

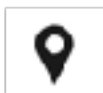


DEEP-TECH & MULTI-SECTORIAL COMPANY

Devang Naik

Head Quantum Technologies Division

●●●●●●● The company



A French start-up based in Limoges. Incubation in Bath (2008). Transfer to and re-incubation in Limoges (July 2011). Trading activities in 2013



~20 employees. 80% in R&D, 12 PhD+



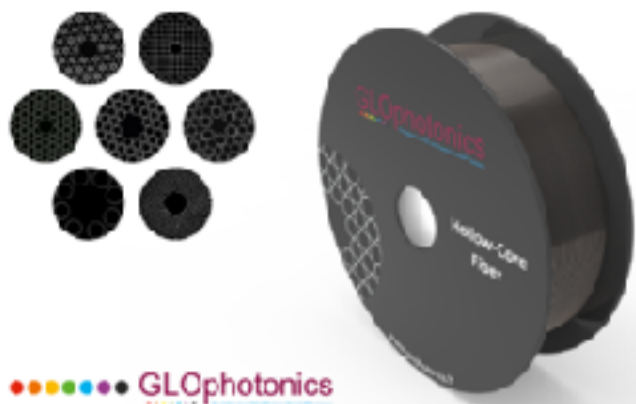
150 m² clean room (ISO-07)
2 drawing fiber towers



Strategic partnership with XLIM / GPPMM

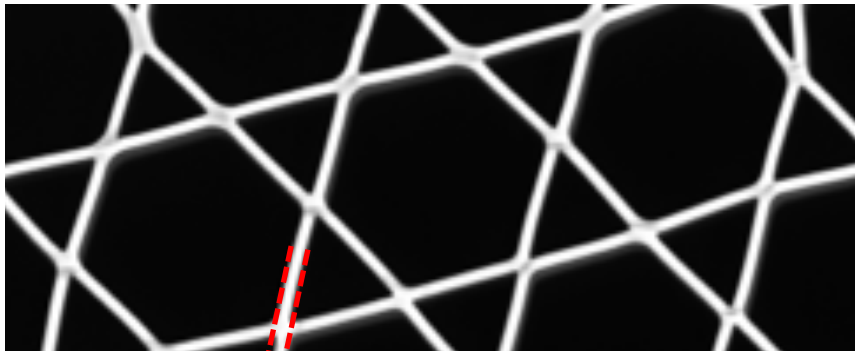
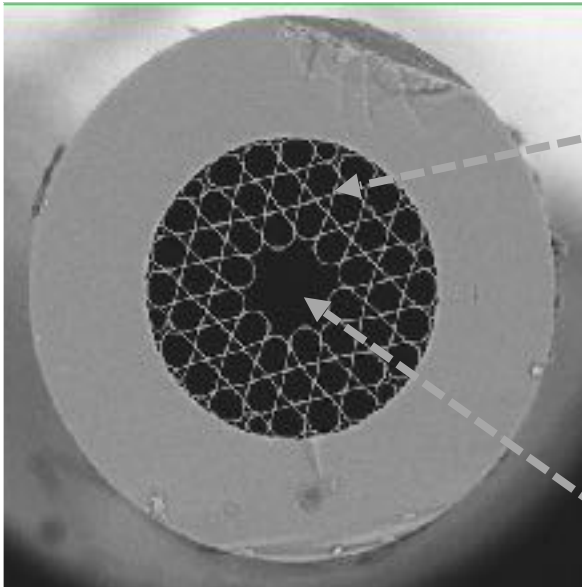


Development & supply of photonic components, modules and/or systems based on a proprietary Technology*.



*Hollow Core Photonic Crystal Fiber (HCPCF) & Photonic MicroCell (PMC) technology

The Hollow Core Family



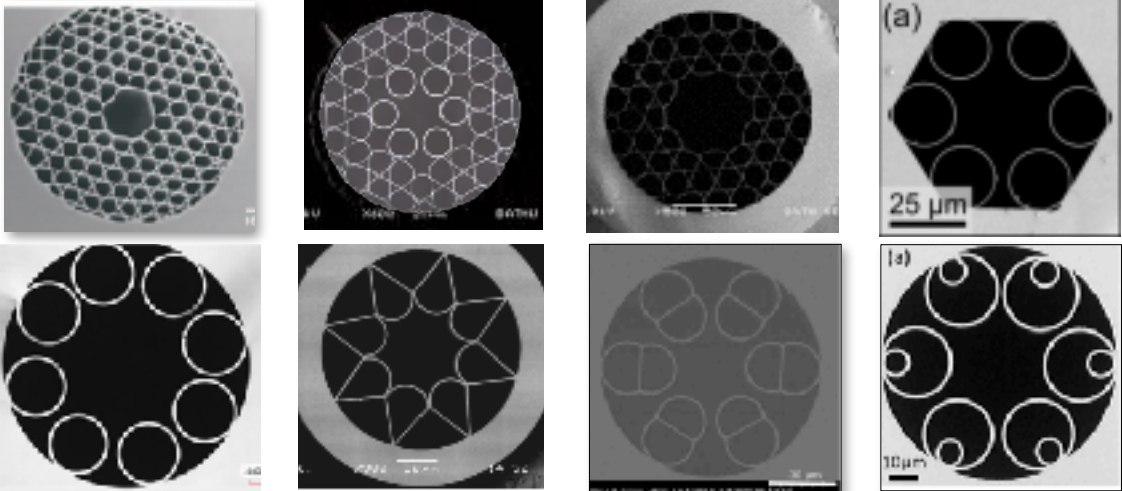
Thickness : $2\mu\text{m}-100\text{nm}$

Microstructured Cladding (Air/Silica)



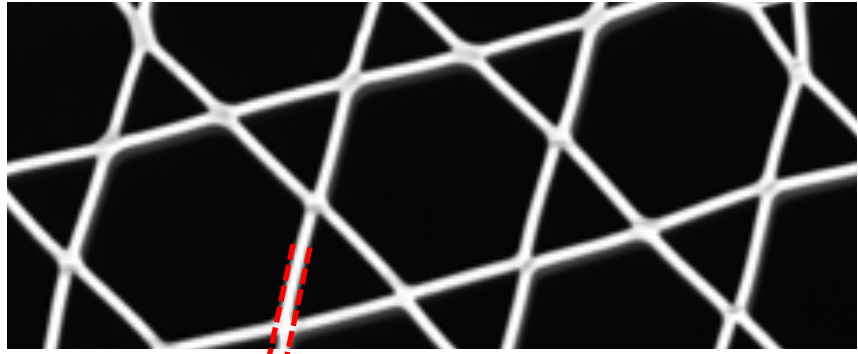
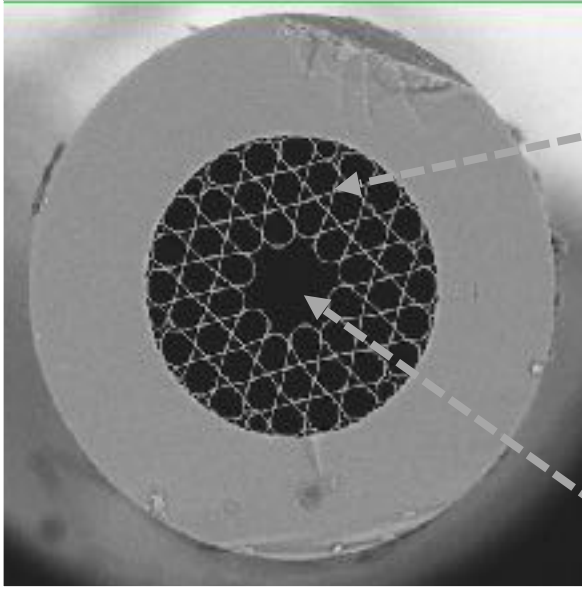
Hollow-core (5-150 μm)

Inhibited-coupling guiding HCPCF



The Hollow Core Family

The extremely cold
S. Okaba et al. Nature Comm. 5, 4098 (2014)

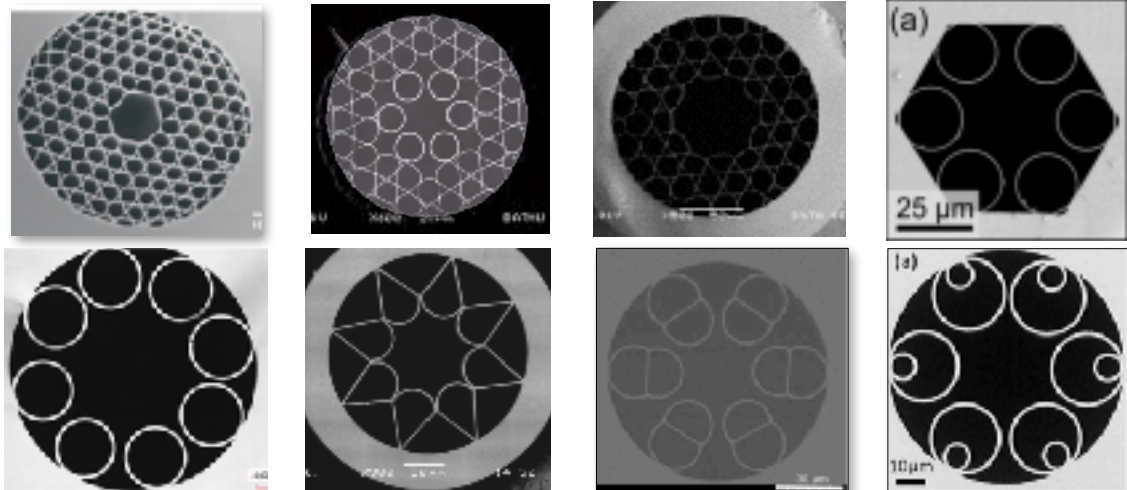


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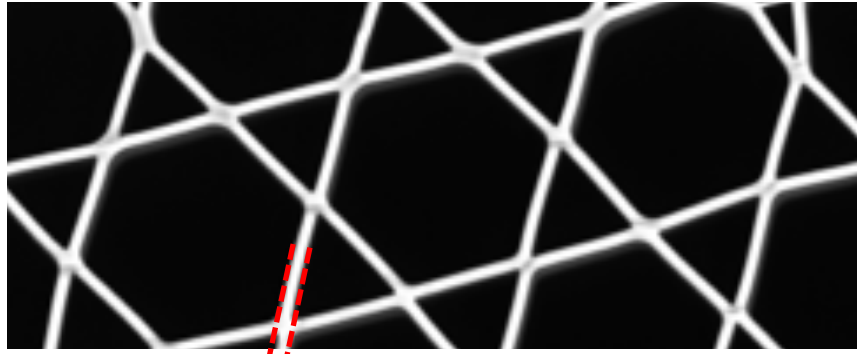
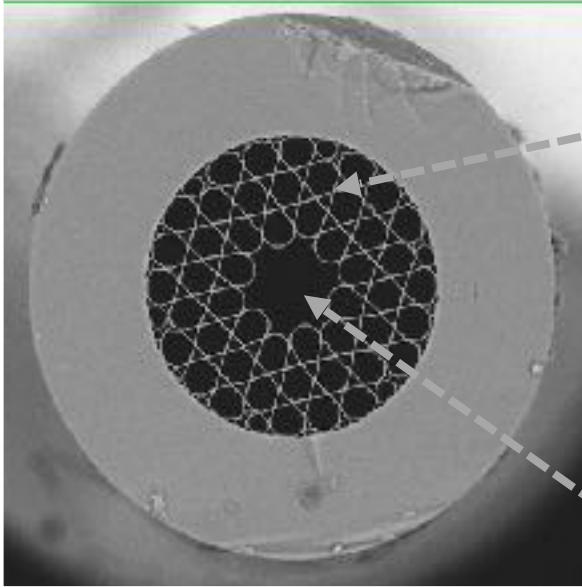
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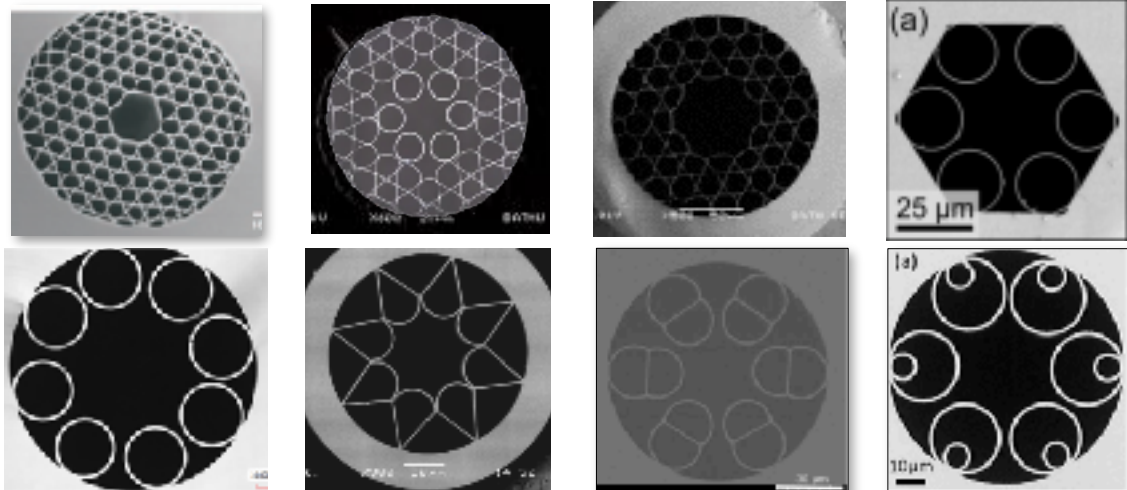


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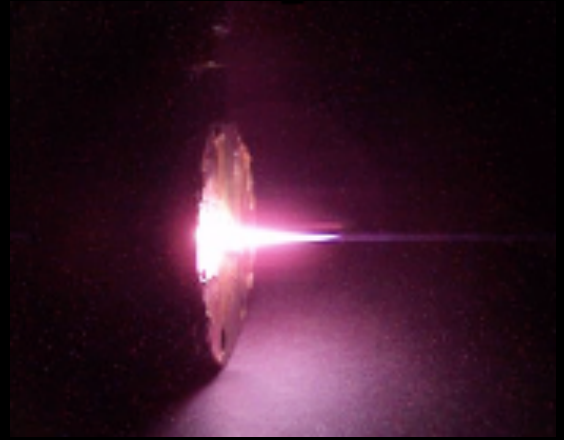
Inhibited-coupling guiding HCPCF



The extremely cold
S. Okaba et al. Nature Comm. 5, 4096 (2014)

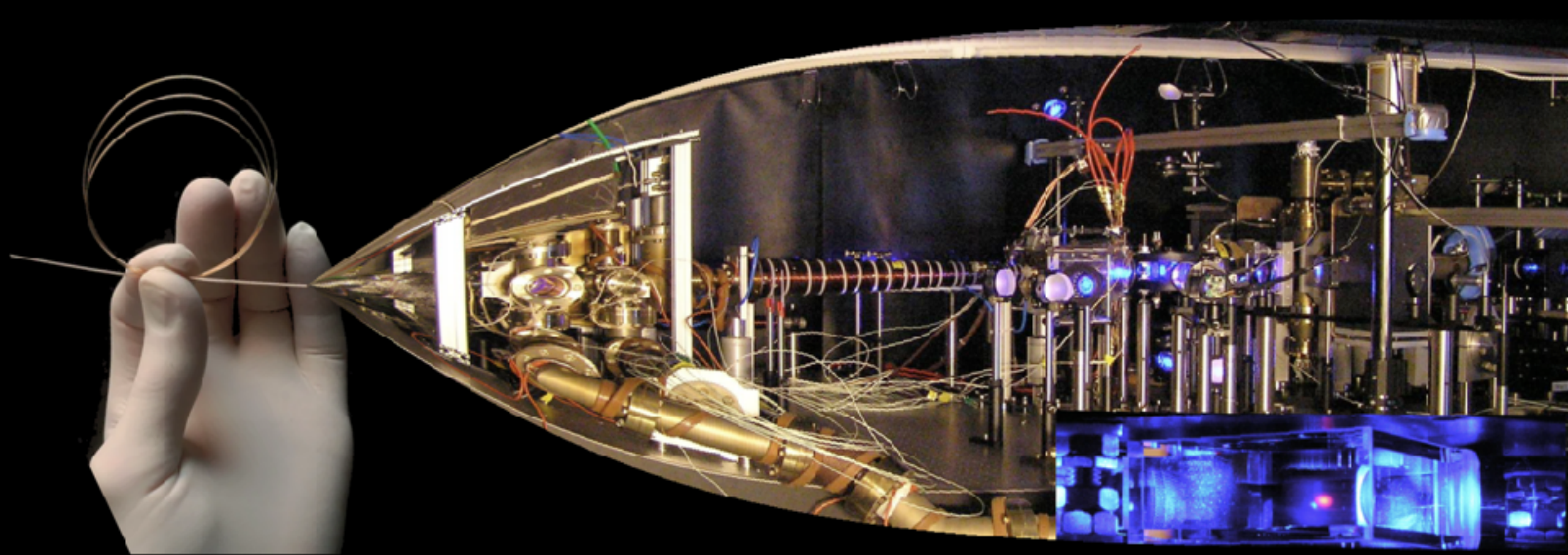


The extremely hot



Highly ionised and hot ($\sim 1000\text{K}$) gas in Kagome HC-PCF

B. Debord et al. Opt. Express 22,10735-10746 (2014)



By confining light + atoms on length scales over kms, we can arrive at Orders of Magnitude Larger Atom-Light Interactions in a compact, simple platform

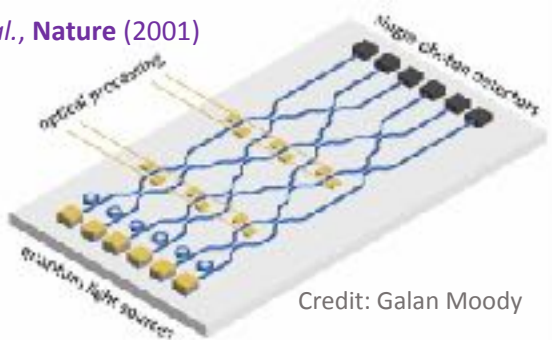
- volume reduced from m^3 to 100s um^3 !!!



Quantum tech

Linear optical quantum computation

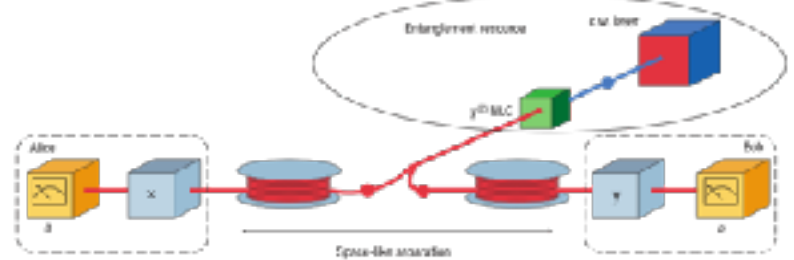
Knill *et al.*, *Nature* (2001)



Credit: Galan Moody

Quantum key distribution

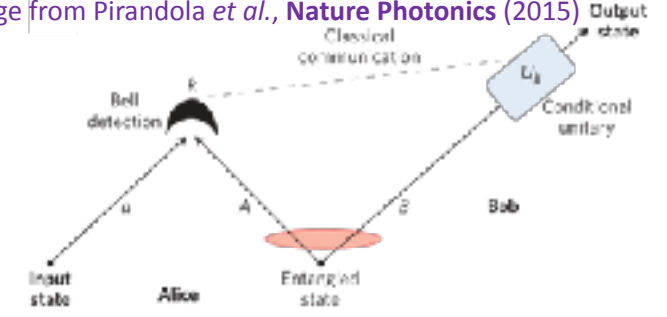
Gisin *et al.*, *Nature Photonics* (2007)



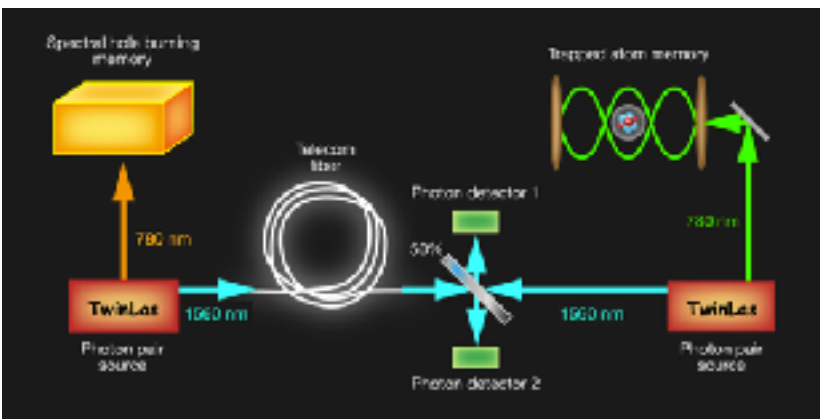
Quantum teleportation

Bowmeester *et al.*, *Nature* (1997)

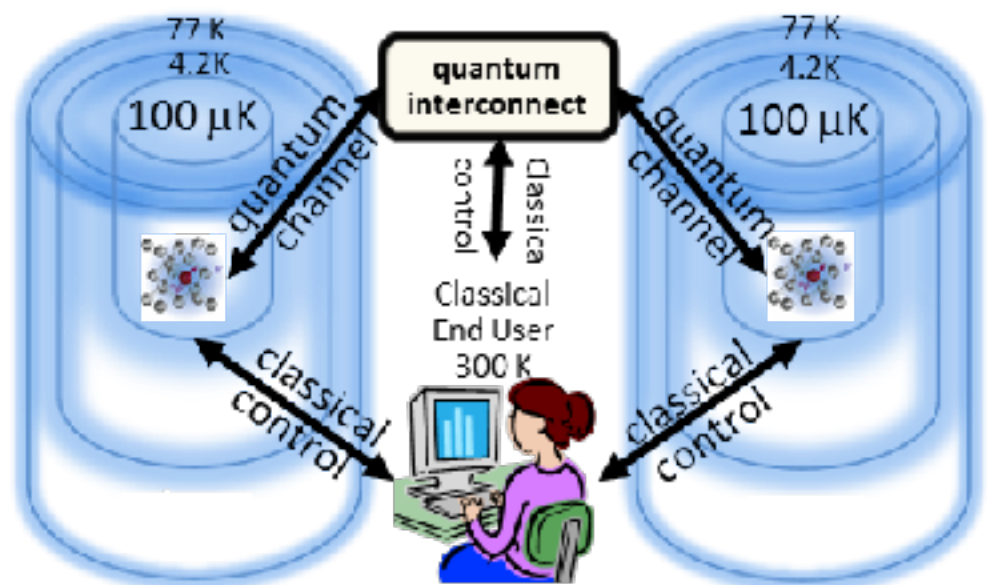
Image from Pirandola *et al.*, *Nature Photonics* (2015)



Quantum Memories



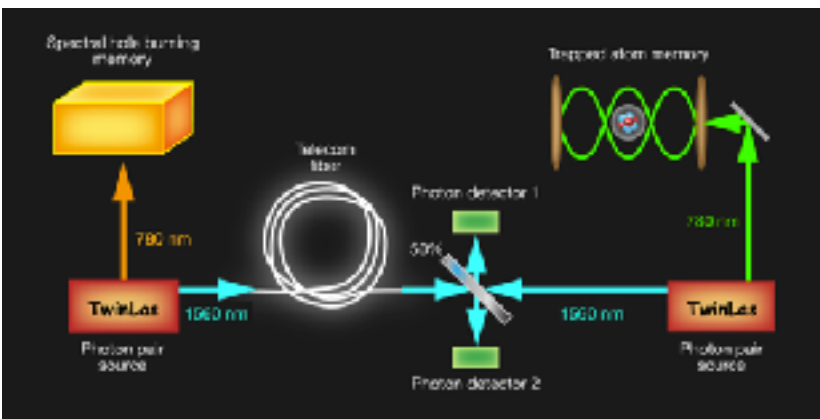
Quantum Interconnects



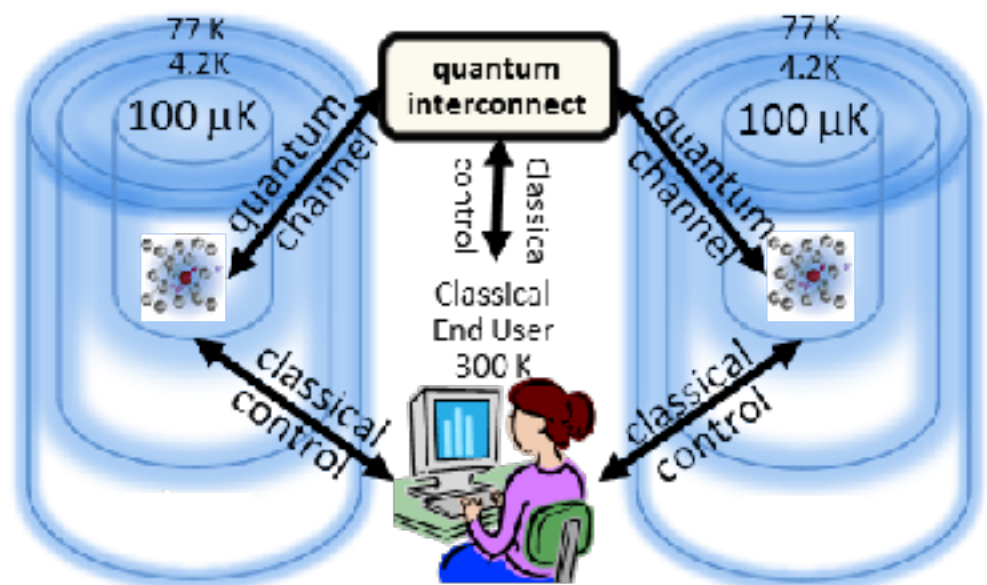


The effectiveness for all these quantum technologies depends on maximizing the correlations within the photon pair and minimizing uncorrelated photons ...

Quantum Memories



Quantum Interconnects



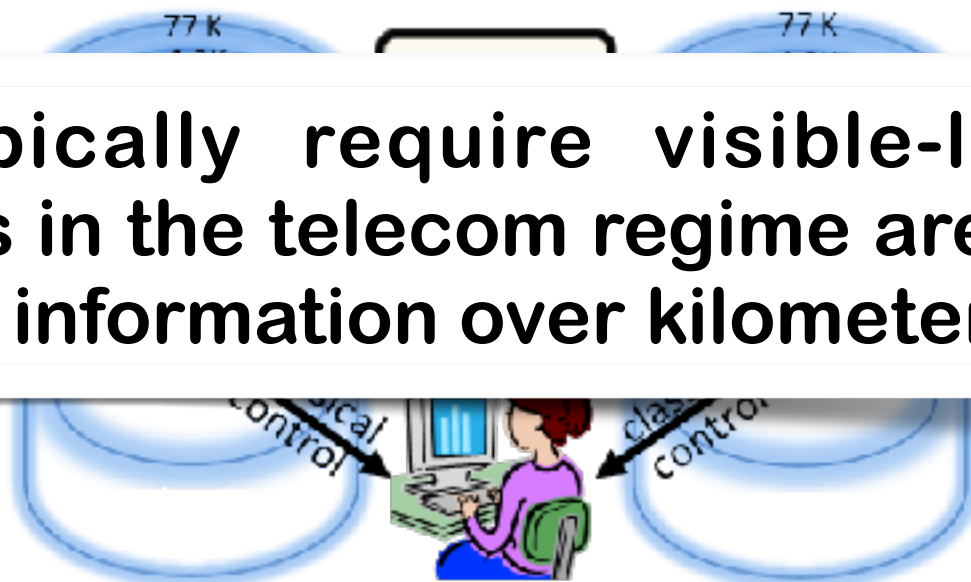
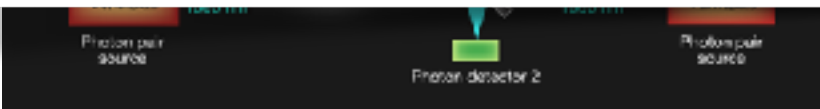


The effectiveness for all these quantum technologies depends on maximizing the correlations within the photon pair and minimizing uncorrelated photons ...

Quantum Memories

Quantum Interconnects

Quantum Memories typically require visible-light photons however, photons in the telecom regime are far superior to transport that information over kilometers

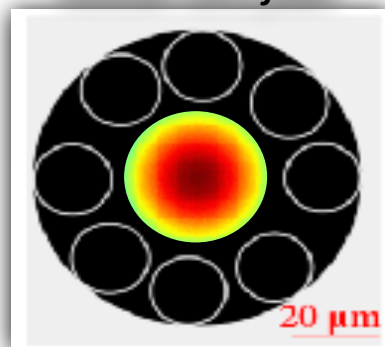
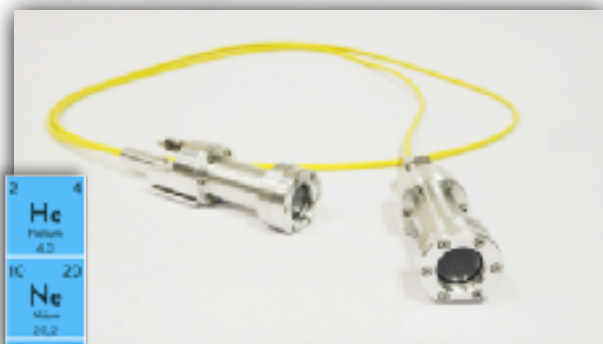




Versatile Entangled Photon Source

Nobel Gass filled Photonic Microcell

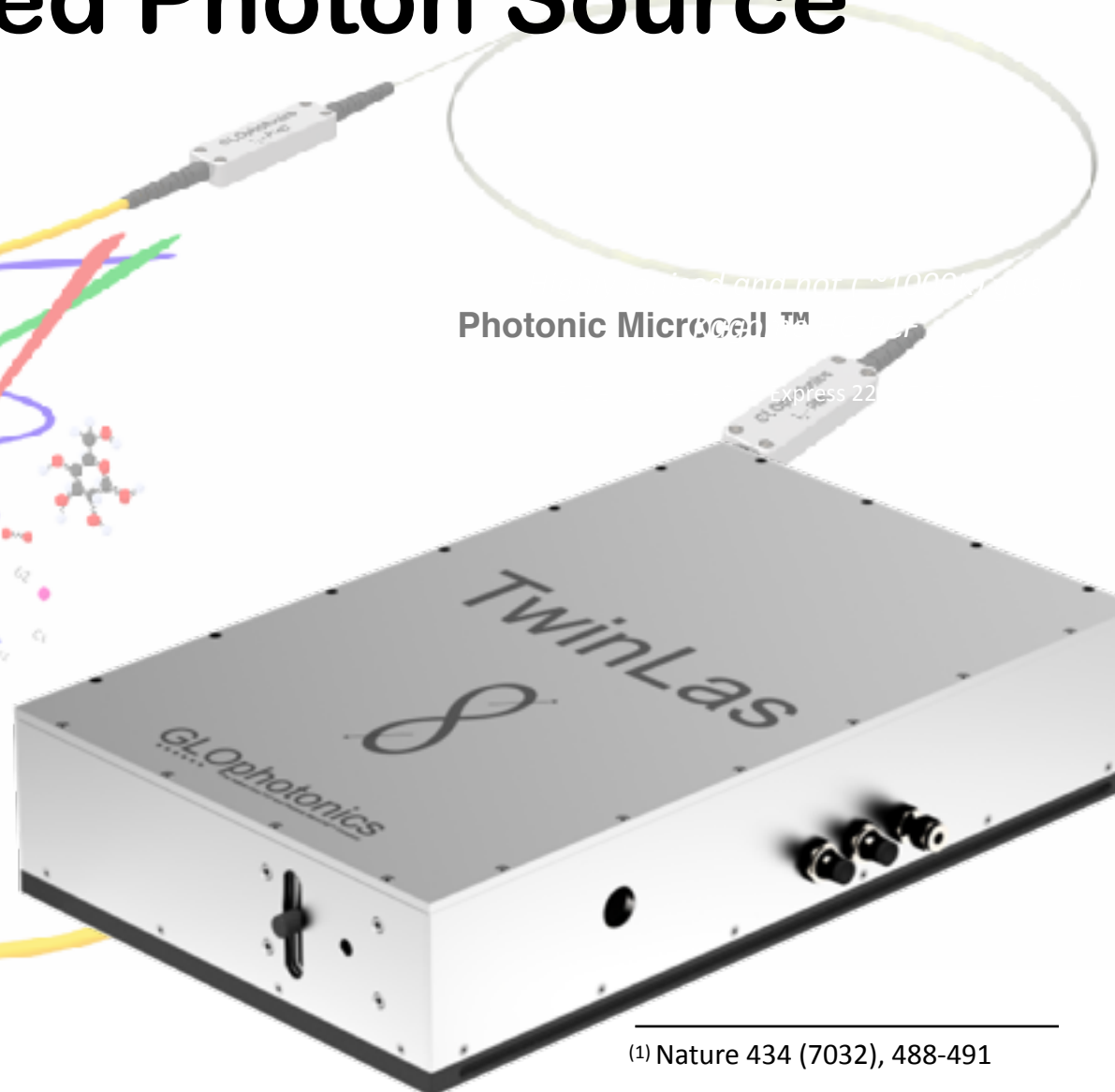
Inhibited-coupling hollow-core fiber



2	He	4
10	Ne	20
18	Ar	40
36	Kr	84
54	Xe	129
86	Rn	222

Versatile platform for photon-pair generation

- Small modal area and long interaction length
- Engineerable dispersion
- Raman free propagation



Photonic Microcell™

Express 22

TwinLas

GL Ophotonics

Non-Linearity

Un-Correlated Photons ?

Spectral Range

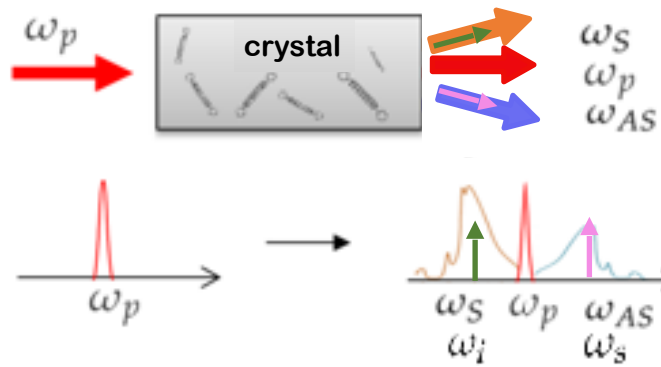
Crystals (BBO, PPLN, LiNbO3)

Limited by Crystal Dimensions

produced by Raman Scattering in crystal

Limited by Crystal Structure

Crystal (BBO, PPLN, LiNbO3)



Non-Linearity

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Spectral Range

Crystals (BBO, PPLN, LiNbO3)

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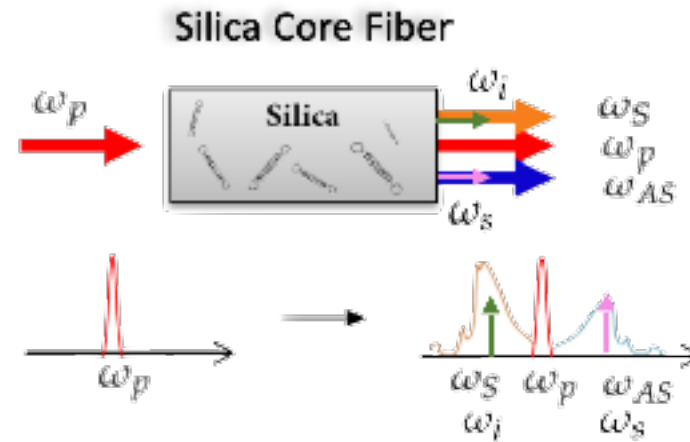
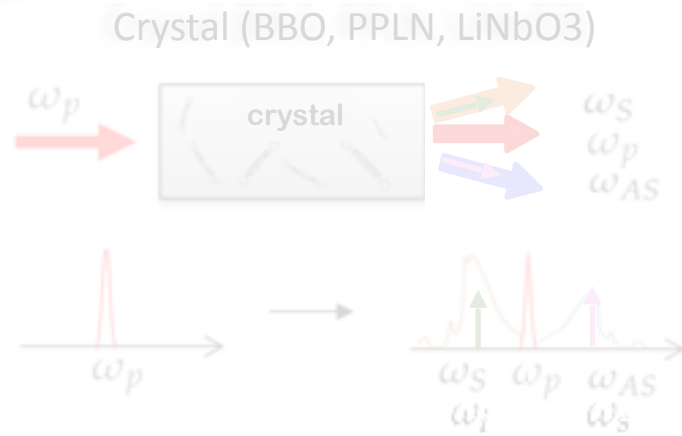
Limited by Crystal Structure

Silica Fiber

Tuneable by fiber geometry

produced by Raman Scattering along silica fiber length

small bandwidth



Non-Linearity

Un-Correlated Photons ?

Spectral Range

Crystals (BBO, PPLN, LiNbO3)

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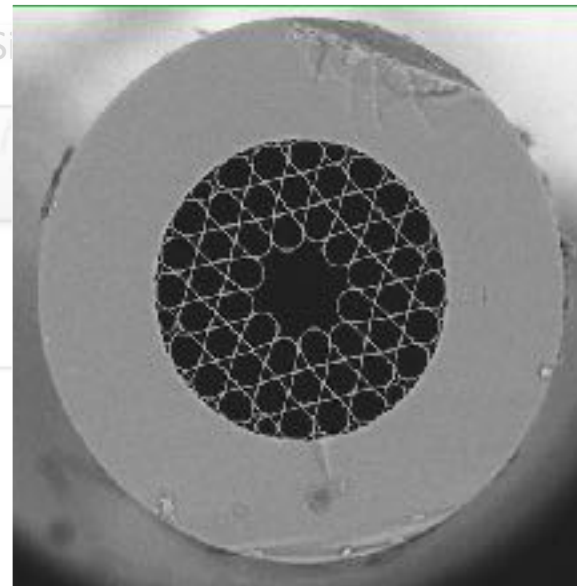
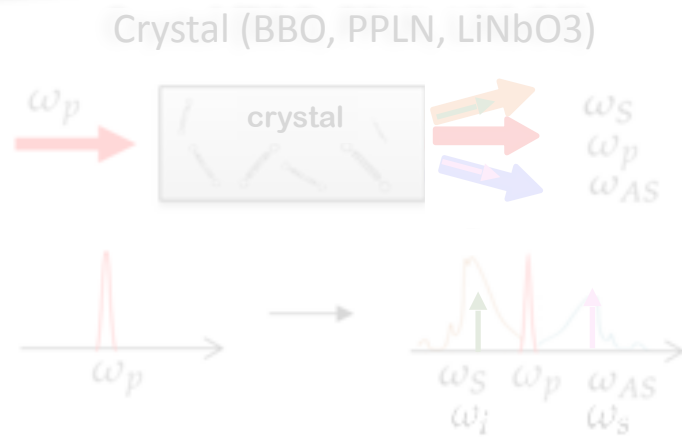
small bandwidth

TwinLas (IC + Xenon)

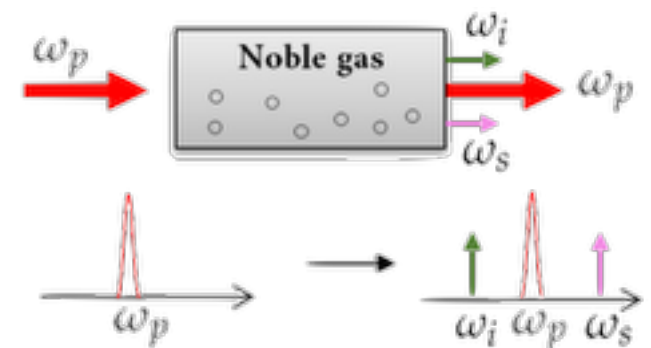
Tuneable by fiber geometry

Zero due to lack of molecular structure in Xenon

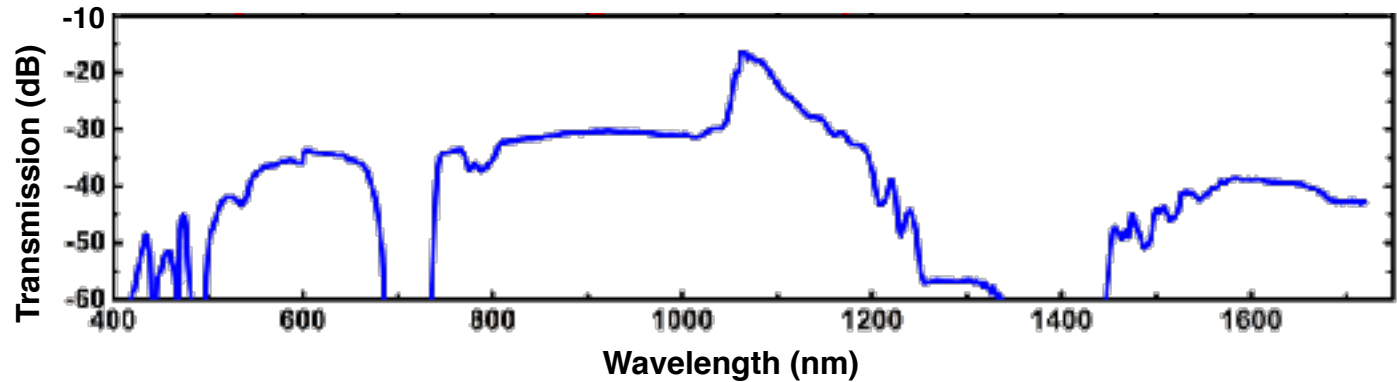
Entire Optical Spectrum



Noble gas-filled hollow-core fiber



Large Spectral Domain !!!



Creating Entangled Photons anywhere on the visible spectrum

Crystals (BBO, PPLN, LiNbO3)

Silica Fiber

TwinLas (IC + Xenon)

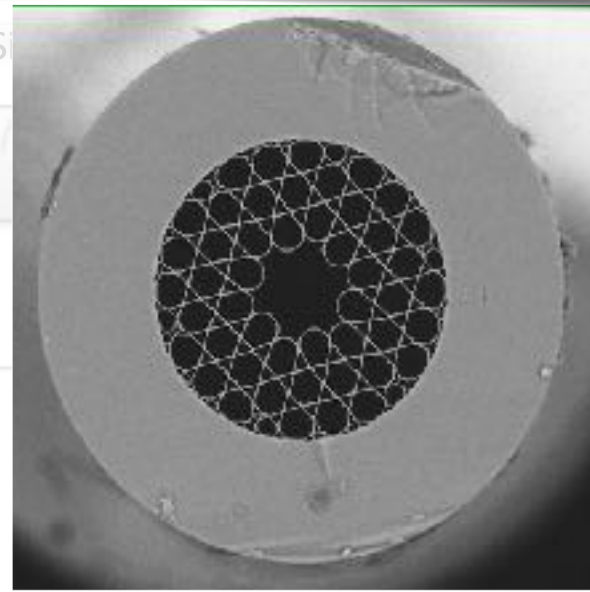
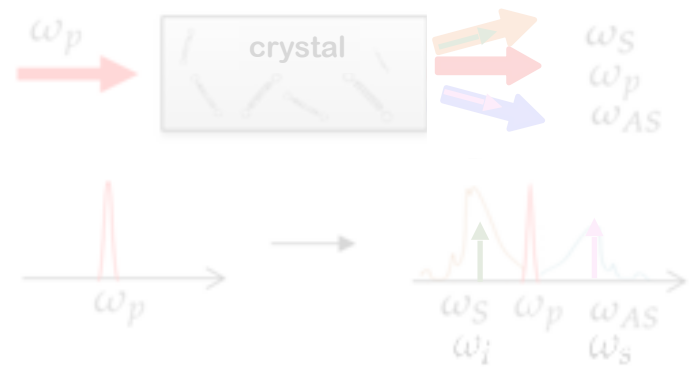
Spectral Range

defined by Crystal Structure

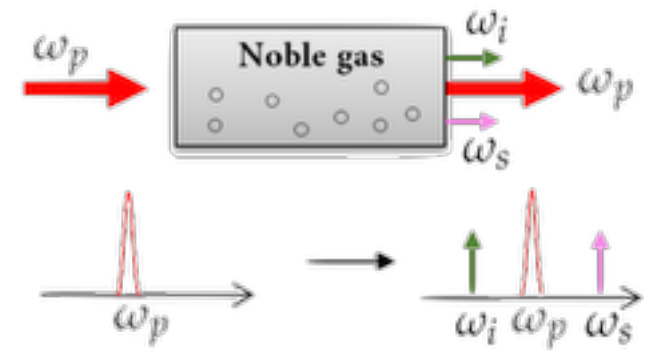
small bandwidth

wide Optical Spectrum

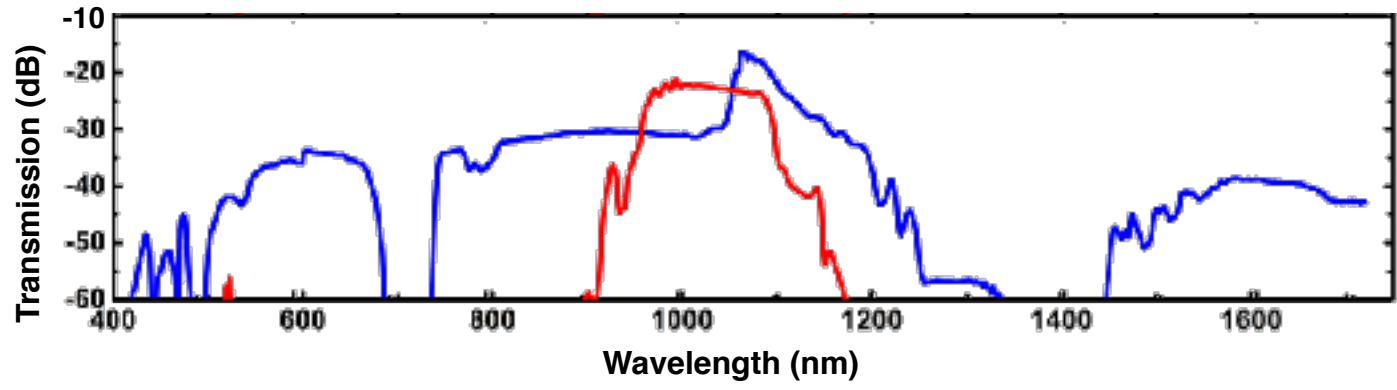
Crystal (BBO, PPLN, LiNbO3)



Noble gas-filled hollow-core fiber



Large Spectral Domain !!!



Much larger Domain with respect to Photonic Bandgap or Free Space

Spectral Range

defined by Crystal Structure

small bandwidth

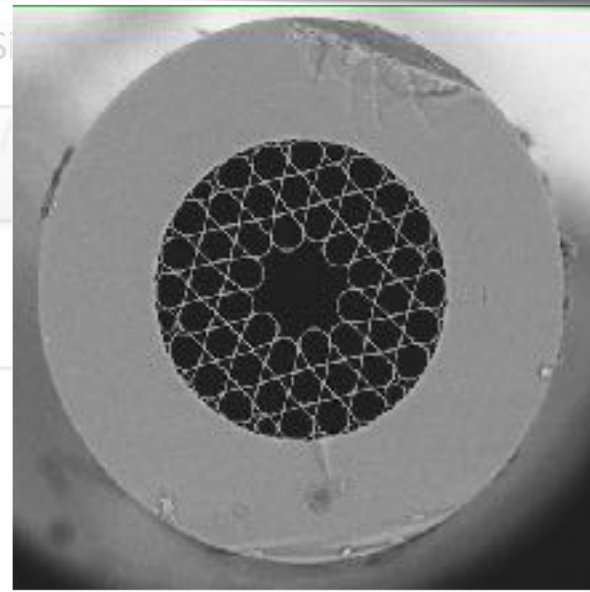
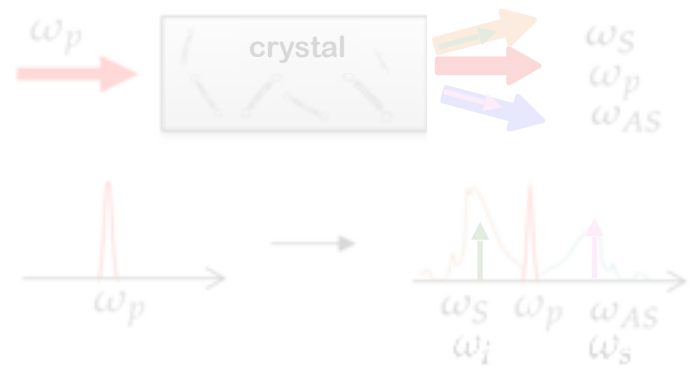
cover Optical Spectrum

Crystals (BBO, PPLN, LiNbO3)

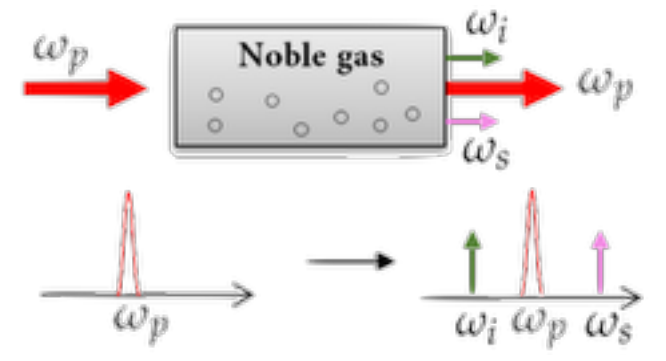
Silica Fiber

TwinLas (IC + Xenon)

Crystal (BBO, PPLN, LiNbO3)



Noble gas-filled hollow-core fiber



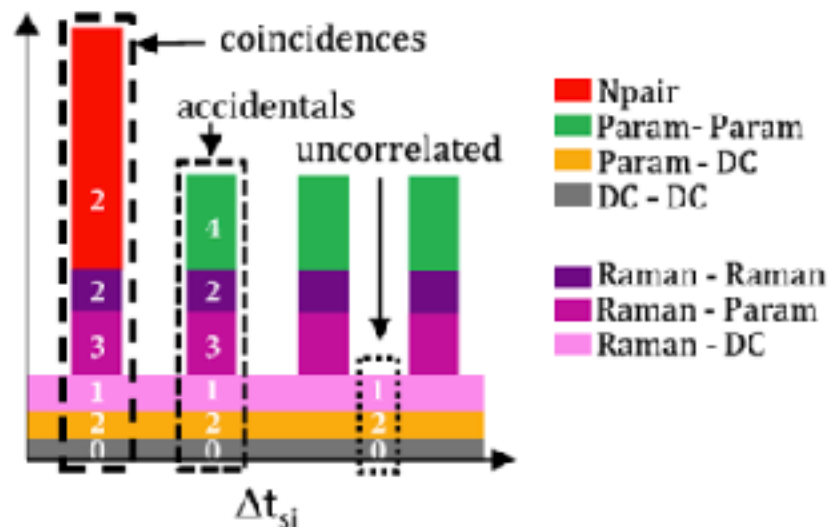
Lowest Uncorrelated Photon Count !!!

Crystals (BBO, LiNbO3)

Silica Fiber

TwinLas (IC + X)

Source with Raman-scattering



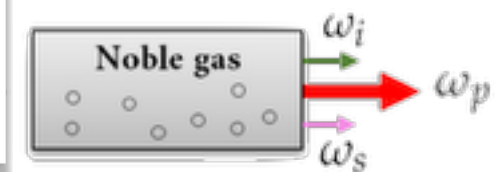
Spectral Range

defined by Crystal Structure

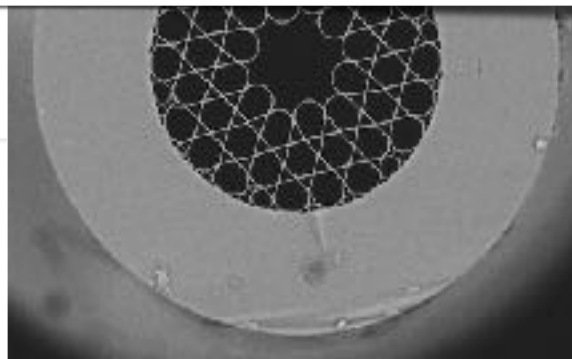
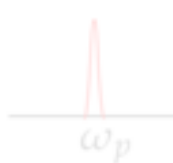
small bandwidth

wide Optical Spectrum

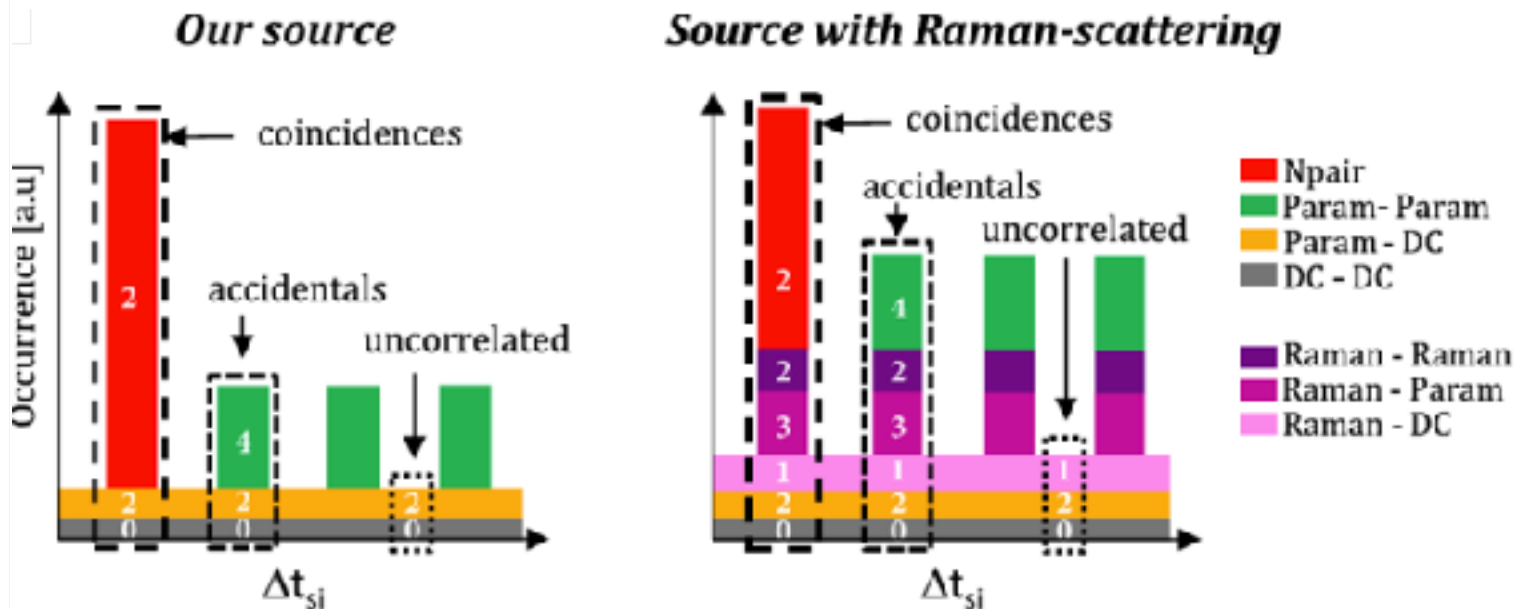
gas-filled hollow-core fiber



Crystal (BBO, P)



Lowest Uncorrelated Photon Count !!!



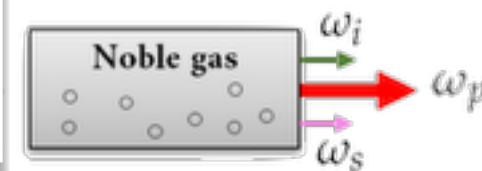
Spectral Range

defined by Crystal Structure

small bandwidth

wide Optical Spectrum

gas-filled hollow-core fiber

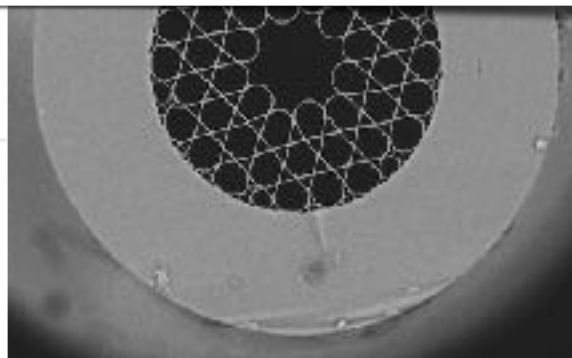
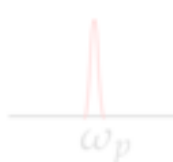
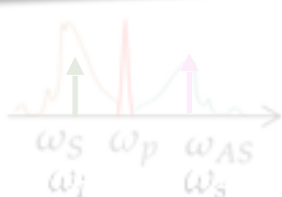
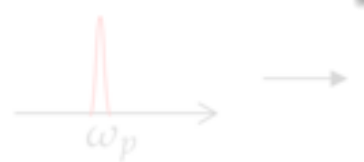


Crystals (BBO, LiNbO3)

Silica Fiber

TwinLas (IC + X)

Crystal (BBO, P)



Reduced Photon Count !!!

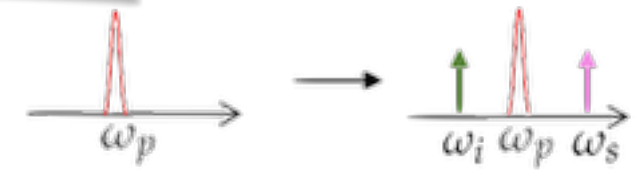
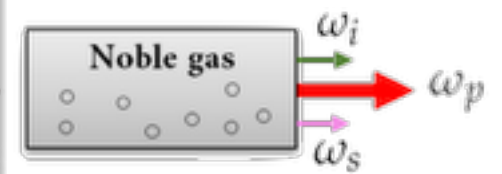
Spectral Range

defined by Crystal Structure

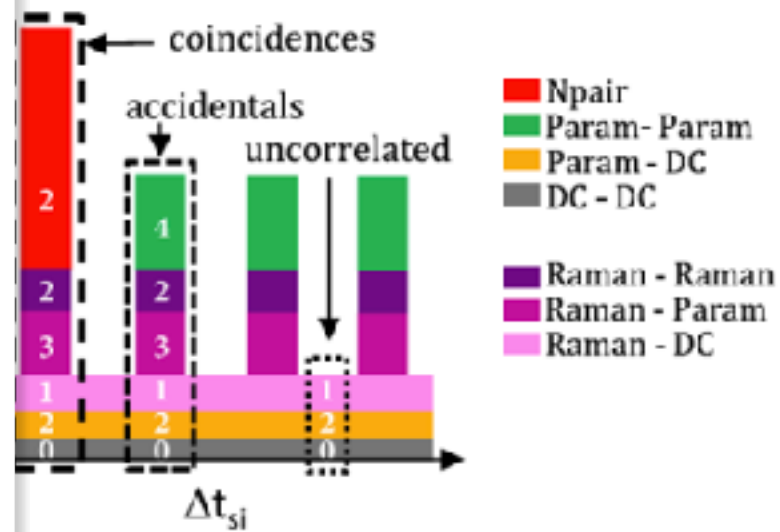
small bandwidth

wide Optical Spectrum

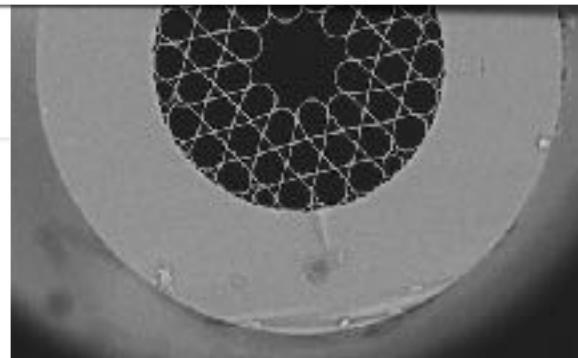
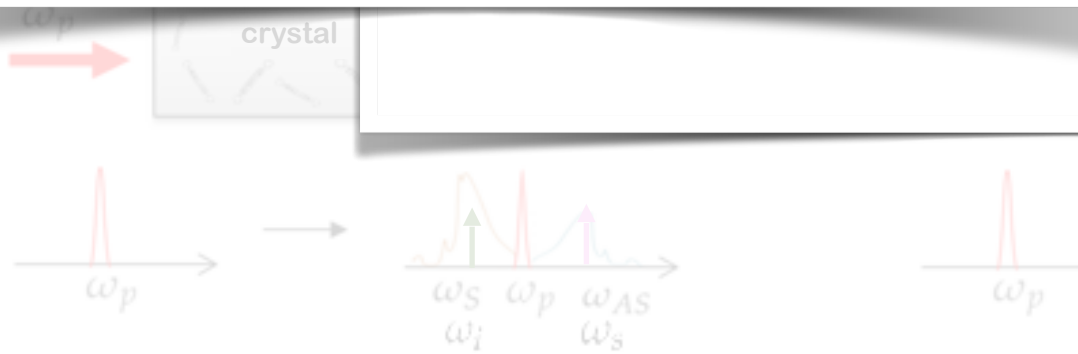
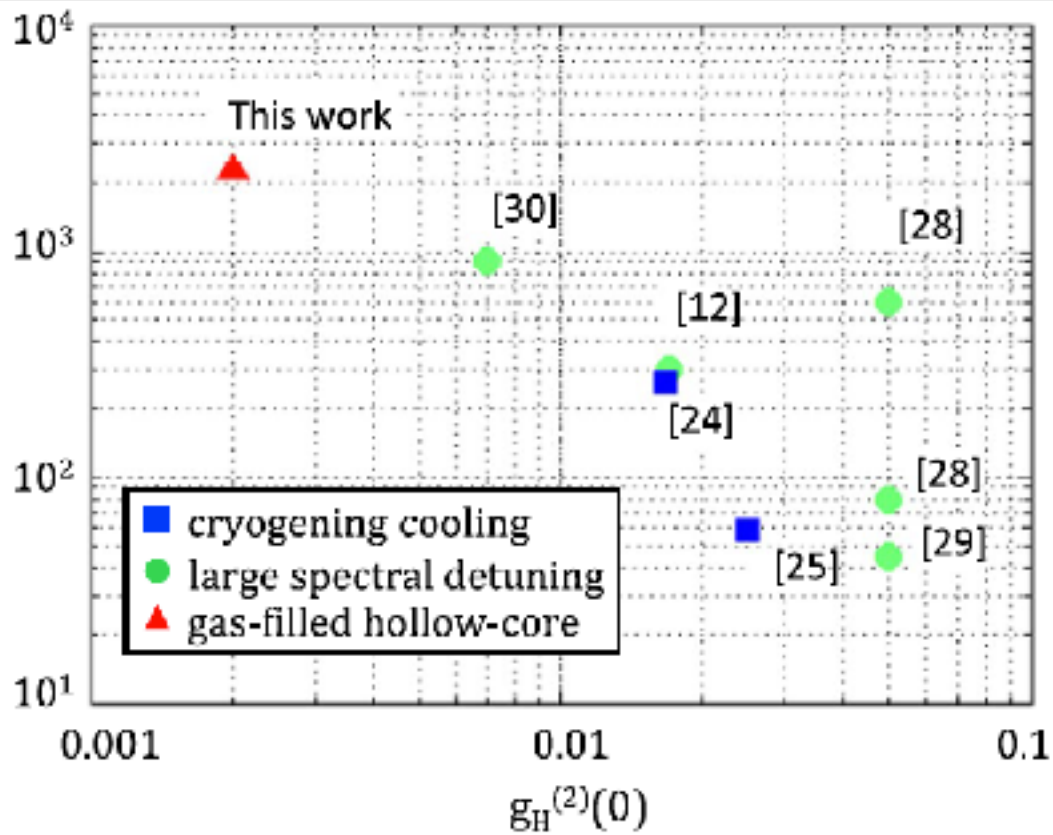
gas-filled hollow-core fiber



Process with Raman-scattering



Occurance/Accidental

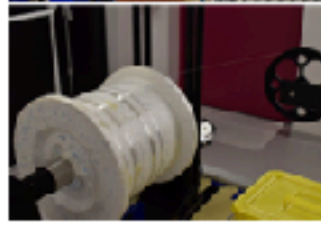
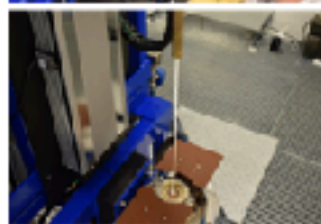
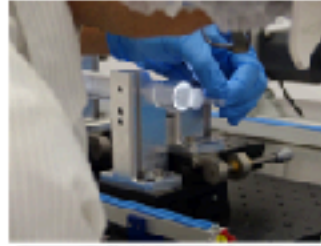




Quantum tech

Unique chain of

Knowledge-base, know-how and facility for highly tailored HCPCF & PMC



<i>In-fiber gas processing</i>	<i>Glass post-processing</i>	<i>Micro-lensing</i>	<i>Fiber side engraving</i>	<i>Fiber-fiber splicing</i>