Phase-only shaping of single-photon pulses

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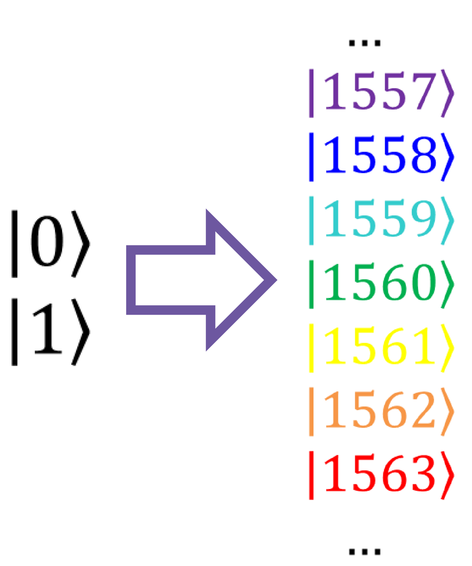
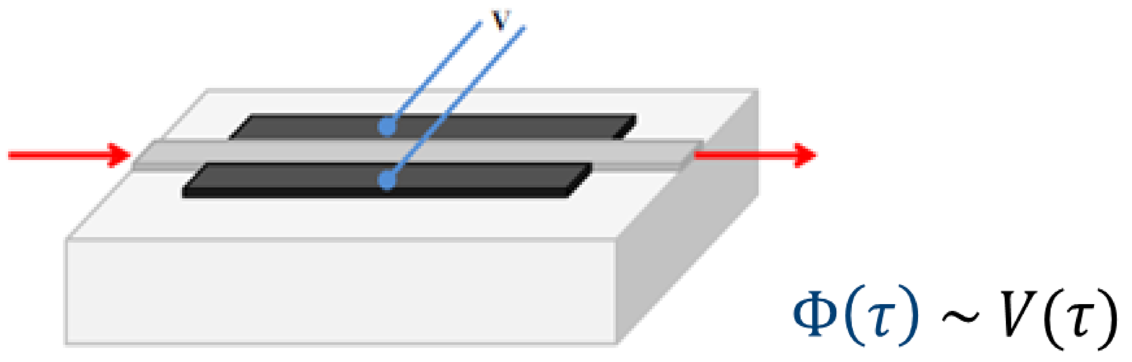
The research at Quantum Photonics Lab involves optical pulses of the lowest possible intensity, such as single photons. We are interested in the conjugate spectra and temporal properties of quantum light, such as the duration of the pulses or their frequency distribution. One of our goals is to modifiy them via phase-only operations, i.e. operations that do not change the number of photons. We experimentally modify the properties of single-photon pulses using electro-optic phase modulators and optical fibers with complex dispersion profiles. Our research contributes to the drive towards worldwide quantum internet.

Quantum information



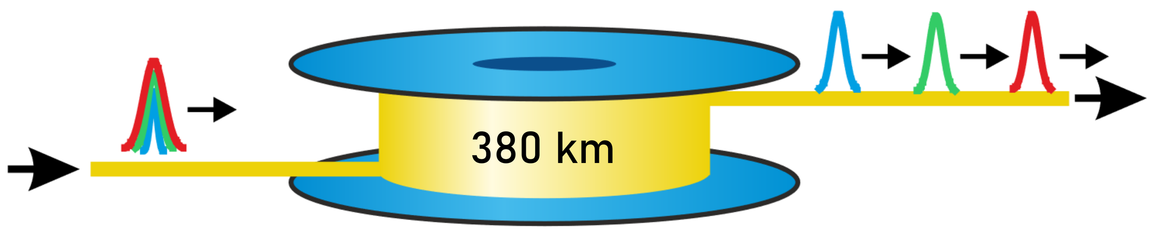
The frequency (energy) or time of arrival of a single photon can be used to encode quantum information – qubits or qudits, i.e. quantum bits that can take value of not only $0, 1, \ldots\ d$, but also any combination of them. The modulation of single photons in time and frequency spectrum will allow efficient quantum information processing.

Electro-optic phase modulation

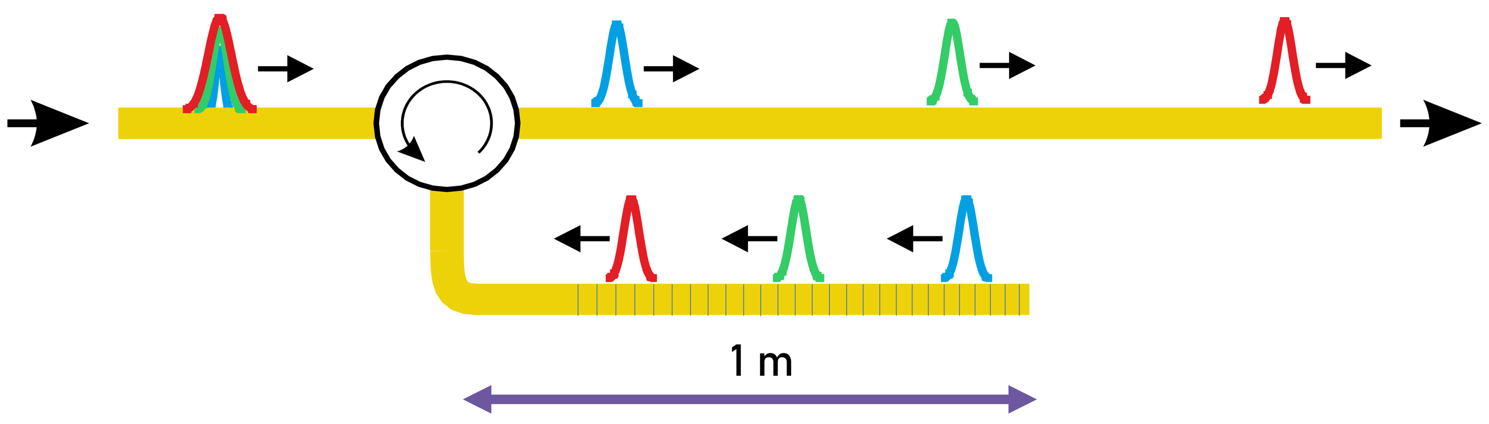


An electro-optic phase modulator (EOM) employs the Pockels effect to introduce a refractive index change, which is proprtional to the applied voltage. Using synchronized voltage pulses we impose a temporally varying phase (i.e. varying optical path) onto single-photon pulses. This way we can introduce a spectral shift - a change in the frequency (colour) of the photons, in analogy to the Doppler effect.
Phys. Rev. Lett. 118, 023601 (2017).

Chirped Fiber Bragg Grating

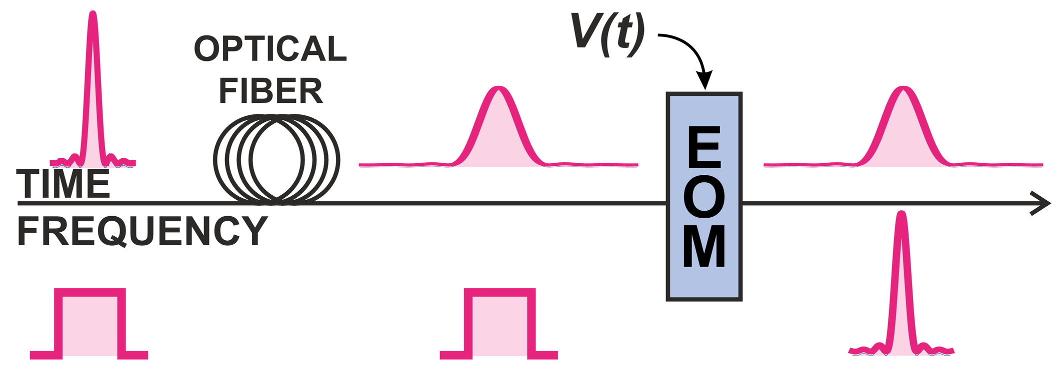


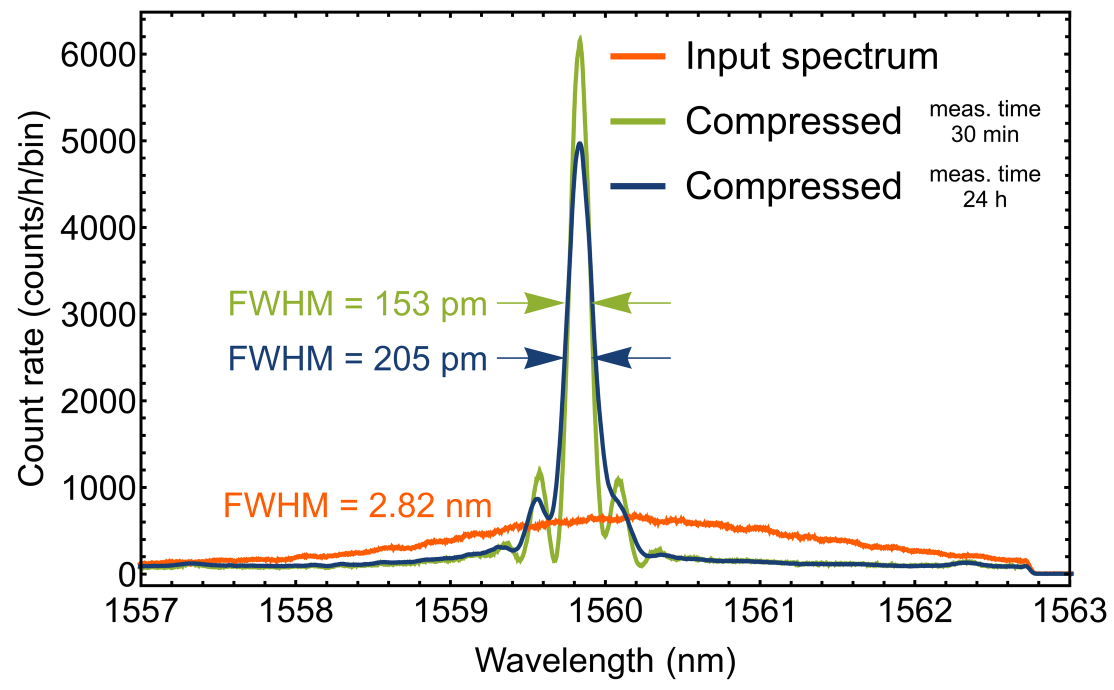
Spectral phase modulation (dependence of optical path on the frequency of light) occurs naturally in optical fibers. However, for higher modulation, we use chirped fiber Bragg gratings – mirror-like structures in an optical fiber, that reflect different colors at different locations, allowing to obtain in a 1-m-long device an effect, equivalent to over 300 km of standard fiber. Thanks to collaboration with the Optoelectronics Research Centre in Southampton (UK) we can produce custom fiber Bragg gratings tailored to our experiments.



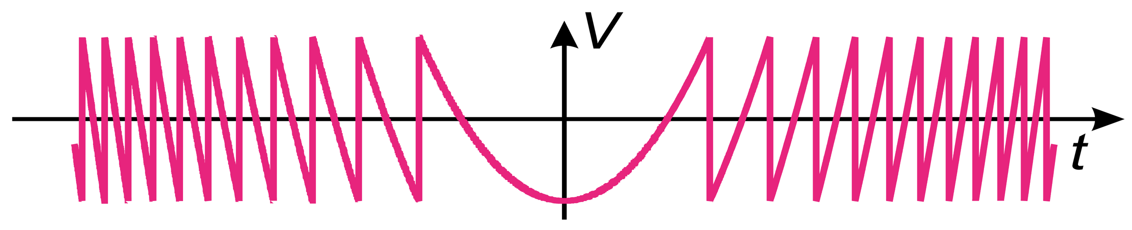
Spectral modification

Combining the modulation of temporal and spectral phase, more general operations can be achieved, e.g. a change in the spectral width of a single photon.
Nature Photon. 11, 53 (2017)
Appl. Phys. Lett. 116, 234003 (2020)

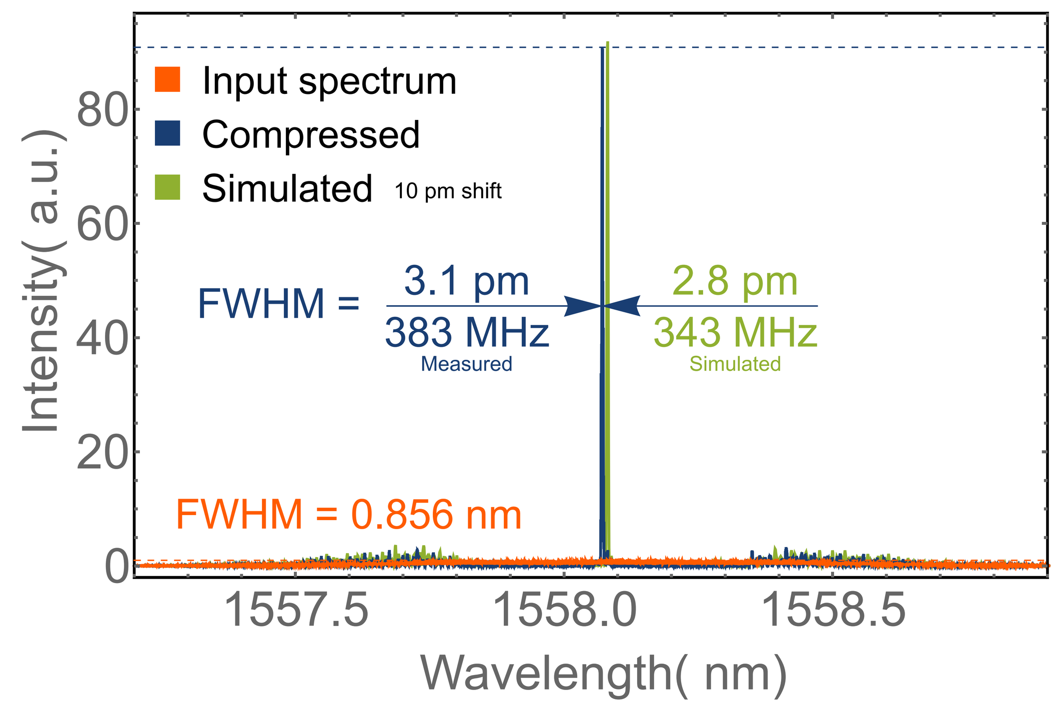




At QPL we use complex electronic waveforms to drive EOMs to maximize the spectral compression factor.

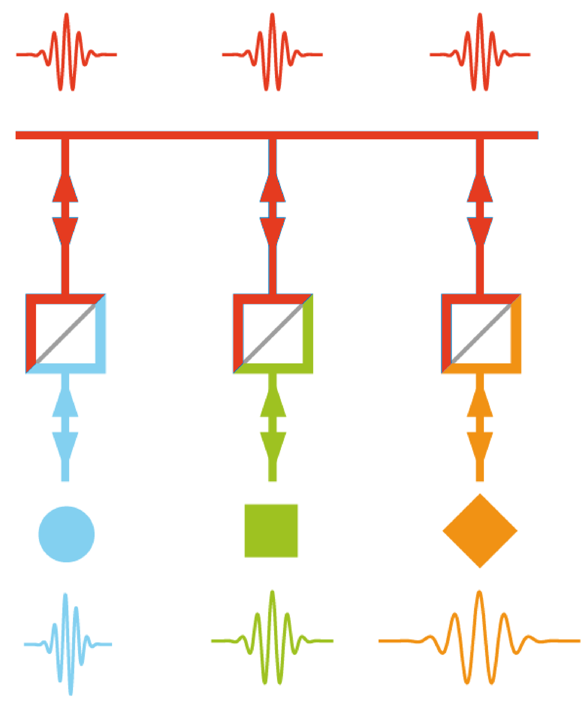


Achievement of over 200-fold spectral compression into the sub-GHz regime will pave the way towards future Quantum Internet.
Opt. Express 26, 31307 (2018).



Quantum Internet

Our transformations will allow a photon emitted by one quantum object (such as a quantum dot, a trapped single atom or ion) to be efficiently absorbed by a quantum object of a different kind. This will allow transferring quantum information and quantum entanglement over long distances, creating the Quantum Internet.



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