All-Fiber Source and Sorter for Multimode Correlated Photons

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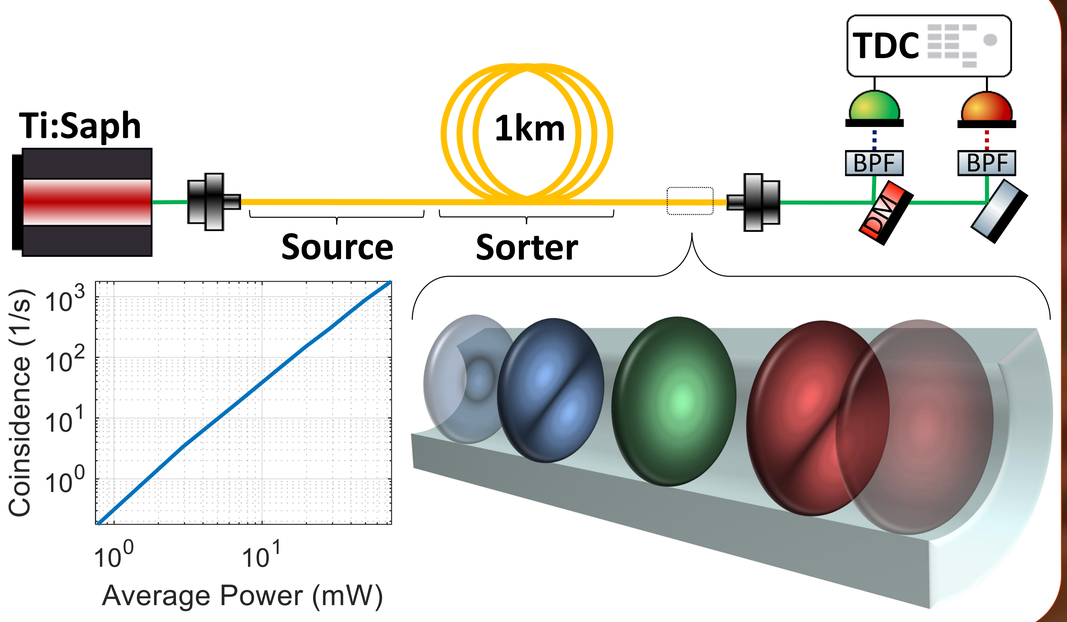
Introduction

- **High-dimensional quantum bits** hold great potential for quantum communication [1].
- Spatially entangled photons generated by spontaneous parametric down conversion in a bulk crystal are convenient for free space implementations [2,3].
- We demonstrate an **all-fiber source of high dimensional photon pairs** which occupy multiple fiber modes [4].
- We show that the **photons are correlated in the guided mode basis**, by mapping the mode the photons occupy to their arrival time at the end the fiber.

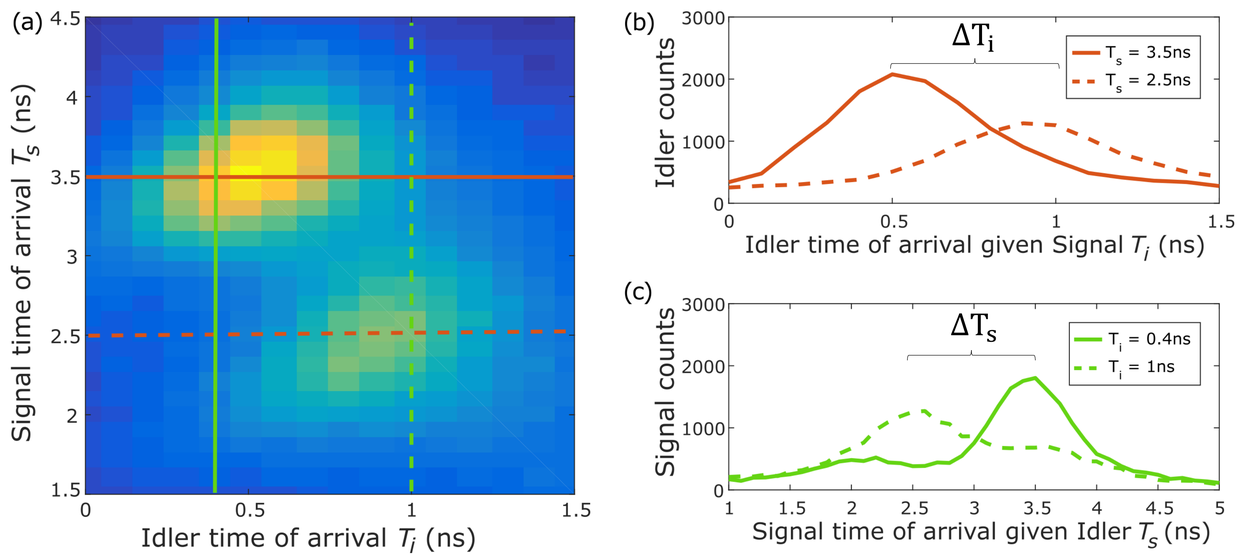
Concept

- We launch Ti:Sapphire laser pulses into a few mode fiber.
- In a **Spontaneous Four Wave Mixing** process, two pump photons are annihilated, and two photons called *signal* and *idler* are generated in two spectral bands.
- Each spectral band is composed of different spatial eigenmodes of the fiber.
- Due to **modal Group Delay Dispersion**, the arrival times of the photons at the end of the 1km long fiber depend on their modal distribution and their spectral band [5].
- We register the detection times of both detectors using a time-to-digital converter (TDC).
- Coincidence rate is quadratic with the average pump power.

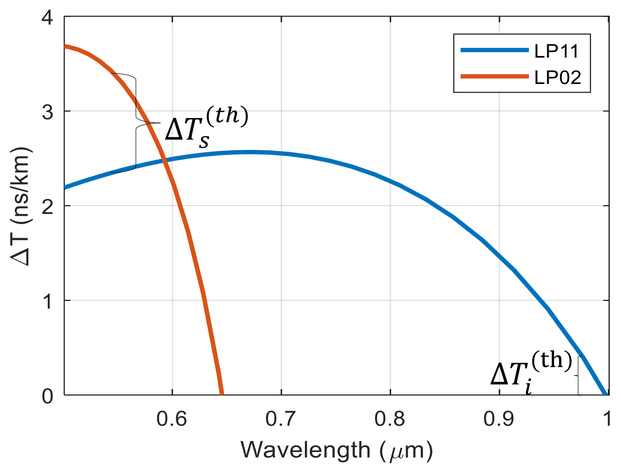


Results

- We measure the temporal two-photon probability $P(T_s, T_i)$, describing the probability to detect a *signal* and *idlers* photons at time T_s , T_i.
- Two correlation peaks are observed, corresponding to the delay between either $|LP_{02}\rangle_s$ and $|LP_{01}\rangle_i$ or between $|LP_{11}\rangle_s$ and $|LP_{11}\rangle_i$.
- The two-photon probability is not-separable, indicating that photons are correlated in the modal basis.
- Cross sections of the two-dimensional histogram along the lines marked in (a) emphasizing the modal correlations (b,c).



- We solve the fiber's scalar wave equation and calculate the modal group delays of the fiber guided modes.
- Present the modal delay of LP_{02} , LP_{11} modes, relative to the fundamental mode. The fundamental mode is chosen as a reference to cancel the chromatic dispersion.
- The delays are in agreement with the temporal correlations found experimentally, supporting our mapping scheme to verify the modal correlations.



Discussion and Conclusions

The all-fiber configuration has two major advantages:

1. Generating the photon pairs in the fiber: bypass the need for precise coupling of high dimensional photons to the fiber.

2. The mode-to-time mapping can solve the challenge of scaling the number of required detectors with the number of fiber modes.

By combining the temporal sorter with an inline wavefront shaping scheme we recently introduced [6] it may be possible to sort in a mutually unbiased basis, opening the door for quantum communication protocols.

References

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For more information:
arXiv:2012.14024