Nothing beats silica

The hollow-core fibre revolution

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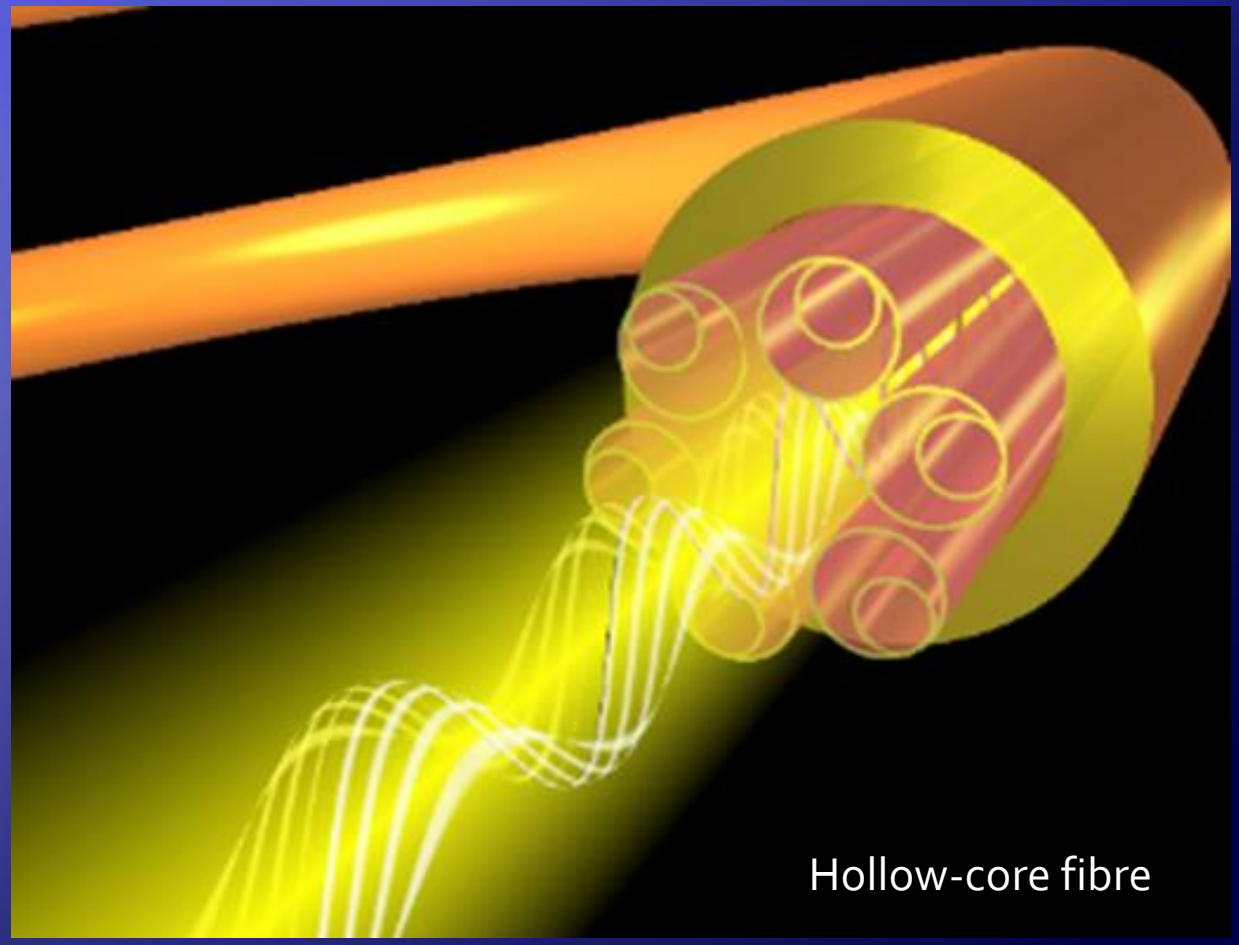


Hollow-core fibre

What's wrong with the global internet? Can we fix it?

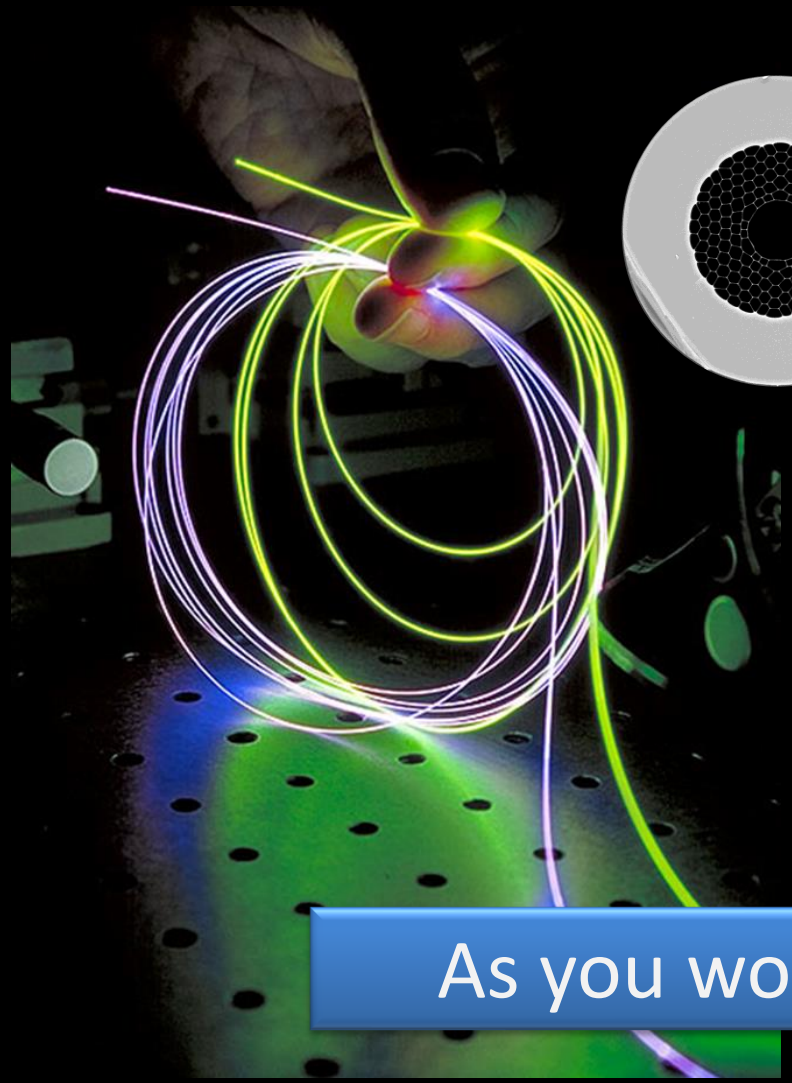
- 99% of all internet traffic travels on optical fibre
- Approaching 5GKm of fibre installed – new installations circle the earth every hour

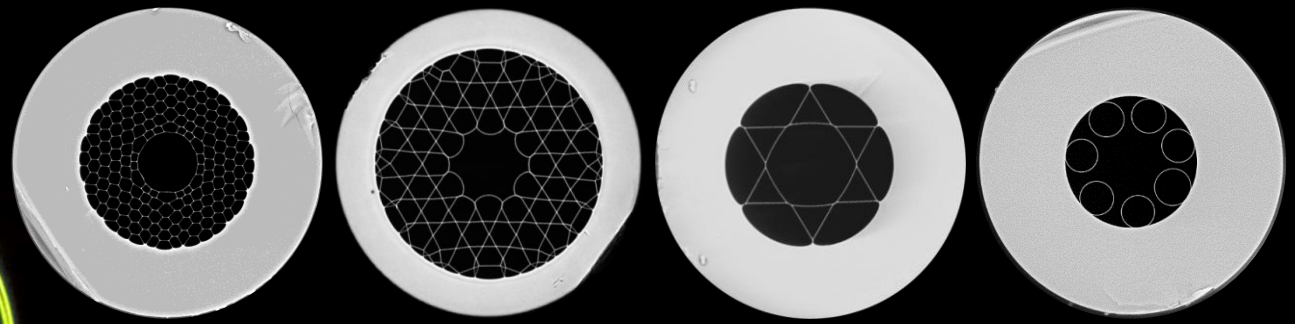
Was Charles Kao right – silica is the best material?

- The fibre loss is too high – 0.148dB/km at 1.55µm for the last 40 years
- The delay is an increasing problem
- The tyranny of wavelength - who needs 1550nm?

Air is better than glass!
Hollow-core microstructured fibres

Properties largely independent of cladding material





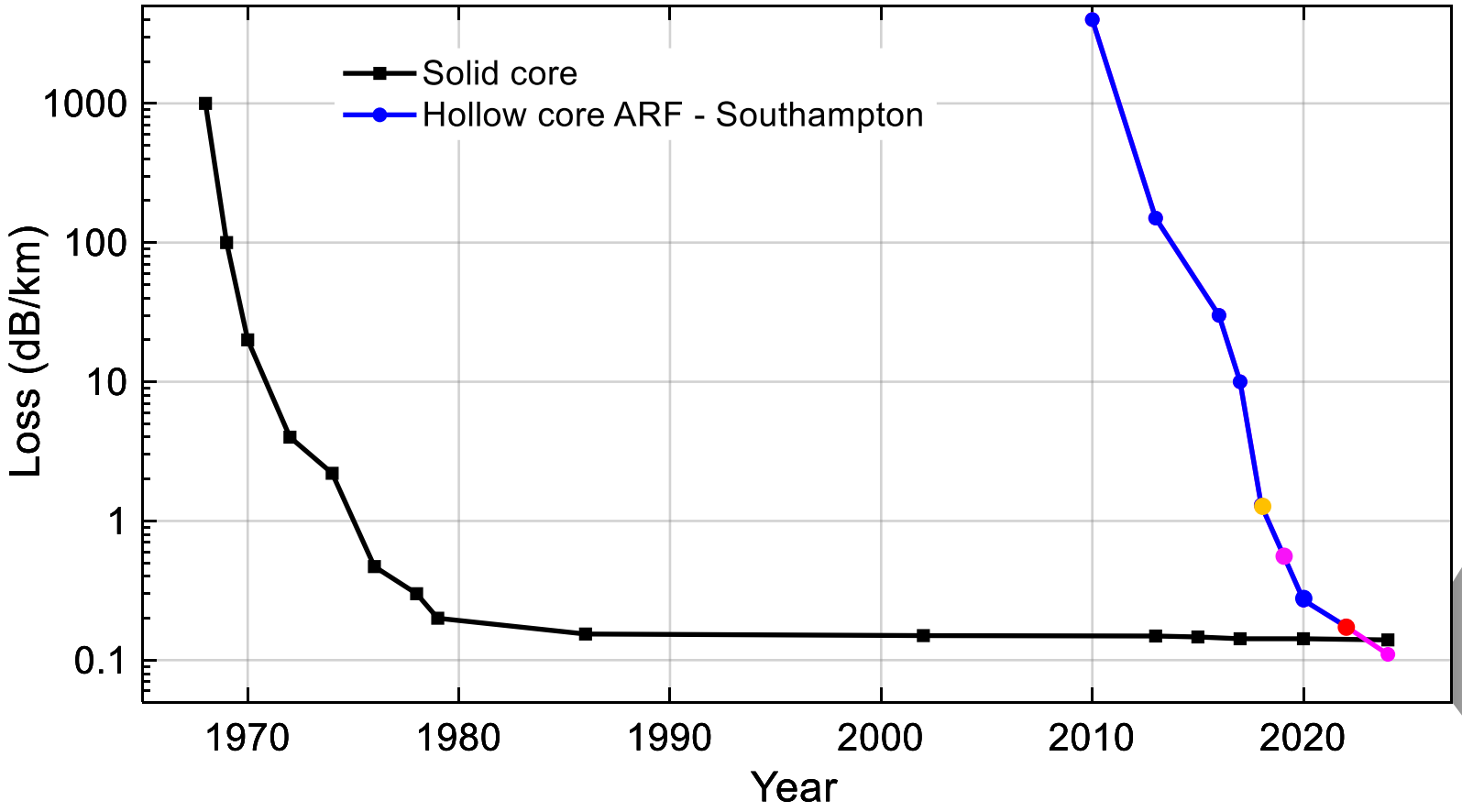
Vast range of fibre designs:

- Low nonlinearity
- 30% lower latency
- Low dispersion
- Wide spectral window
- High damage threshold (kW over kms)
- Radiation hard
- Temp coef of phase/group delay can be zero
- A complete solution to QKD
- Perfect for optical fibre gyros

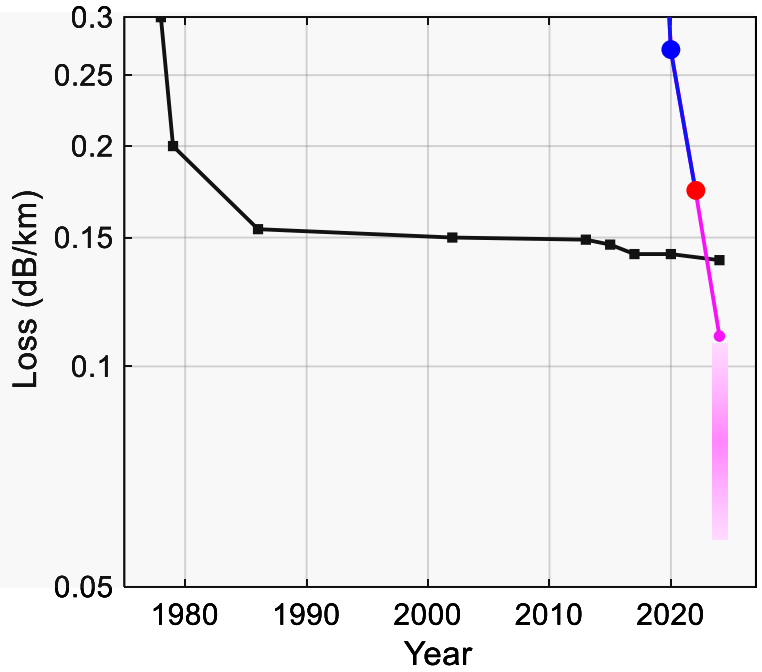
As you would expect from air!

History repeats itself

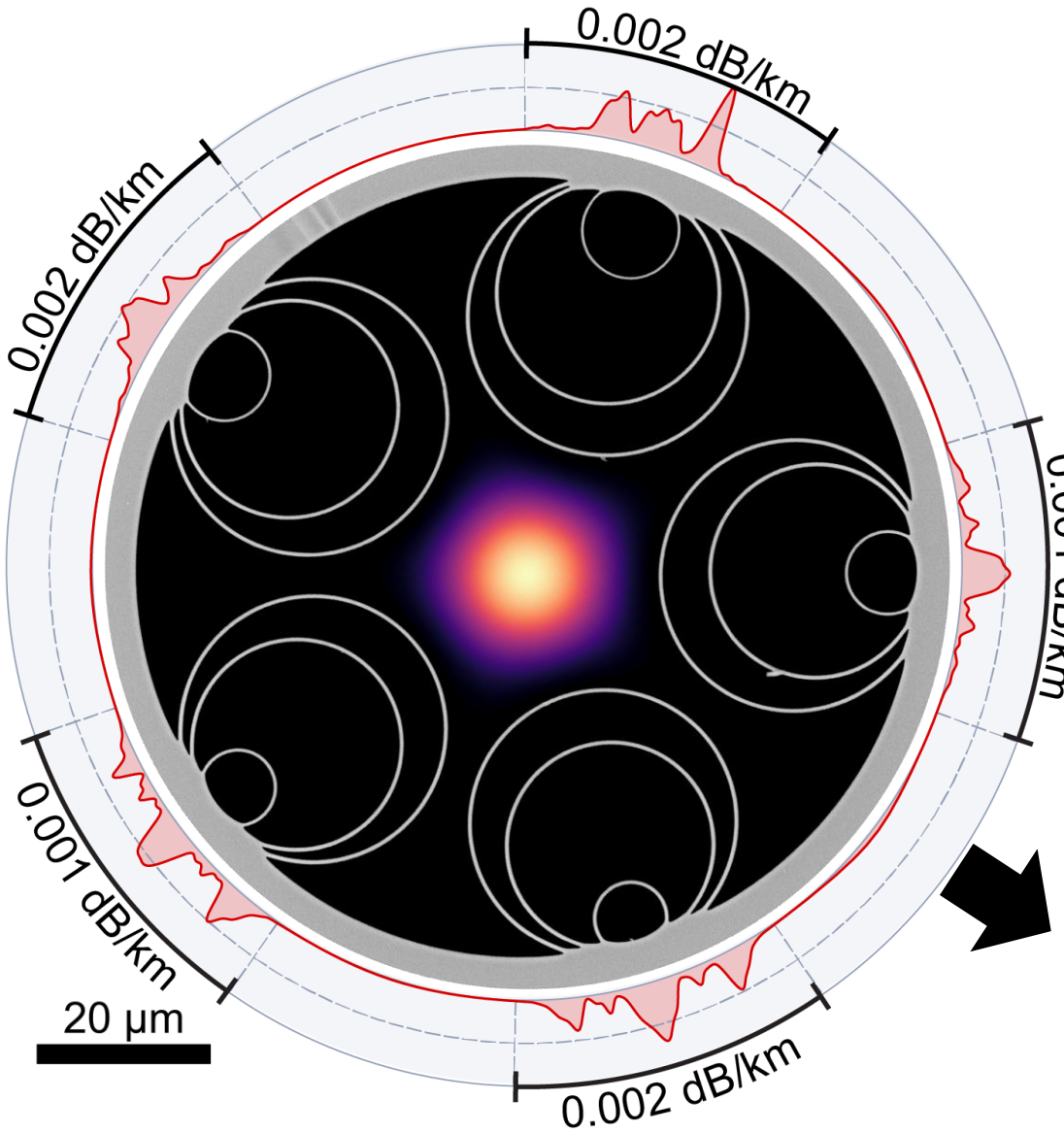
40 years later



HC-NANF:
From 1.3 to 0.11 dB/km
in 6 years



The latest fabricated fibre



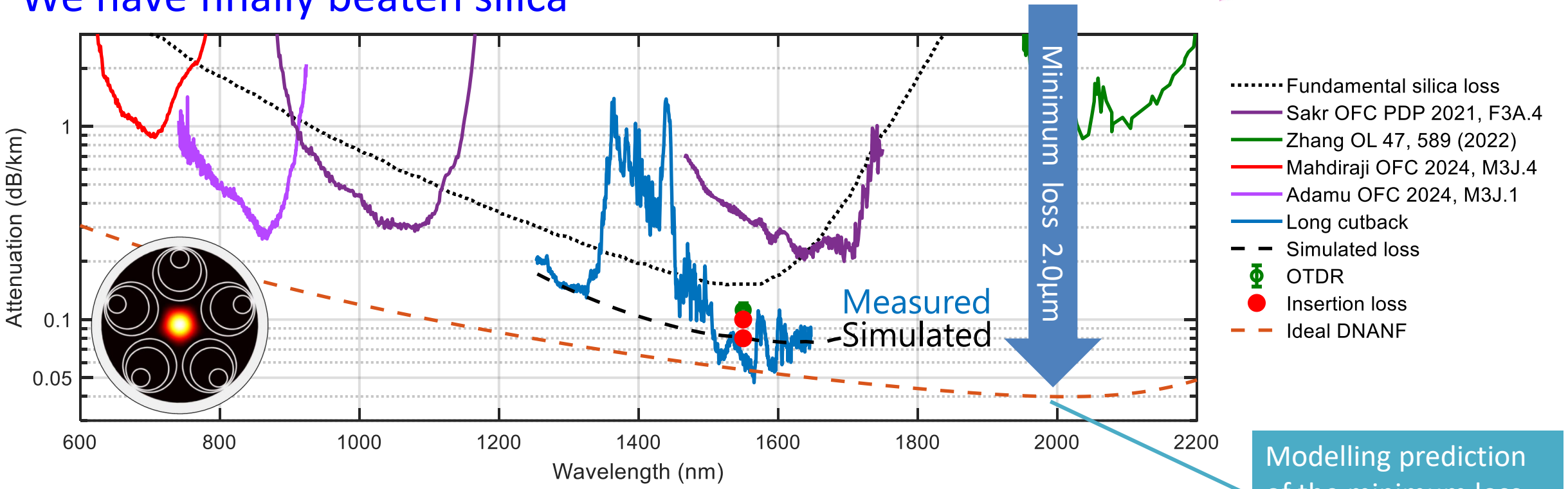
Length: **4.12 km**

	Azimuthal and longitudinal average (µm)
Core diameter	28.8 ± 0.5
Average Azimuthal Gaps	4.4 ± 0.5
Cap diameter (out)	31.0 ± 1.5
Cap diameter (middle)	24.8 ± 2.0
Cap diameter (inner)	10.0 ± 3.0

Loss contributions:
- Scattering: 68%
- Microbend: 21%
- Confinement: 11%

DNANF: lower loss wherever you need it

We have finally beaten silica



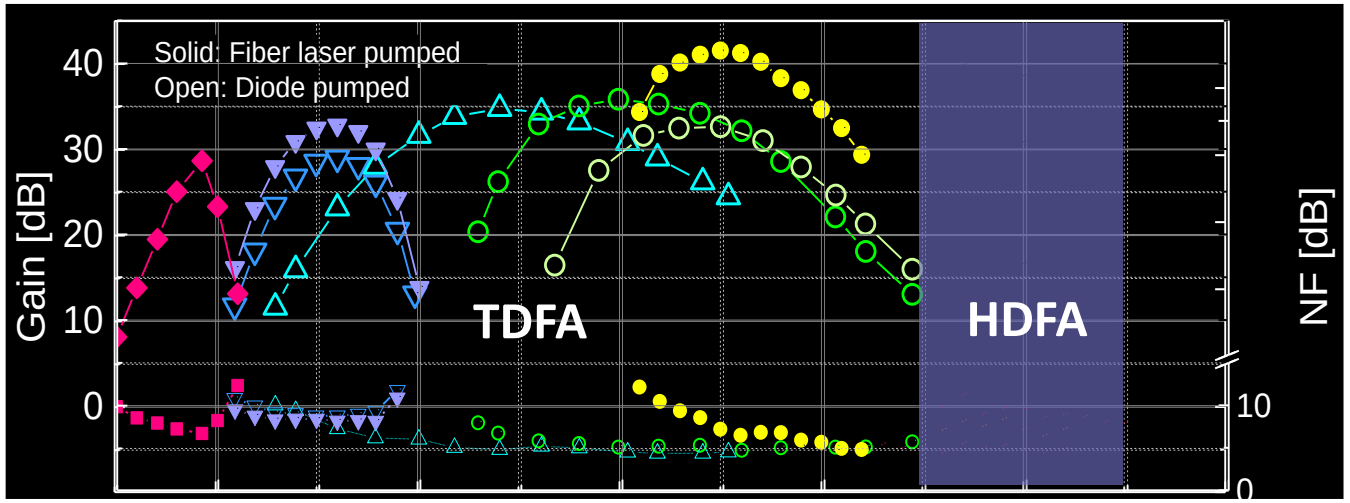
- **Loss now <0.11 dB/km** (**0.08 dB/km** mean value) at 1550 nm
- **Note: 0.5dB/km at 850nm**

Modelling prediction of the minimum loss achievable in a fully optimised DNANF

0.02 dB/km achievable?

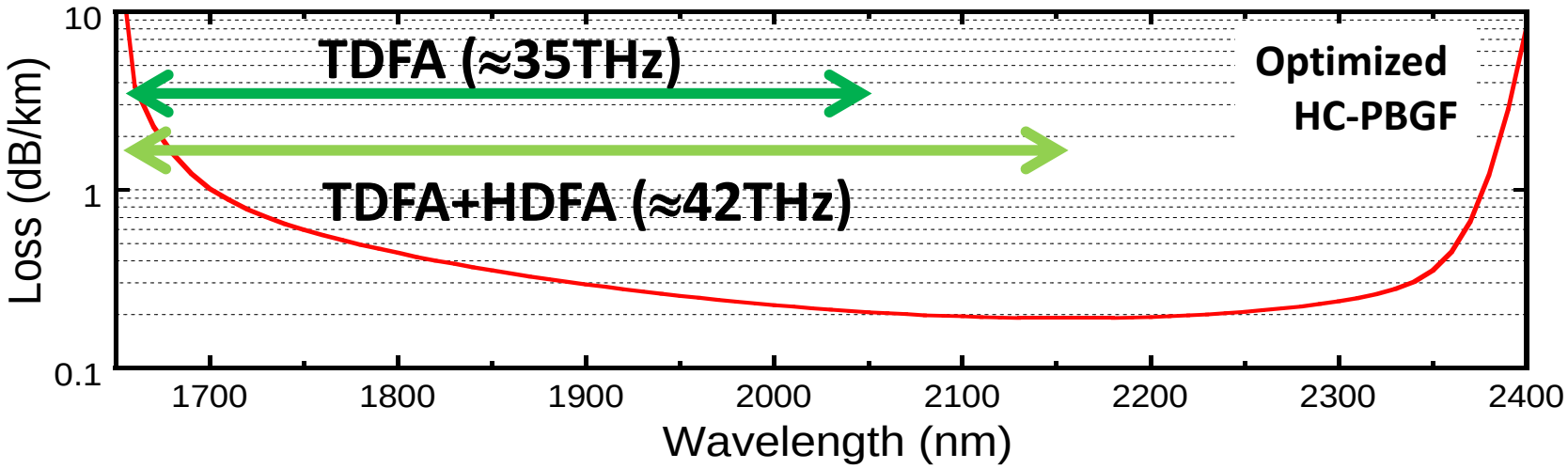
Eric Numkam Fokoua et al., "Loss in hollow-core optical fibers: mechanisms, scaling rules, and limits," Adv. Opt. Photon. 15, 1-85 (2023)

Do we have amplifiers at other wavelengths?



Potential Capacity Improvement (as compared to **C+L**):

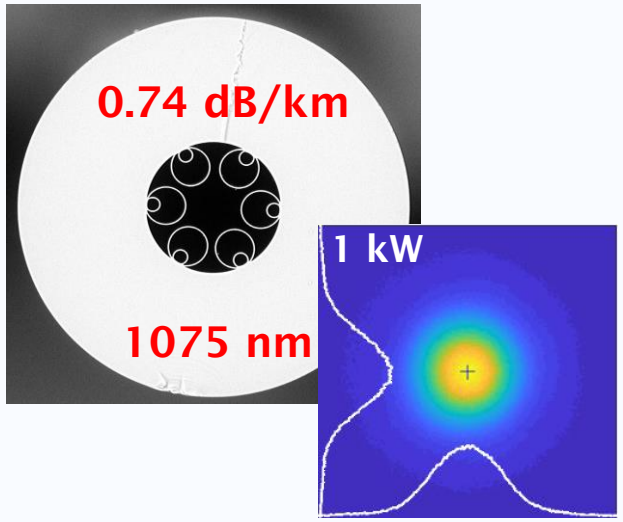
- **x3-x4** from Wider BW
- **x3** from Ultralow Nonlinearity



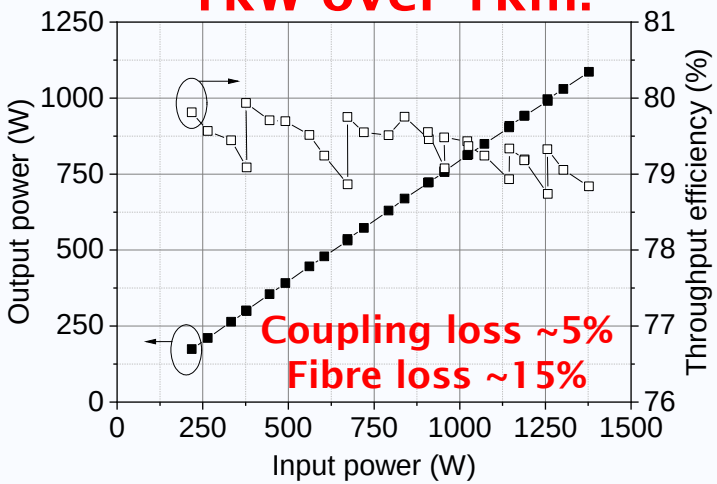
TDF and HDF Amplifiers with high gain and low NF demonstrated

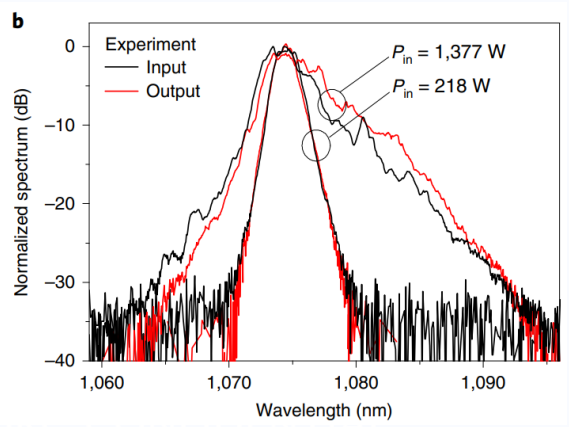
kW laser delivery

- Low loss and nonlinearity enables kW over km single-mode laser delivery

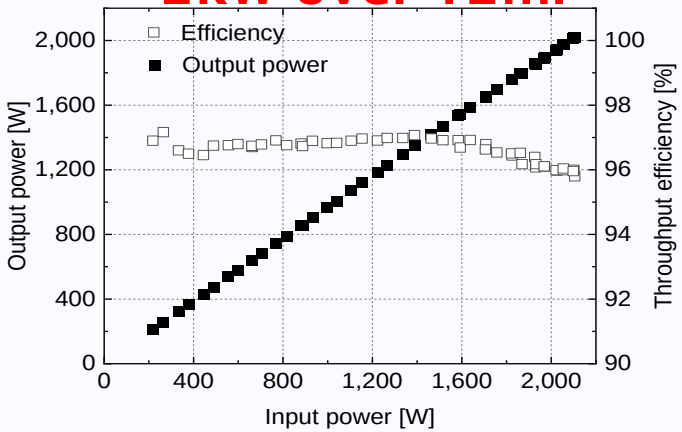


1kW over 1km:





2kW over 12m:

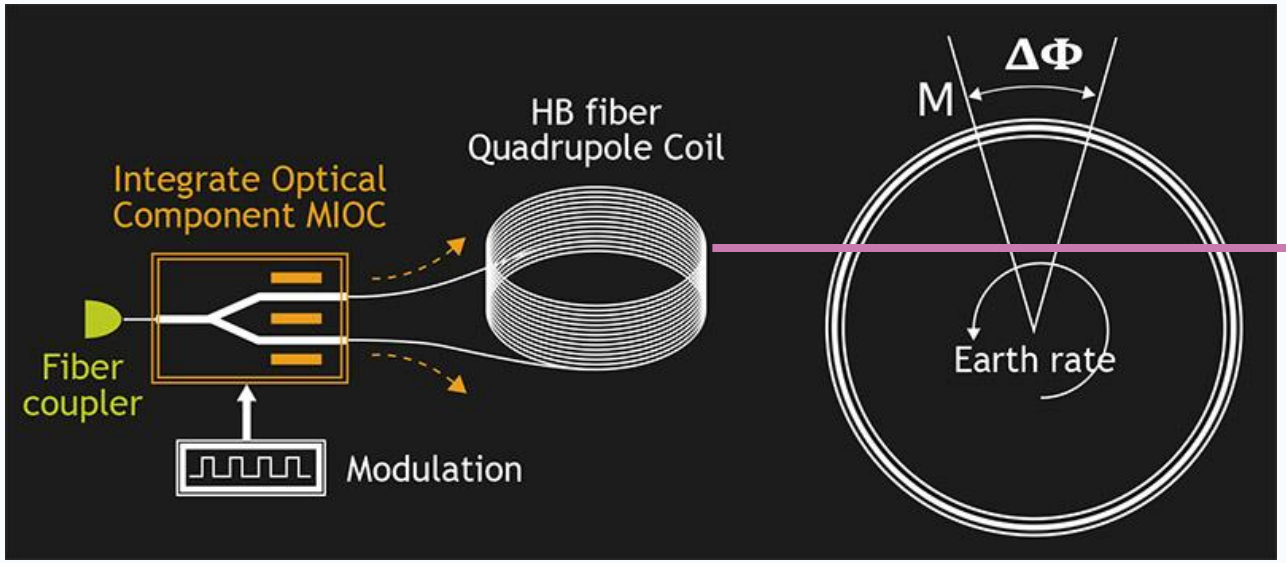


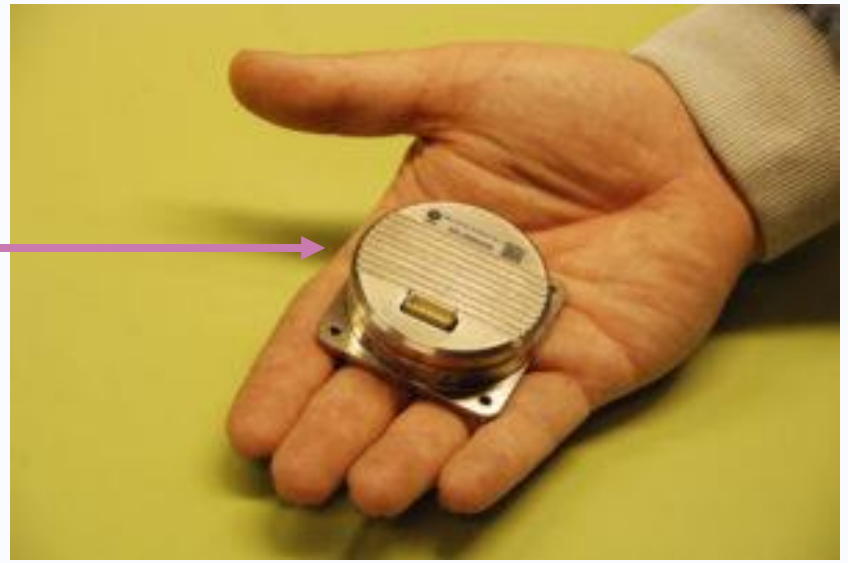
aramco

Laser drilling of oil wells

Simulations indicate this is scalable to even higher powers (e.g. 10kW over ~1km)

Fibre gyroscopes





- Used for inertial navigation/stabilization, especially in Aerospace
- Increased accuracy using resonant fibre gyro architecture requires PM fibers with low thermal sensitivity, nonlinearity and backscattering
- → HCFs ideal replacement for standard optical fibre.

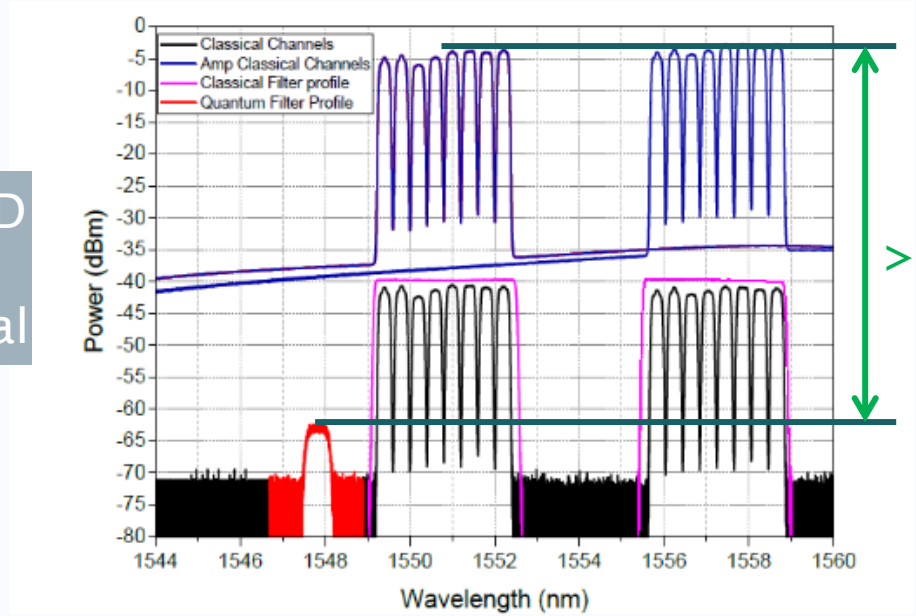
Sanders et al, Hollow-core resonator fiber optic gyroscope using nodeless anti-resonant fiber," Opt. Lett. 46, 46-49 (2021)

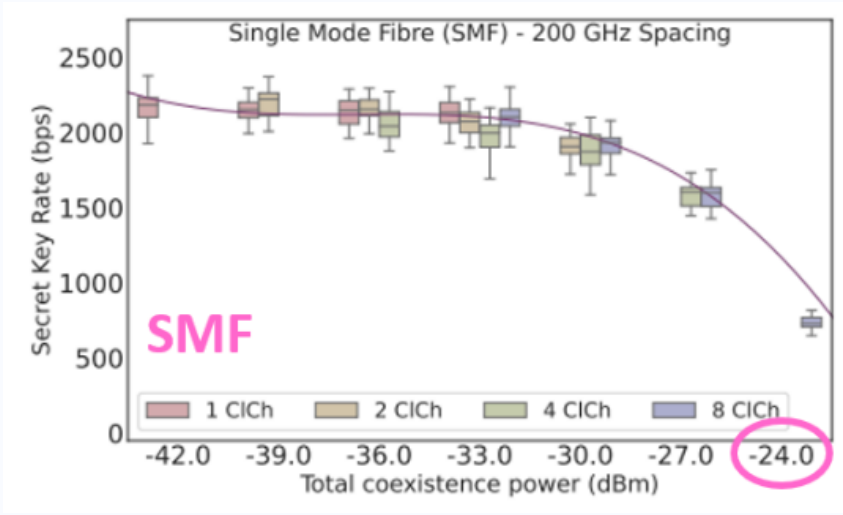
Improving transmission security through QKD

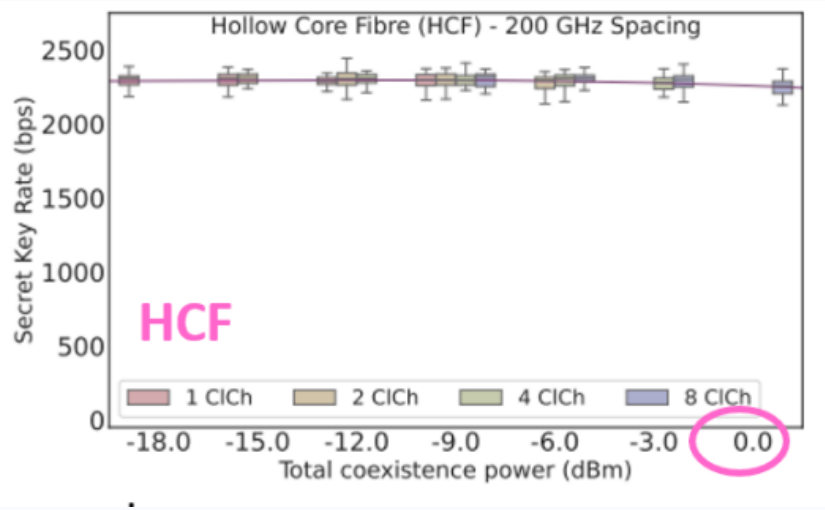
University of Southampton

Absence of nonlineairties enables the **coexistence of quantum and classical** channels:

DV-QKD + classical







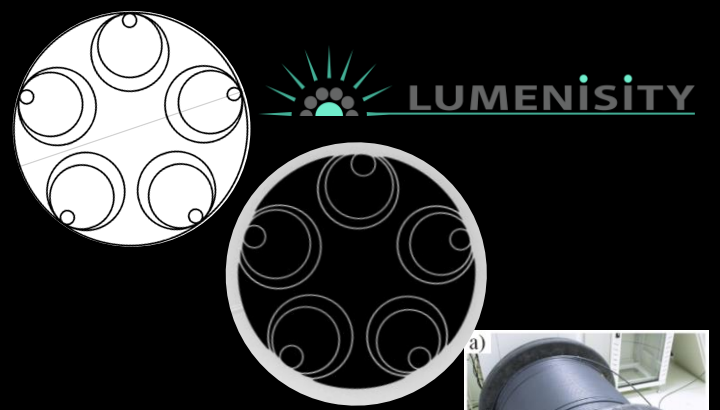
University of BRISTOL Smart Internet Lab

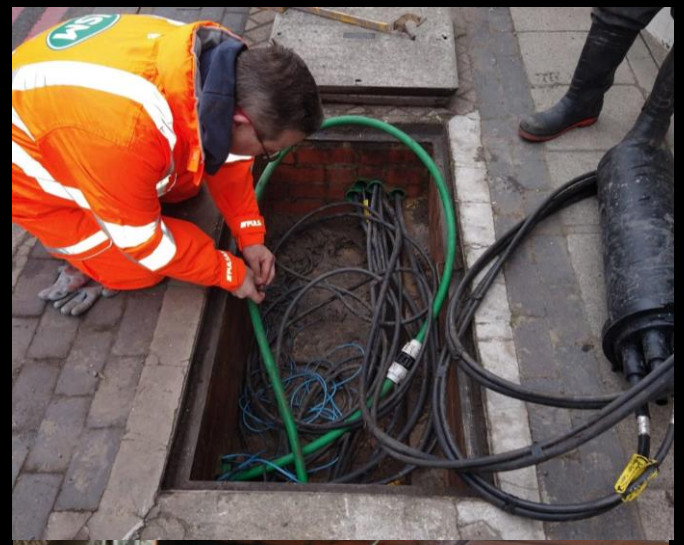
BT

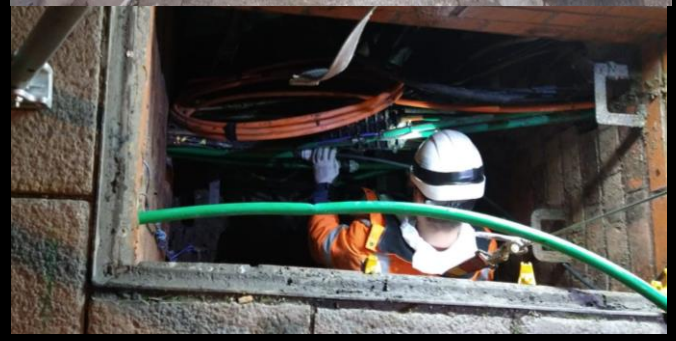
O. Alia *et al*., "DV-QKD Coexistence With 1.6 Tbps Classical Channels Over Hollow Core Fibre," in *Journal of Lightwave Technology*, vol. 40, p. 5522, 2022

Quantum key distribution

2021-22: DNANF CONCEIVED, FABRICATED AND INSTALLED



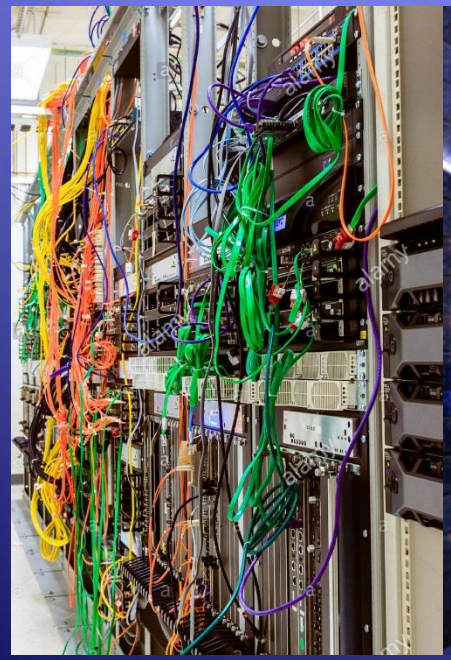




Lightpipe LUMENiSiTY

The Data Centre Opportunity

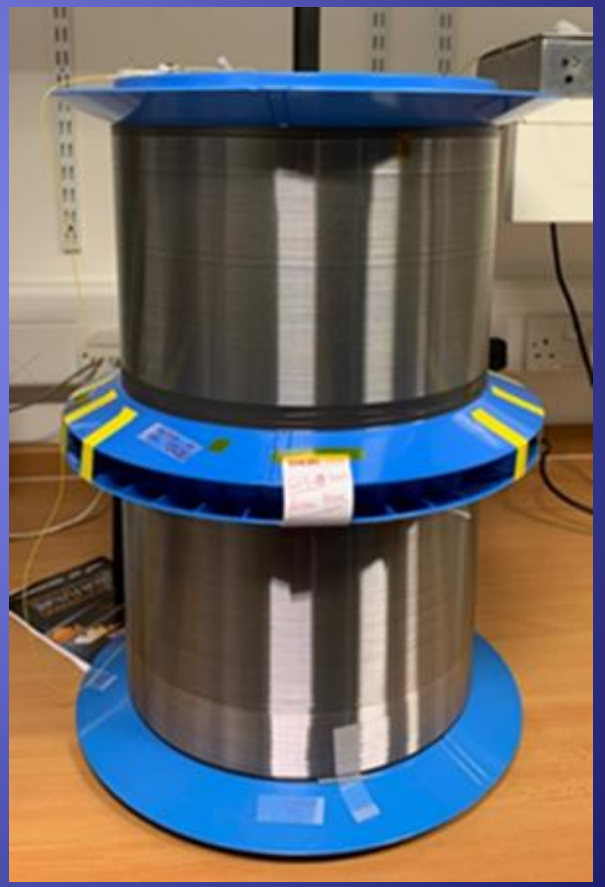
Information flow/unit area and latency is key in supercomputers and data centres. 20,000 km of fibre in one Facebook data centre alone!



Hollow-core fibre transit time is 30% less!
Financial traders care about this

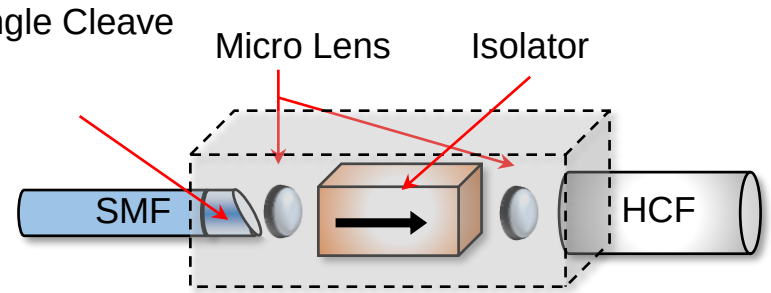
Conclusions: "Nothing is better than silica"

- Hollow-core antiresonant fibres are an internet game changer
- Can now beat the loss of standard fibre at all wavelengths 250nm – 5200nm
- Lower loss, larger capacity, radiation hard, 30% less delay
- A perfect solution to quantum distribution
- Cables already installed for use in Fintech
- Enable the use of other wavelengths in datacentres that suite e.g. silicon photonics or VECLS (0.5dB/km at 850nm)
- Perfect for next generation fibre gyros
- Capable of 10kW + power transmission

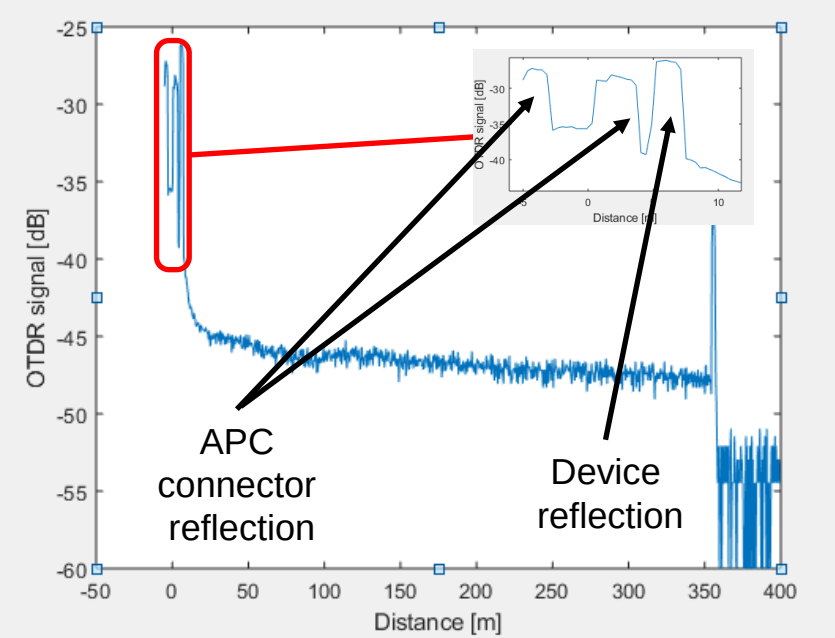


How do you splice HCF to SMF?

Effective index mismatch gives reflection



SMF to HCF Isolator

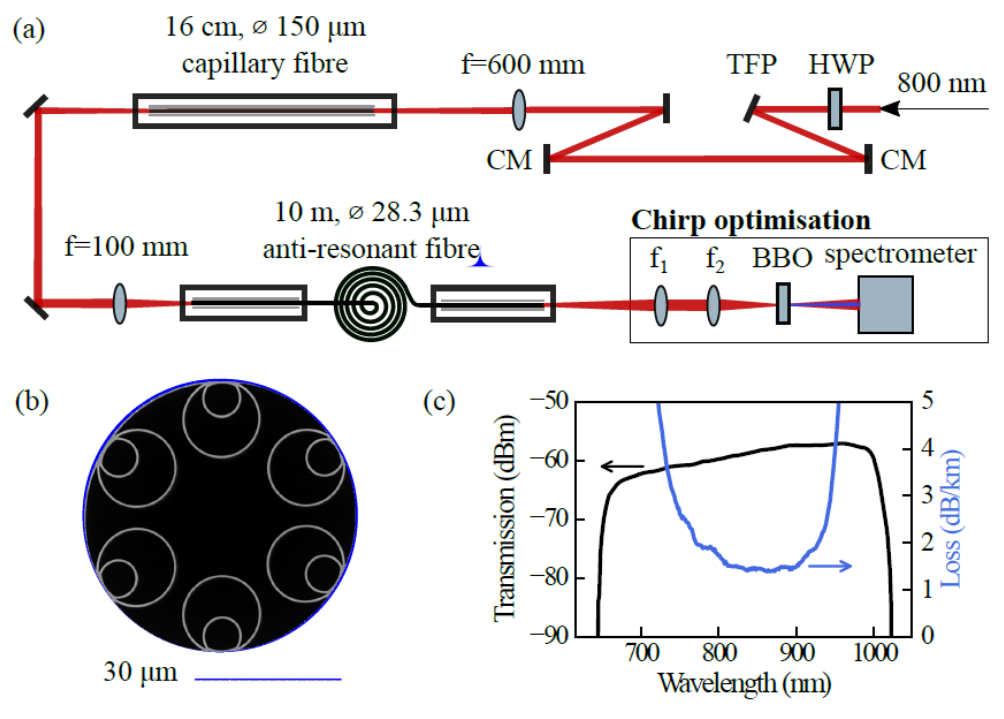


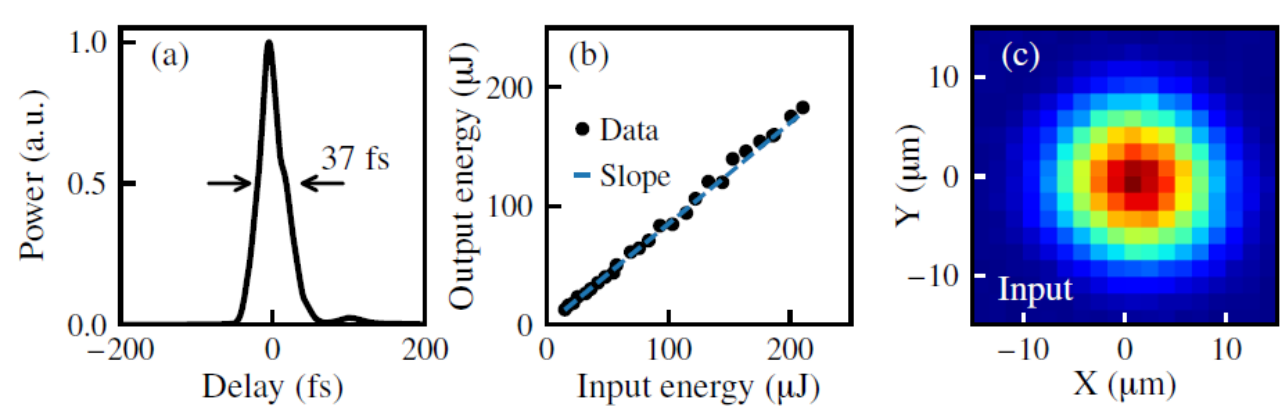
OTDR Measurement (Before ISO)
Expected PBGF loss ~7dB/km (~ 2.4 dB for 350 m)

Low loss, in-line integrated HCF components

H. Kim, OFC 2019

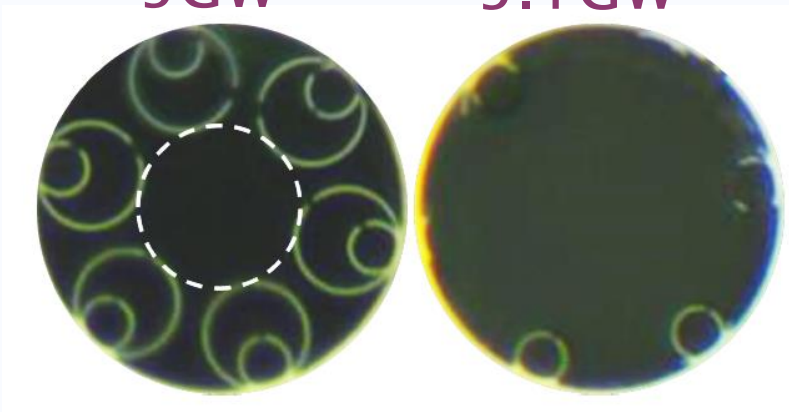
Delivery of GW peak power pulsed





40 fs pulses, 5 GW peak power transmitted through 10m of coiled HCF

5GW 5.1GW



Damage fluence at surfaces: 3 J/cm^2

A. Lekosiotis et al., "On-target delivery of intense ultrafast laser pulses through hollow-core anti-resonant fibres", Optics Express 2023 (submitted)