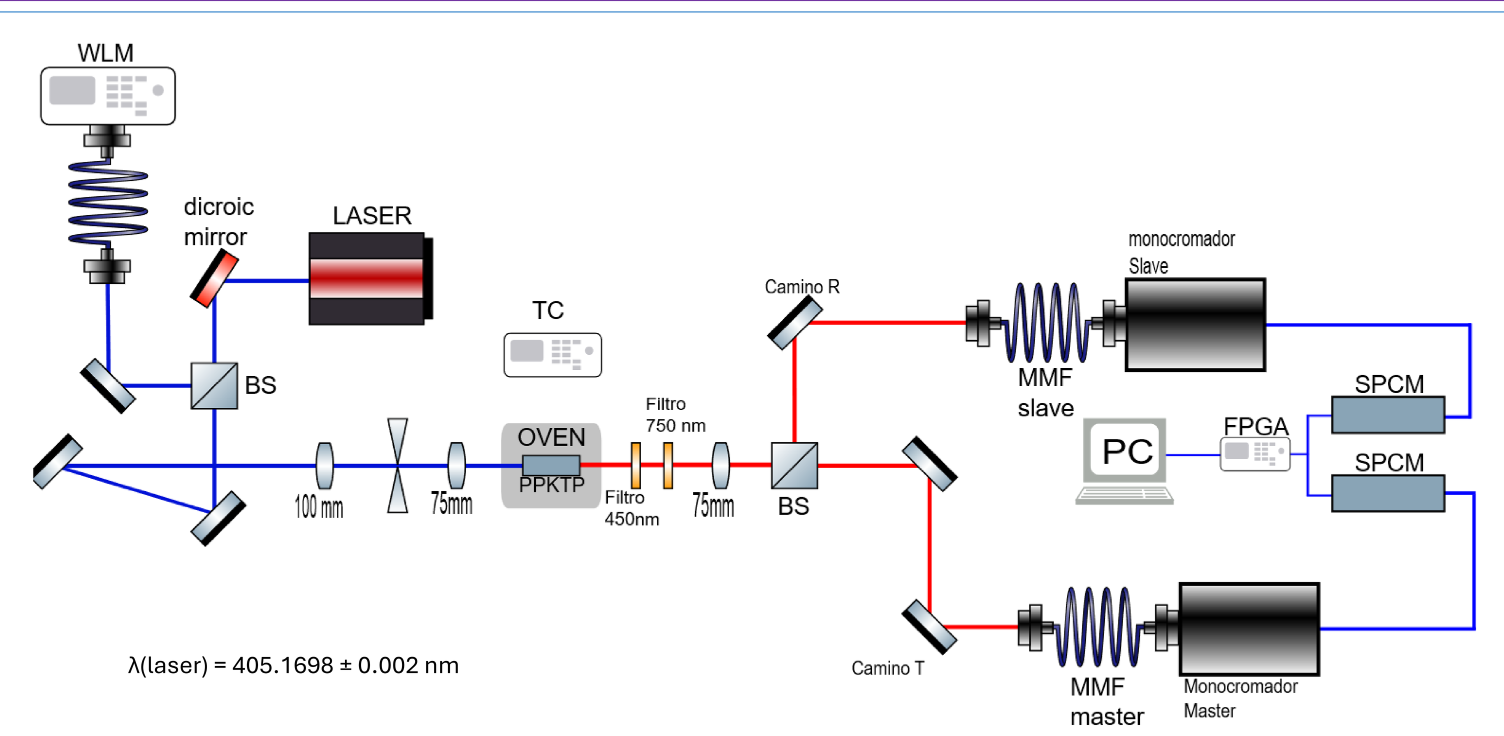


The wavelength of the pump λ is 405.6 nm
Crystal Temperature of 55.00 ± 0.01°C

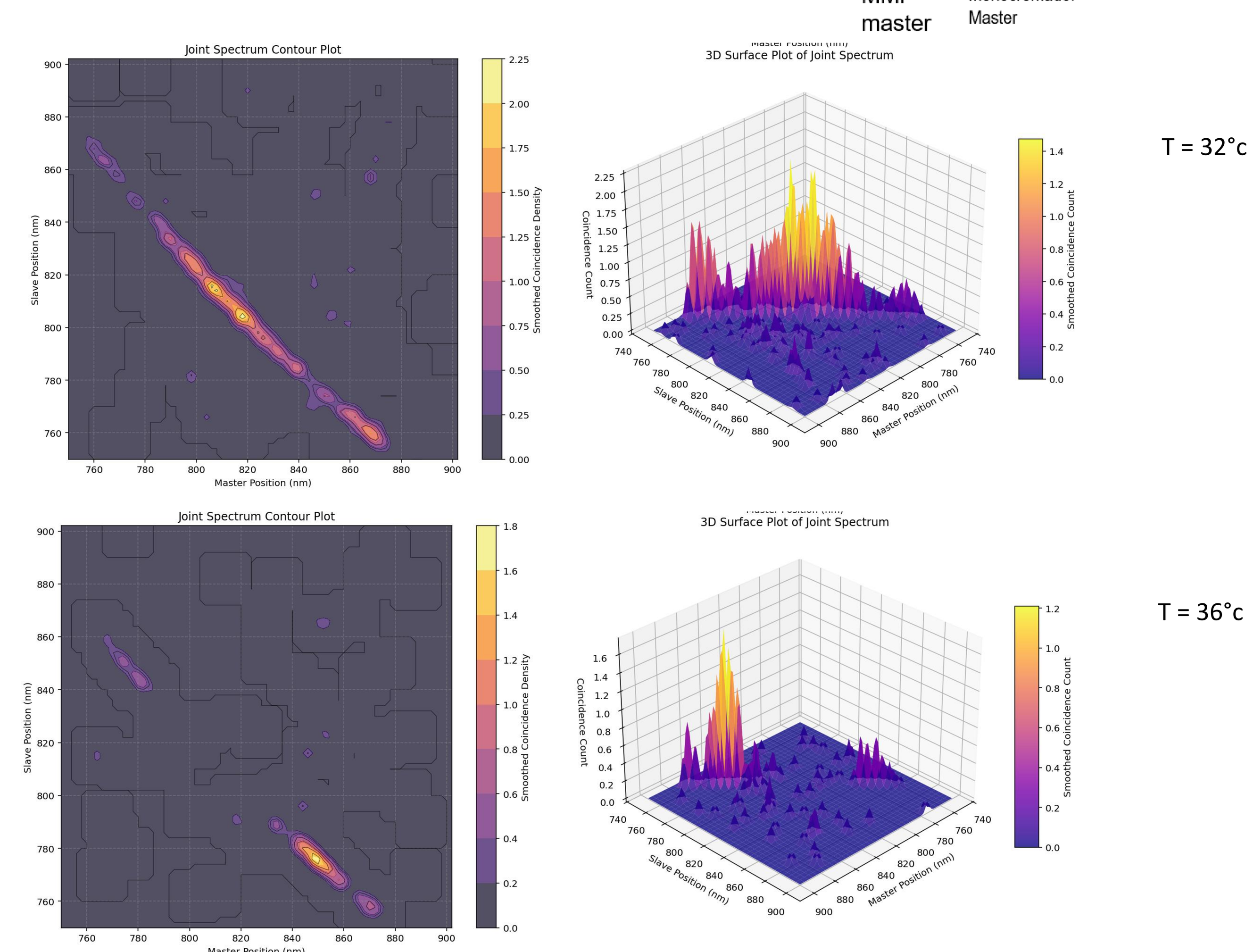
Measurement of the Second-Order Correlation Function
λ(laser) = 405.1698 ± 0.002 nm



Experimental Setup: Measurement of the Joint Spectrum



λ(laser) = 405.1698 ± 0.002 nm



Conclusions and Future Work

- High Efficiency: PPKTP shows high photon pair generation efficiency due to its d_33coefficient and quasi-phase matching (QPM).
- Phase Matching: QPM efficiently compensates for phase mismatch, enabling continuous photon pair amplification.
- Spectral Measurement: The joint spectrum was measured, and experimental results match theoretical predictions.
- Simulations Consistency: Simulations of the spectral density align with experimental data, confirming the model.
- Quantum Applications:PPKTP is ideal for quantum technologies, offering precise spectral control for applications like ETPA.

References

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