

Frequency-definite photon pairs from a Lithium Niobate waveguide resonator

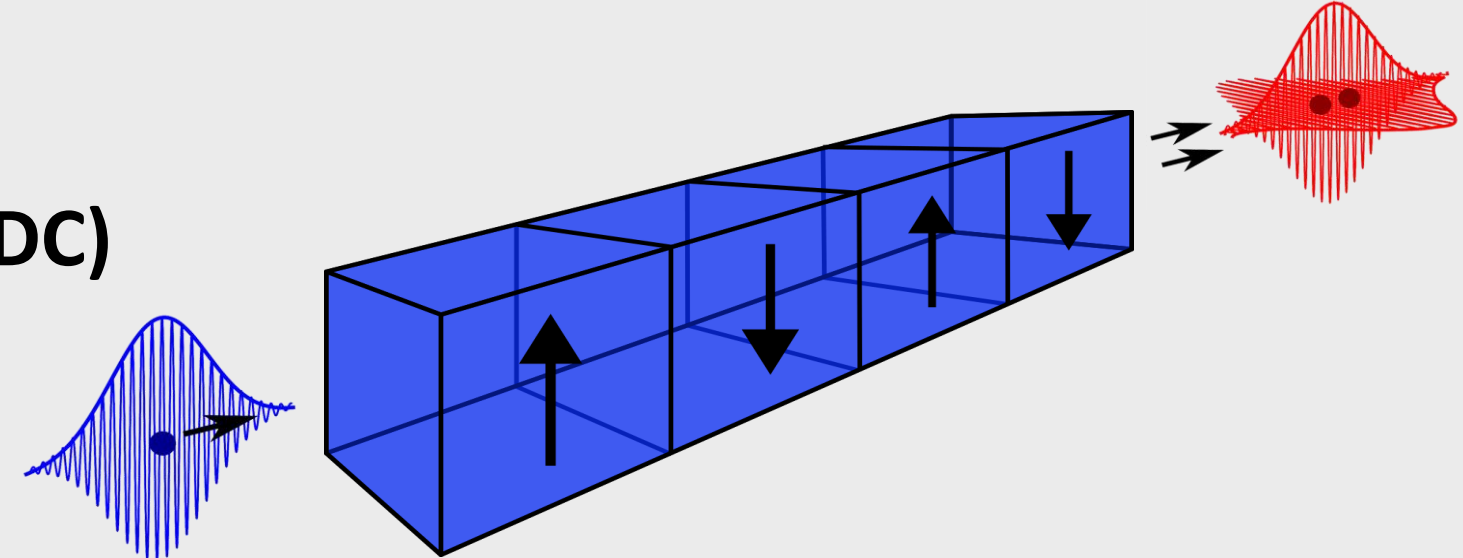
Stefan Kazmaier and Kaisa Laiho

German Aerospace Center (DLR e.V.), Institute of Quantum Technologies, Wilhelm-Runge-Str. 10, 89081 Ulm, Germany
stefan.kazmaier@dlr.de

Motivation

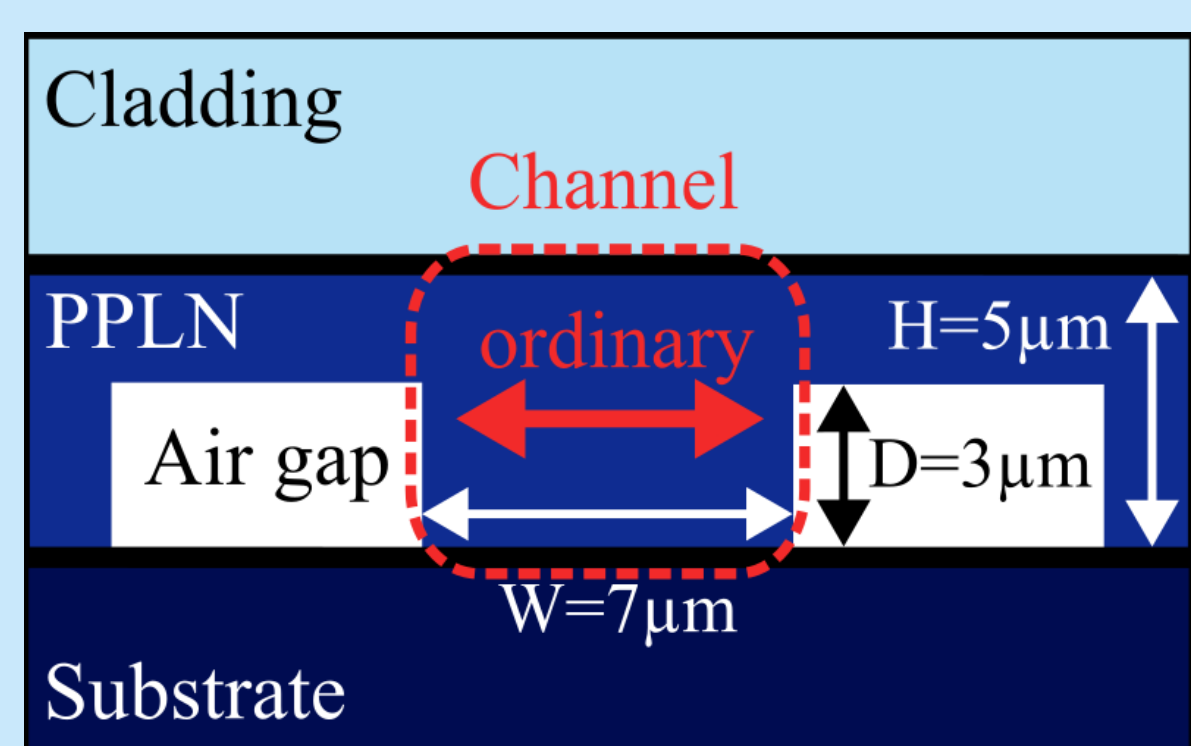
- Lithium Niobate is a promising candidate for generating quantum light.
- Dispersion and optical losses dictate the spectral properties of generated states.
→ We show a linear optical measurement of the group refractive index in a periodically poled Lithium Niobate waveguide (PPLN-WG) resonator.

Photon Pair generation via Parametric down conversion (PDC) in a PPLN WG



- Hybrid Quantum Networks require versatile hardware components.
 - Ideally narrowband entangled photon pairs but pulsed for synchronization.
 - Optimized to be compatible with other components like quantum memories.
- We measure and simulate spectral and temporal properties of our source.

Dispersion Measurement [1]



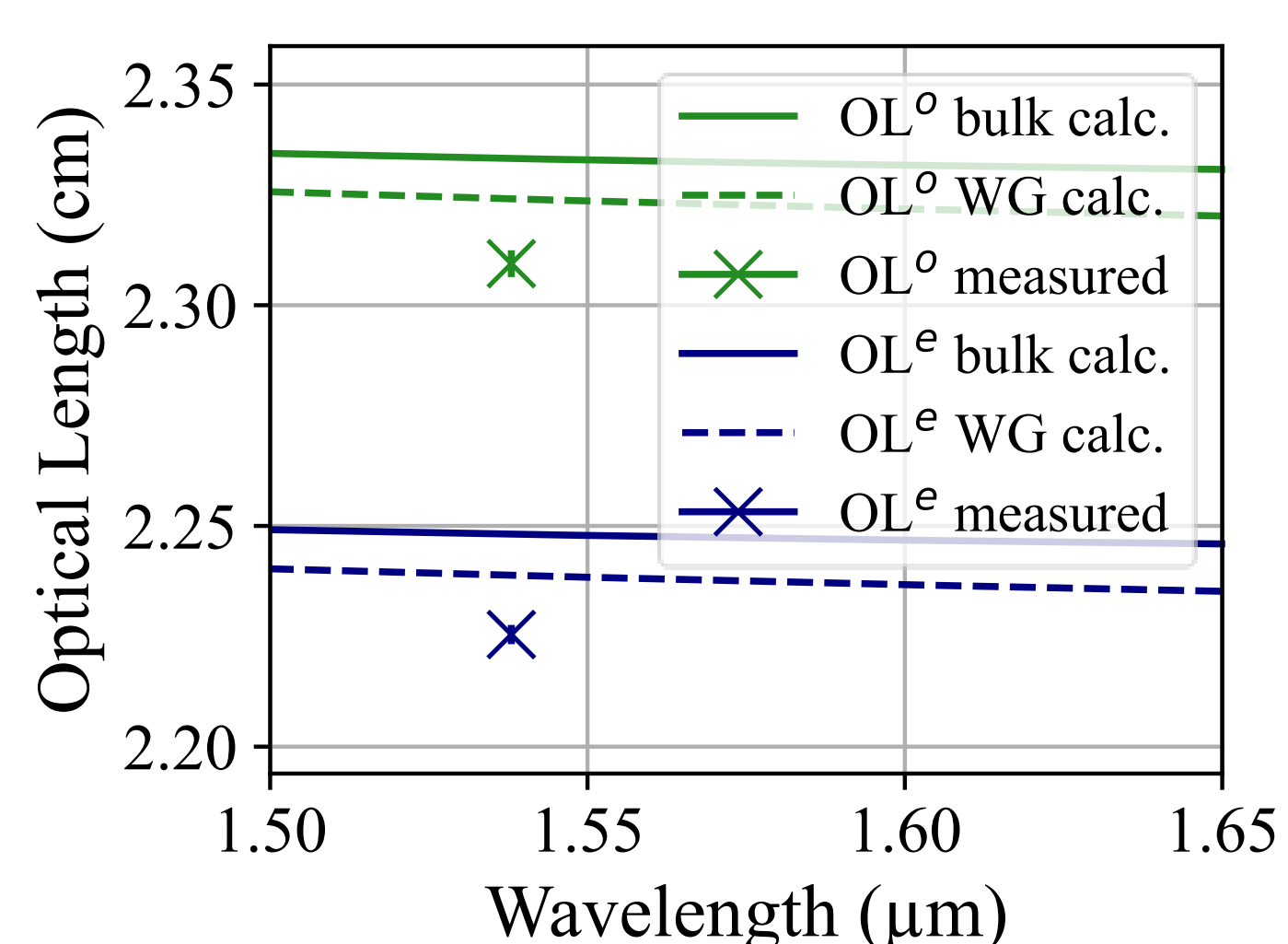
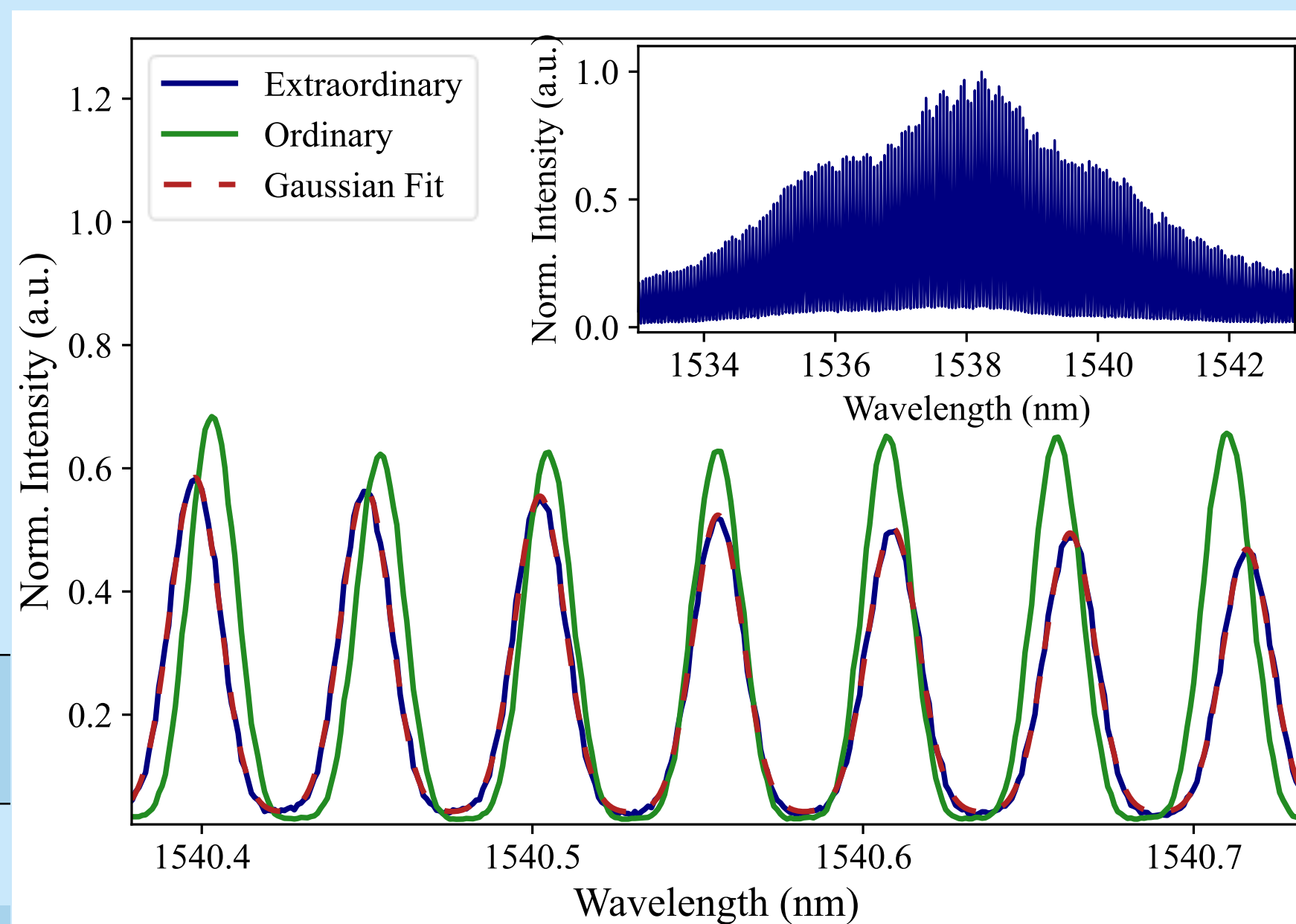
PPLN-WG Cross Section

- WG channel is formed by air gaps and oxide layers.
- End facets with high reflection coating $R=97\%$ form a Fabry-Pérot Resonator.
- Waveguide length $L=10.30(5)\text{mm}$.
- Ordinary (slow) crystal axes shown as red arrow extraordinary (fast) is perpendicular.
- PPLN-WG is made of congruent MgO:LN.

Transmission Spectrum

- Airy-peaks $A(\omega)$ expected from the Fabry-Pérot resonator are resolved [2].
- Fourier transform from frequency into time domain, converted via group velocity into optical length and group index using PPLN-WG length.

	FSR (GHz)	FWHM (GHz)	Finesse
extrao.	6.70(1)	2.29(1)	2.92(2)
ordinary	6.45(1)	2.14(1)	3.01(2)

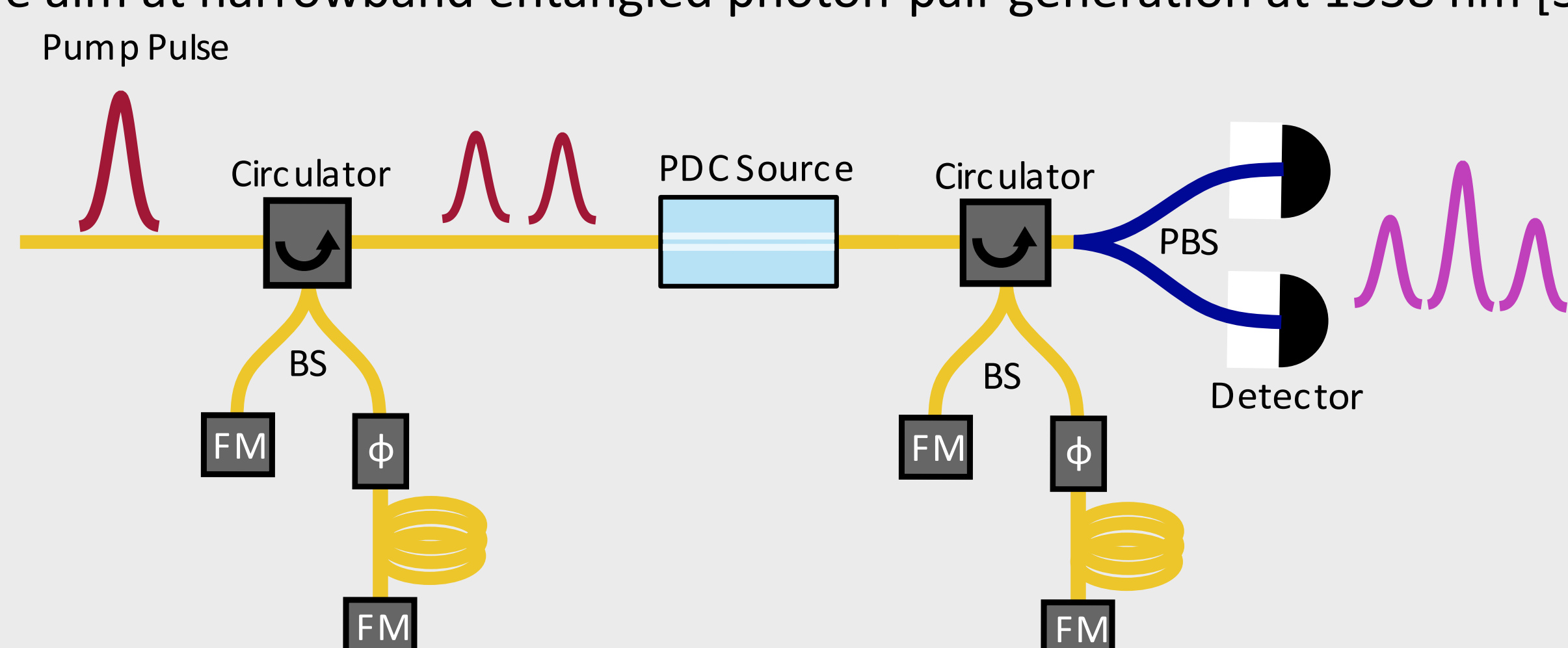


Group Index Measurements

- Sellmeier's equation is used for the simulation of bulk PPLN.
- Metallic waveguide approximation is used to simulate the PPLN-WG.
- Measured birefringence predicts PDC properties:
 - Cluster spacing: 1.4(1)nm
 - Group delay: 1.4(1)ps
 - Phase matching width: 2.5(2)nm

Conclusion and Outlook

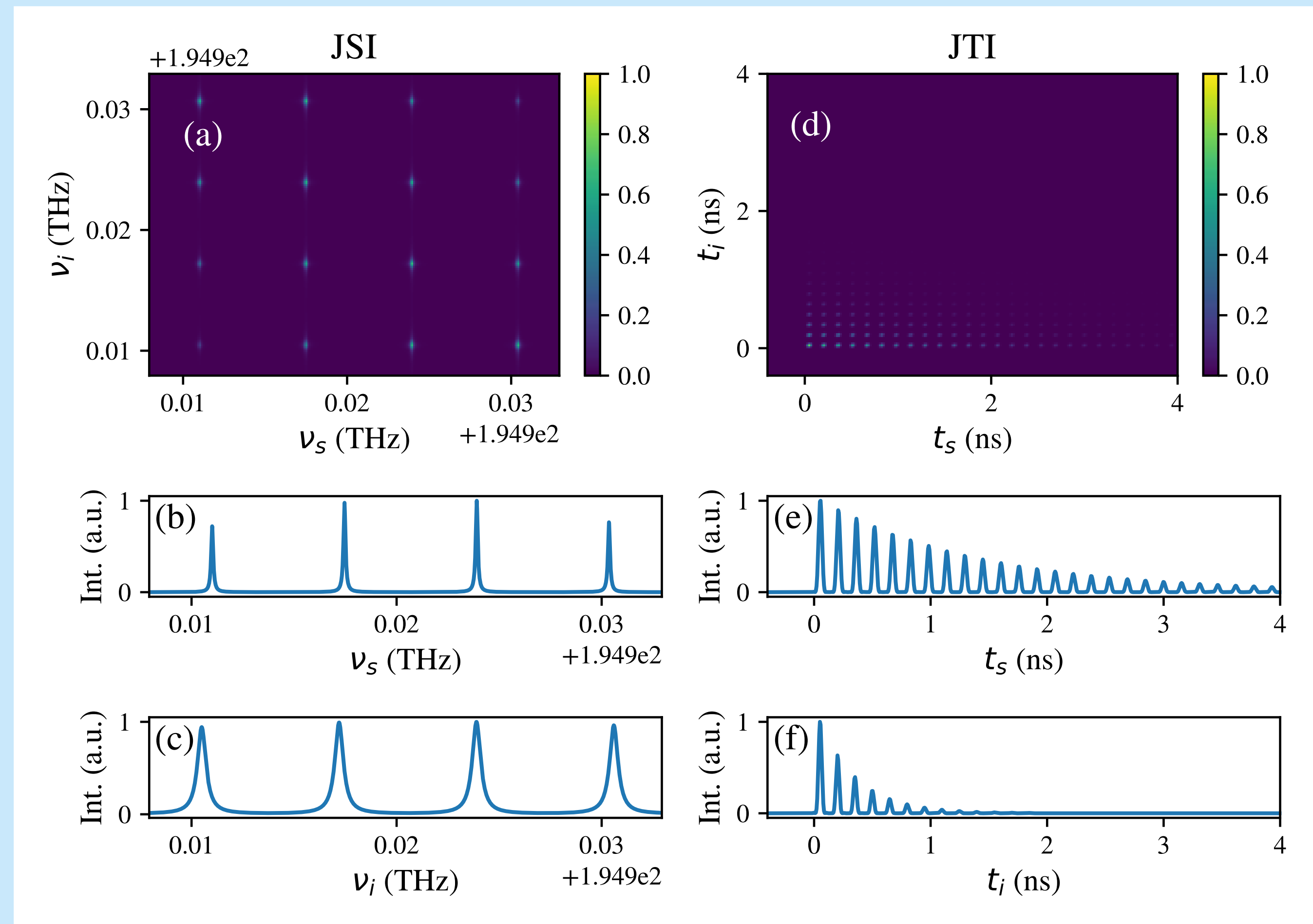
- We conducted high accuracy birefringence measurements.
- Measured 2GHz bandwidth at PDC wavelength of 1538nm.
- Signal and Idler half times are 0.9ns and 0.2ns due to different optical losses.
- We aim at narrowband entangled photon-pair generation at 1538 nm [3].



Spectral and Temporal Investigation

Simulation for Multiple Resonator Modes

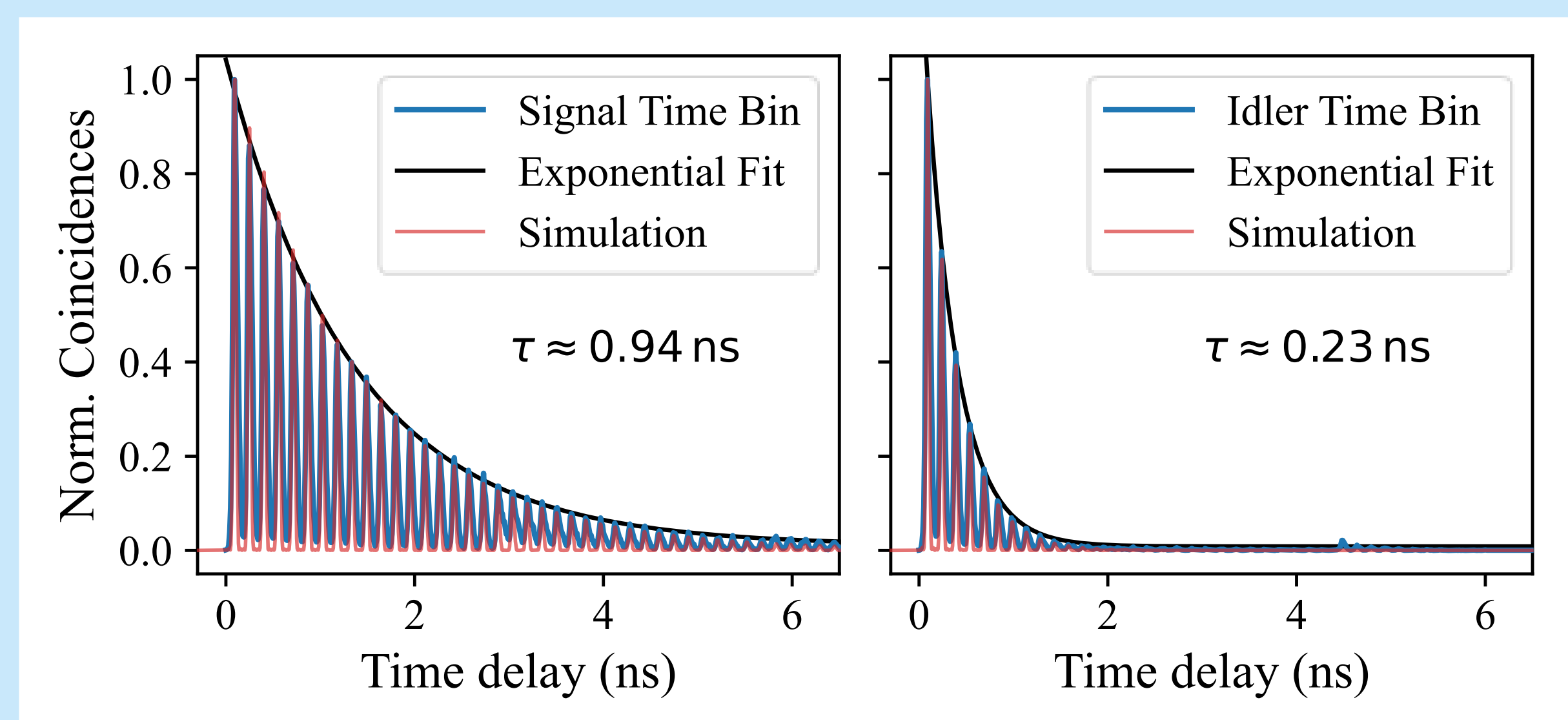
- Joint Spectral Intensity (JSI) from phase matching, pump spectrum, resonator [2].
- Joint Temporal Intensity (JTI) via 2D Fourier transformation into time domain.



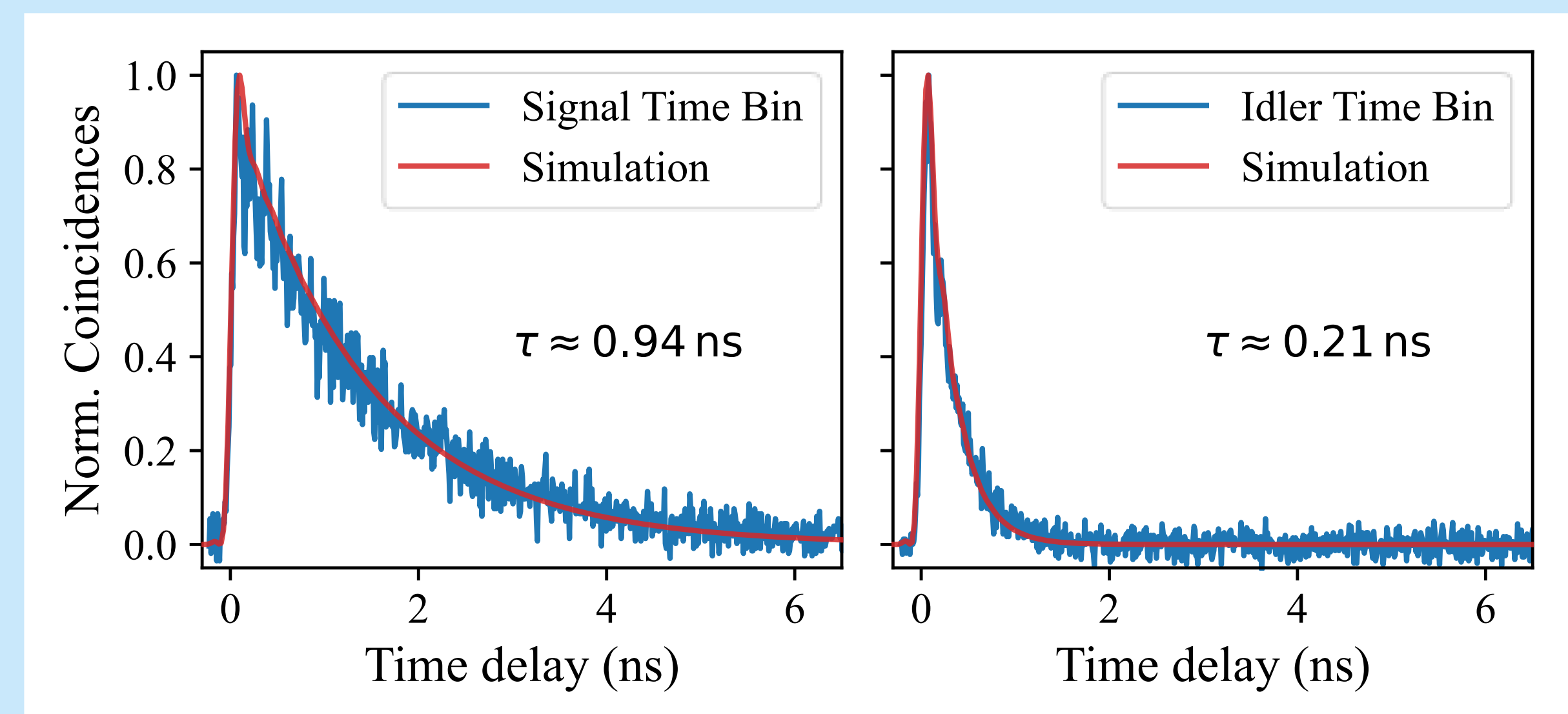
Optical loss: 0.3dB/cm and 2.0dB/cm; Pump pulse length: 0.4ps; refractive index correction of 0.4% to match FSR of simulation to the measurement

Measured temporal shapes

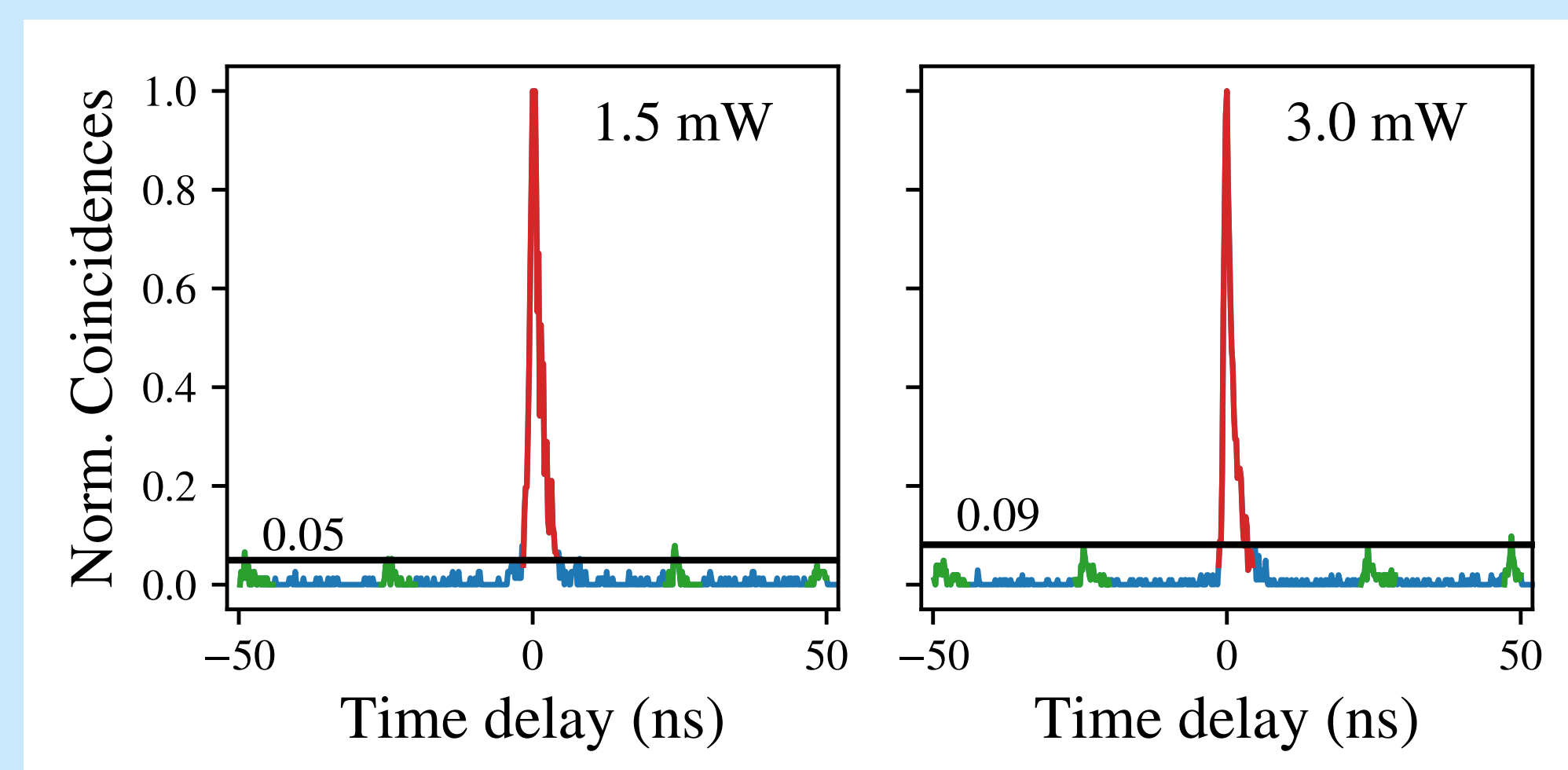
- Correlation measurement between pulsed laser trigger and photon detection.
- Multiple resonator modes** cause fringes due to interference of spectral modes.
 - The delay between the fringes of 0.15ns is linked to the FSR of 6.7GHz.
- The envelope is fitted with an exponential decay revealing the half times τ .
- Temporal shapes are simulated using different optical loss for signal and idler.



- Single resonator mode** causes the fringe pattern to disappear.
 - One peak of the resonator spectrum is filtered with a variable bandpass filter.
 - The temporal shape can again be simulated with the method above.



- Histogram of coincidences between signal and idler for a single resonator mode.
 - Correlated photon pairs CAR= 31.3(10) at 1.5mW / CAR=16.8(2) at 3mW.



[1] Stefan Kazmaier and Kaisa Laiho "Achieving precision in measuring birefringence characteristics of a periodically-poled Lithium Niobate waveguide" Phys. Scr. 100 081502 (2025)

[2] Brecht Benjamin et al. "A versatile design for resonant guided-wave parametric down-conversion sources for quantum repeaters" Applied Physics B 122.122 (2016)

[3] Enrico Pomarico et al. "Waveguide-based OPO source of entangled photon pairs" New J. Phys. 11 113042 (2009)