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Hollow-Core Fiber: *Nothing* is Better Than Glass?

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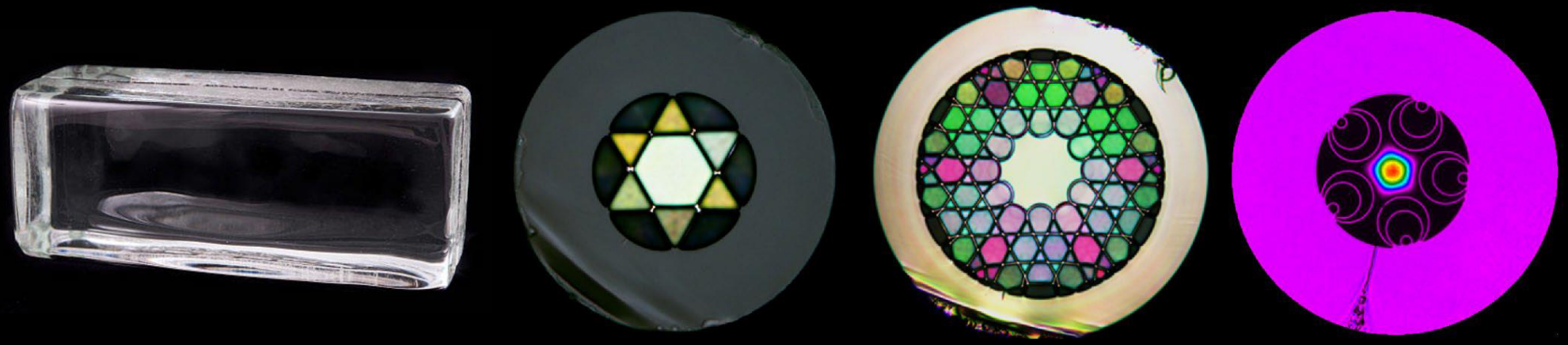
Hollow Core Fiber



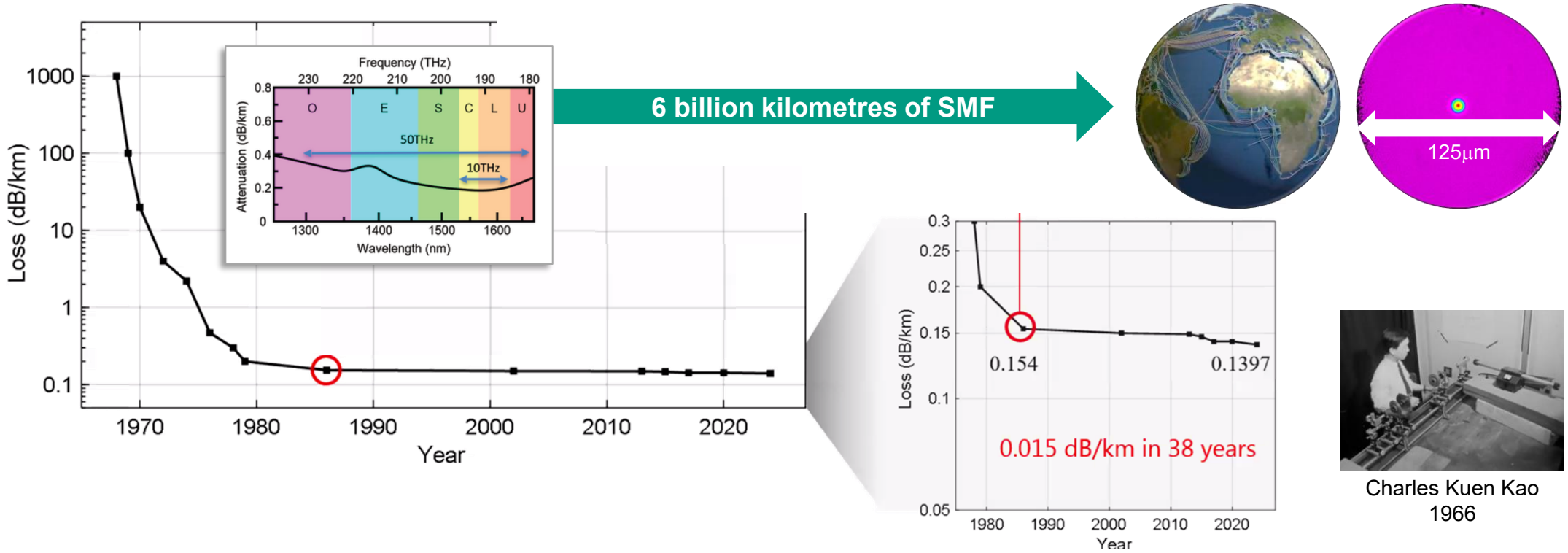
“Nothing is better than glass for guiding light”

Francesco Poletti, ORC

50 years of single mode optical fiber deployment

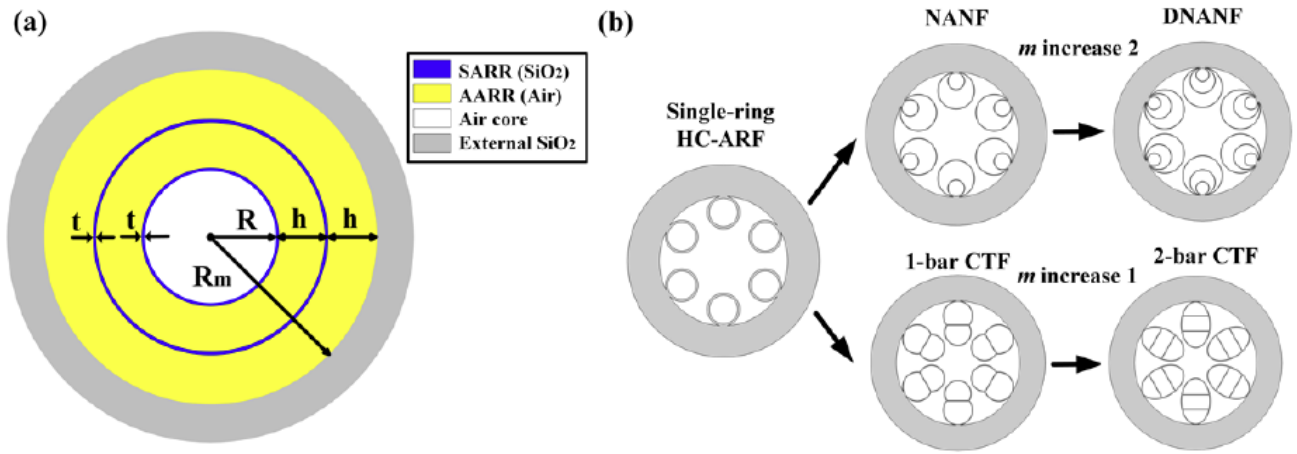
6 billion kilometres of telecom-grade single mode fiber installed worldwide

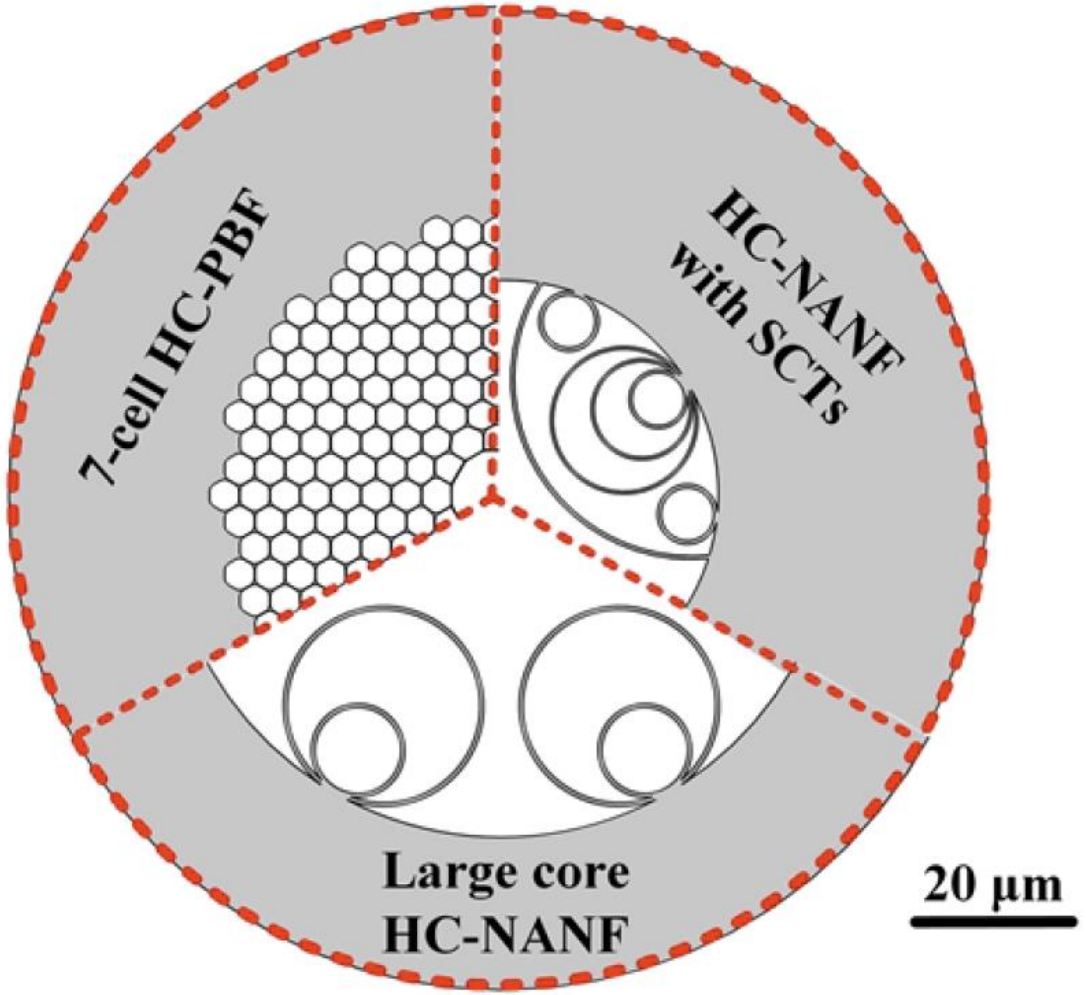
Fundamental limitations of solid glass fiber now reached: loss, nonlinearity, latency, capacity…



Hollow Core Fiber History

- HC-PBFs: Hollow-Core photonic-bandgap fibers
  - Medium Loss, Narrow Bandwidth
- HC-ARF: Hollow-Core Antiresonant Fibers
  - Medium Loss, Wide Bandwidth
- HC-NANF: Hollow-Core Nested Antiresonant Nodeless Fiber
- Low Loss, Very Wide Bandwidth
  - With Semi-Circular Tubes
- DNANF: Double Nested Antiresonant Nodeless Fibre



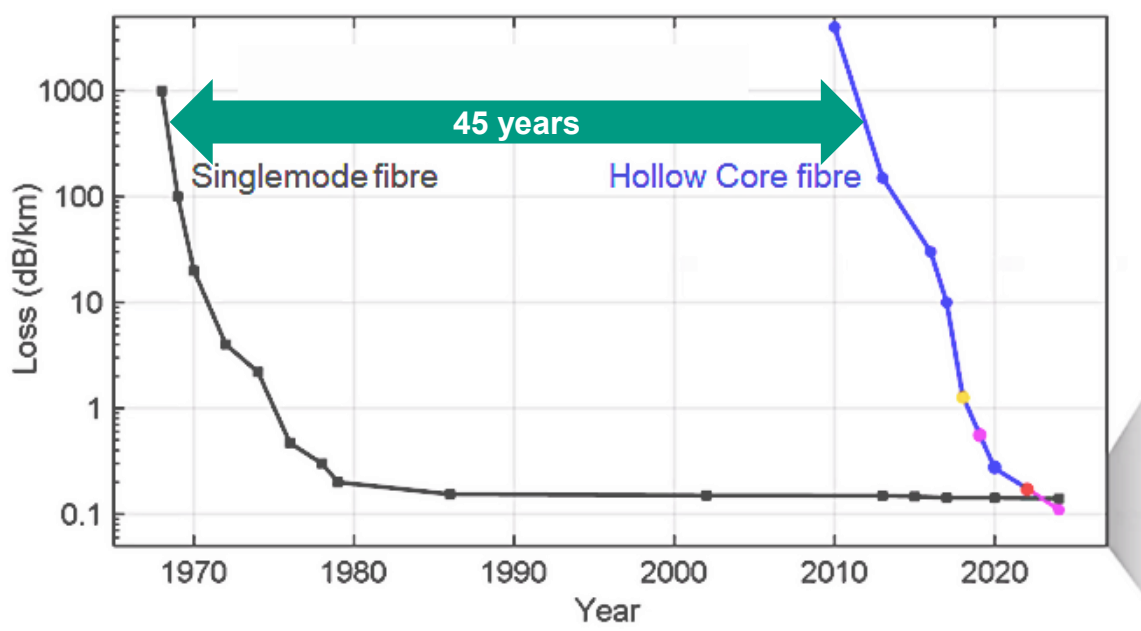


Yunhao et al., "Small-core hollow-core nested antiresonant nodeless fiber with semi-circular tubes", in *Optics Express*, vol. 30 no. 12, June 2022

Rapid advances in hollow-core fiber development

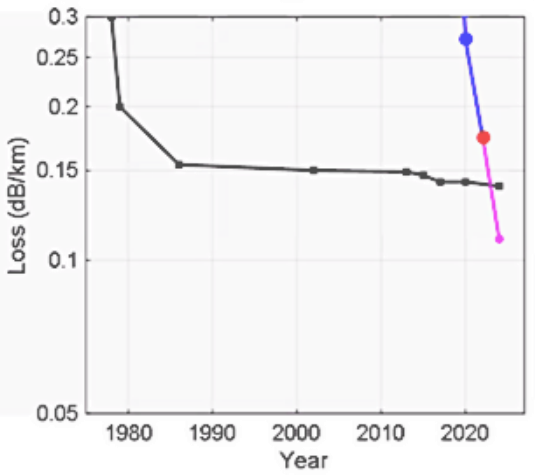
Micro-structured glass fibers confine light to a hollow air core

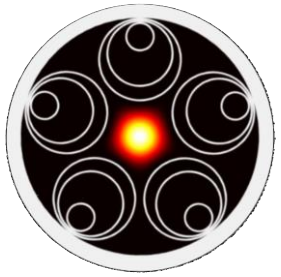
Loss below silica glass in optical fiber first achieved by Microsoft and Southampton University in 2023. HC-NANF

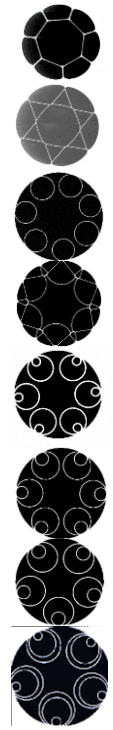


Microsoft Lynt

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



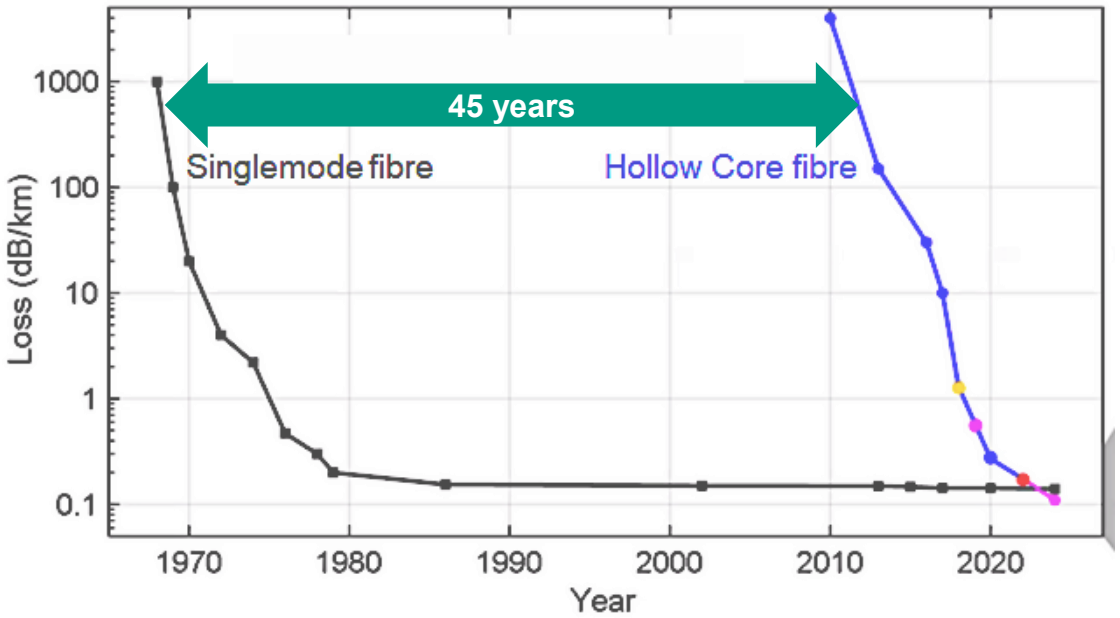




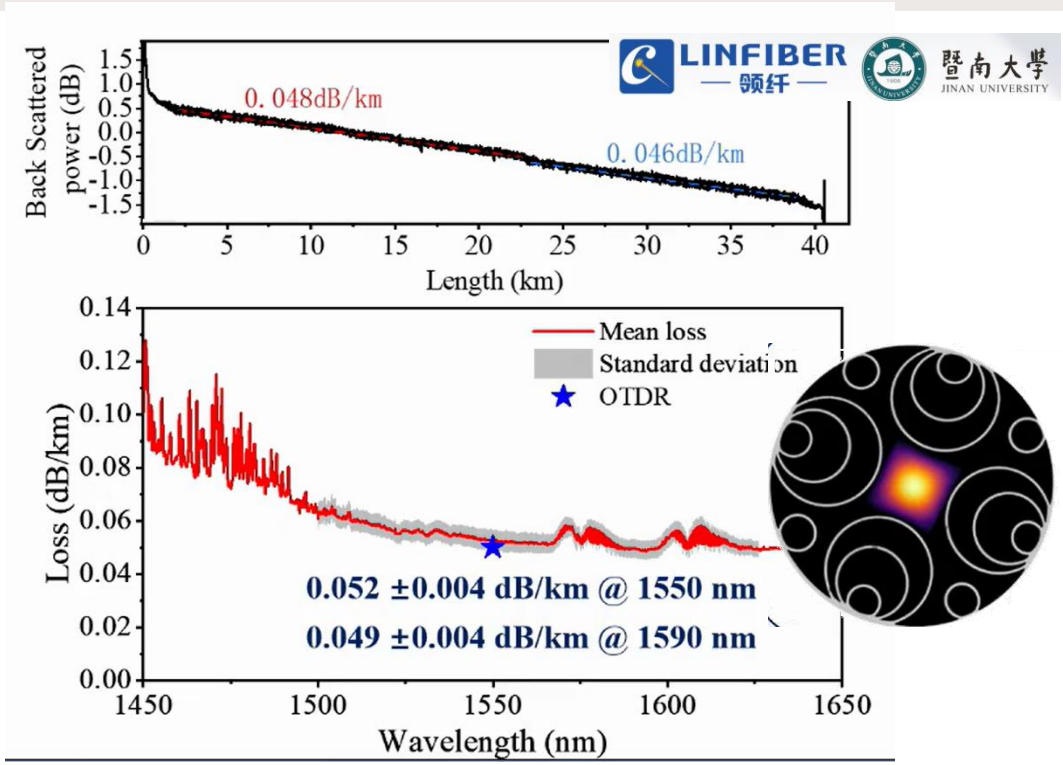
Rapid advances in hollow-core fiber development

Micro-structured glass fibers confine light to a hollow air core

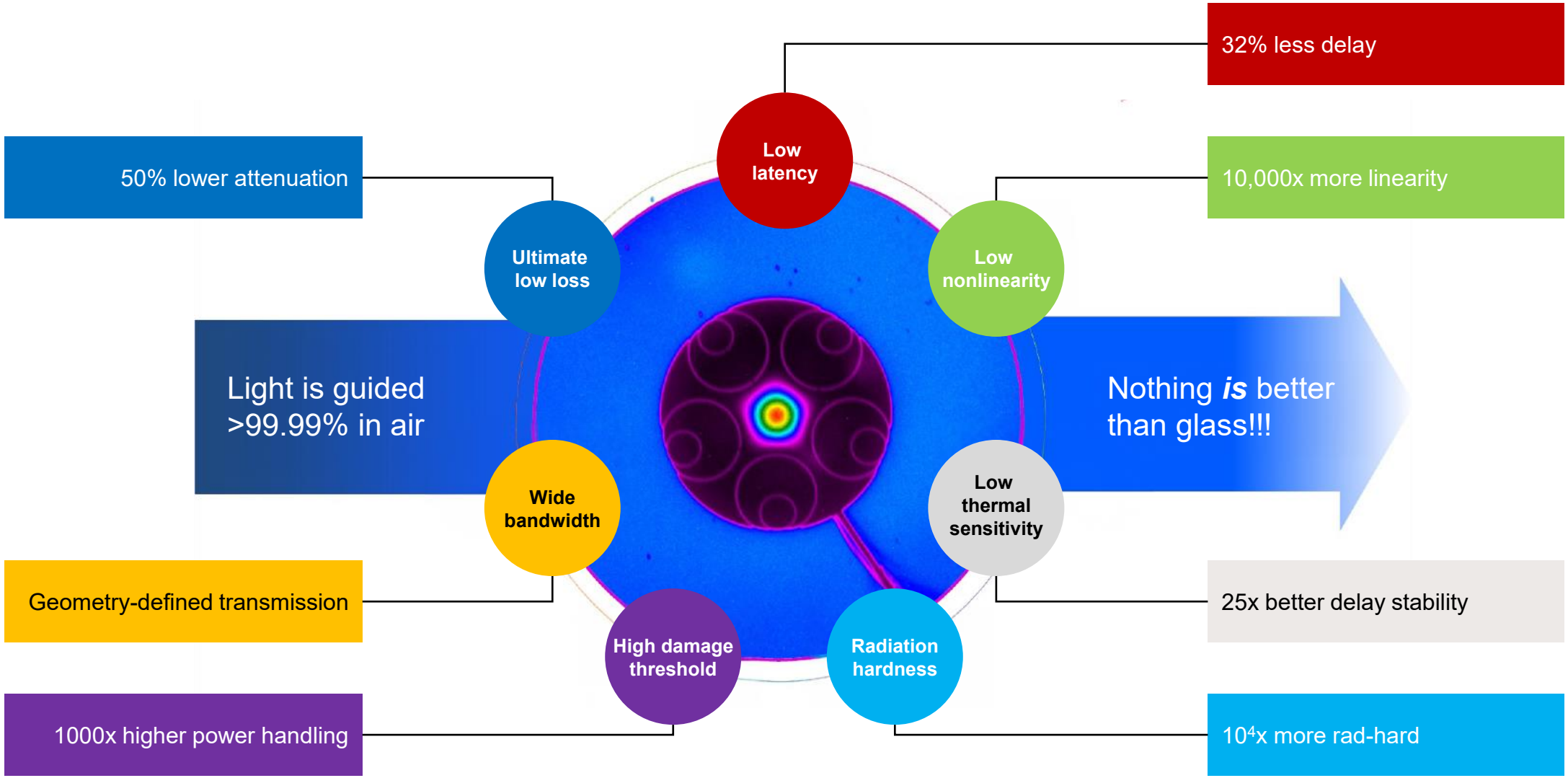
Lowest ever loss in any waveguide recently reported by Linfiber at ECOC 2025: **0.05dB/km** over 40km of HCF.



DNANF
0.11 dB/km @ 1550 nm
0.13 dB/km @ 1020 nm



Performance benefits of hollow-core fiber

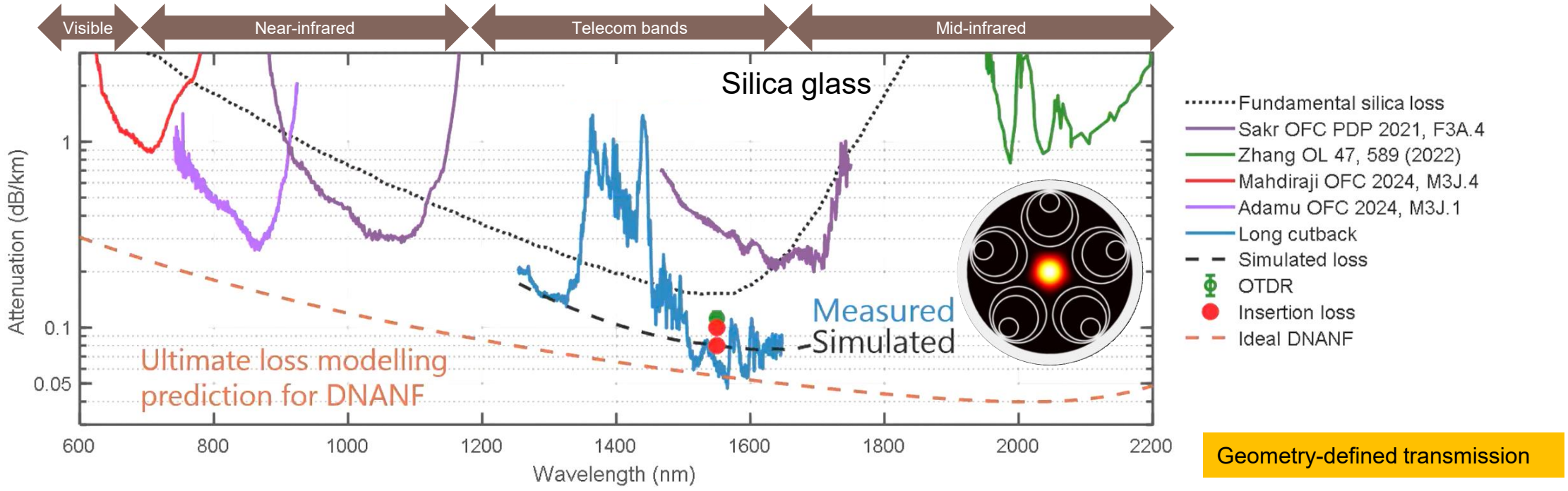


Hollow-core fibers can work at any wavelength

HCF transmission windows defined by **microstructure geometry**, not material properties

DNANF fibres fabricated with **loss below silica** across the visible and mid-infrared bands

Even **lower attenuation** possible at longer telecom wavelengths



Geometry-defined transmission

Hyperscalers accelerating investments in hollow-core fiber

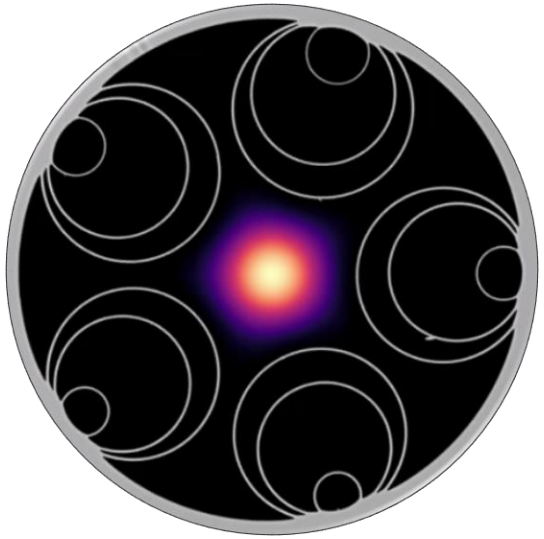
Microsoft acquired Lumenisity in 2022 and is now **scaling HCF fab capacity** with vendors Corning and Heraeus

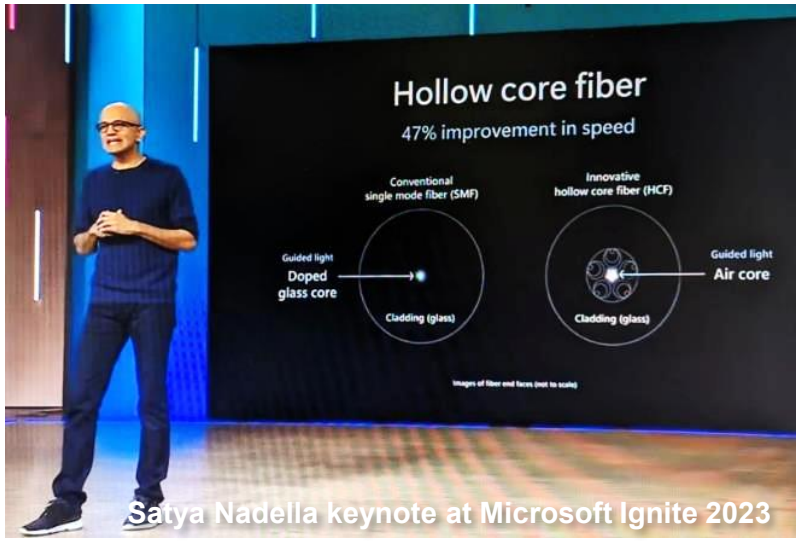
Hollow-core fiber can provide long-term **sustainable differentiation** for datacenter networks

Brings servers, data centers and - ultimately - continents closer together for **latency-critical services**

H+S seen as **trusted partner** for HCF datacenter interconnect cables

Further opportunities for HCF patch cords to reduce latency in high performance **AI compute clusters**





Satya Nadella keynote at Microsoft Ignite 2023

Drivers for HCF deployment in datacenter networks

32% faster transmission | 50% lower attenuation | 1000x higher power | 10,000x more linearity

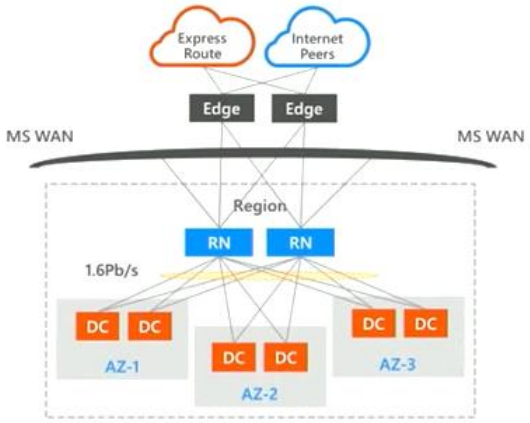
Metro/regional data center interconnect

- **Low latency** improves service response speeds
- Wideband links with **200km** reach and **no amplifiers**
- **Linear transmission** properties allow high launch power

High speed connectivity in AI compute clusters

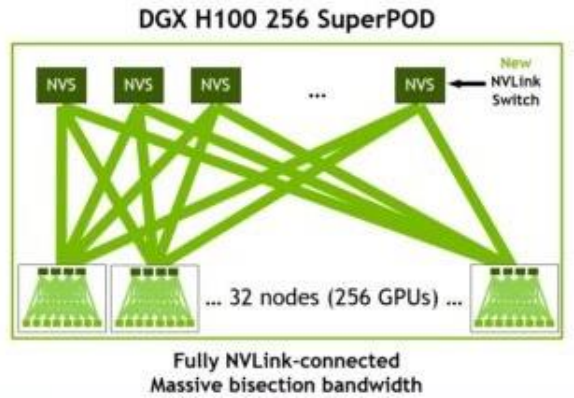
- **Low latency** interconnect between GPU arrays
- Allows **faster completion** of LLM algorithms
- **Doubles compute capacity** within max latency radius

Clear value-add for HCF connectivity solutions



200km

High volume patchcords at commodity prices



200m

LLM: large language model

HCF Deployment Challenges

- **Production capacity / cost**
- **Operational Practices**
  - Bending radius
  - Splicing
  - Measurements
- **Ecosystem Readiness**
  - No HCF standard
  - Information on HCF durability
  - Existing SMF installed base

Examples of HCF during the manufacturing process (Microsoft)

Hollow-core fiber connectivity challenges

Open fragile core structure

- Not possible to polish – only cleaving of endface
- Open end needs sealing against environment
- Microstructure geometry can vary along fibre length

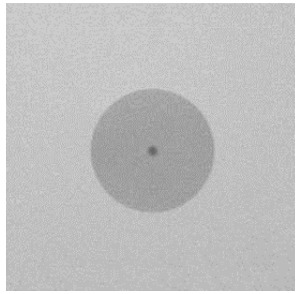
Mode field diameter is >2x the size of standard SMF

- Mode size conversion is necessary
- Back reflections at interface to SMF need to be suppressed
- Large cladding diameter limits min bend radius to ~75mm

SMF-28e

$Ø_{Cladding}$ = 125µm

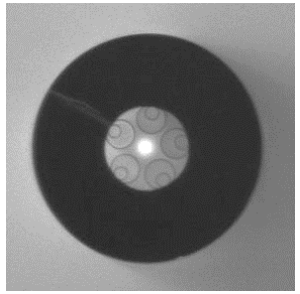
MFD = 9.2µm



NANF-HCF

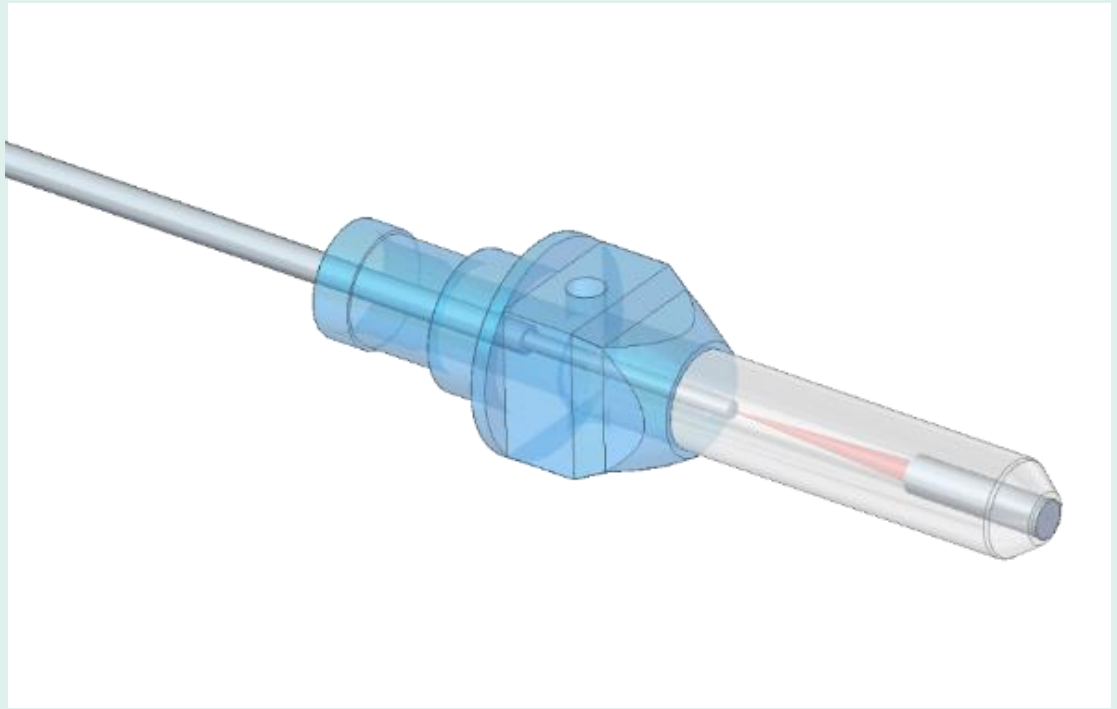
$Ø_{Cladding}$ = 235µm

MFD = 24µm

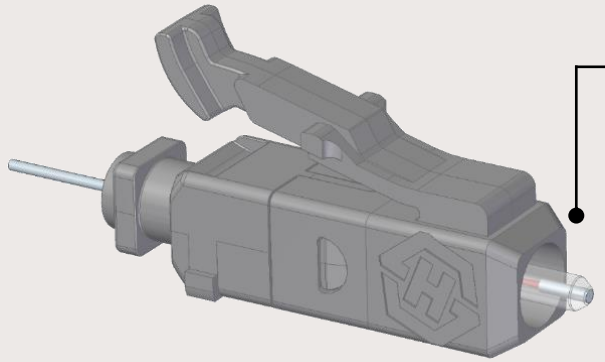


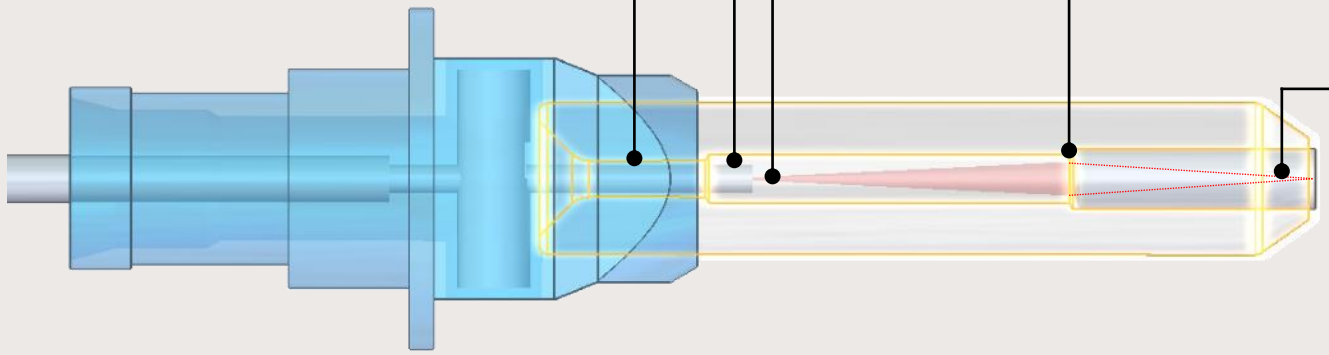
Need for an element to connect to the world of SMF!

- CUBO HCF-Lens-Connector



Patented Mode Converting HCF-LC-Connector





LC Connector

Quasi-hermetic sealing at fiber and lens fixing

HCF actively aligned *(MFD = 24µm)*

HCF cleaved to air – no back reflection

Anti-reflection coated lens

Interface to standard SMF28 fiber *(MFD = 10,4µm)*

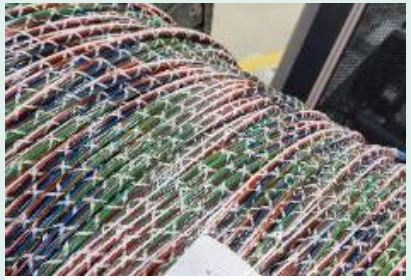
Cabled HCF patchcords with LC/UPC Termination

Cable-Side	Ferrule	IL Assembly	IL QC	Return Loss
H1284-1	F006357	-0,36 dB	-0,28 dB	-49,4 dB
H1284-2	F006358	-0,29 dB	-0,30 dB	-51,0 dB
H1285-1	F006359	-0,54 dB	-0,76 dB	-50,1 dB
H1285-2	F006360	-0,24 dB	-0,53 dB	-49,9 dB

Connectors qualified for high optical power handling up to +34dBm at 1550nm

H+S HCF connectivity roadmap

Cable



32/64f MLT

Zip Duplex

Ferrule

LC/UPC

LC/APC

Connector

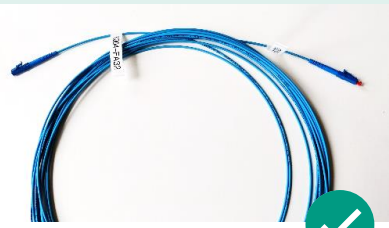
LC

LC Duplex

VSFF

Q-ODC Mini

Assembly



Patch cords

Breakouts

Outdoor terminations

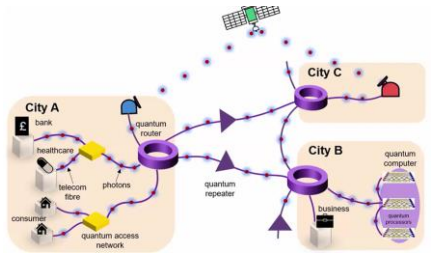
Management

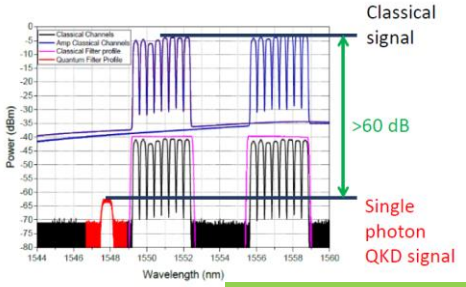
Fiber Mgmt Systems

Connectivity automation

Beyond datacenters: broad applications for hollow core fiber

Quantum networks

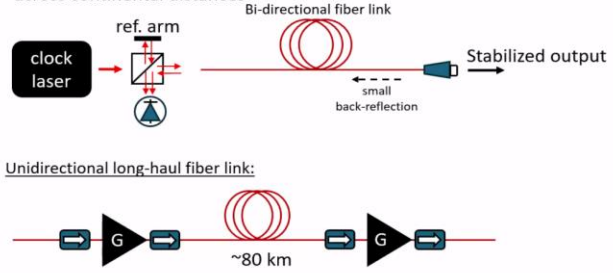


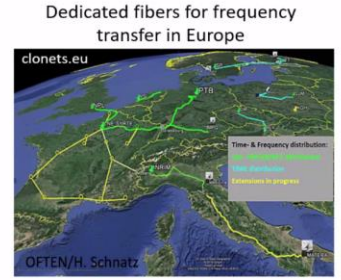


10,000x more linearity

Time synchronisation

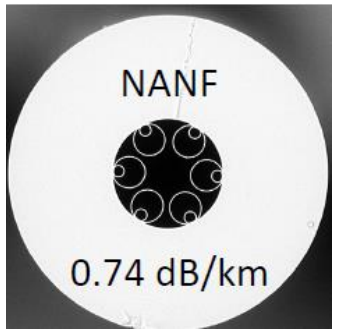
- Doppler-canceled fiber links support optical clock level stability across continental distances

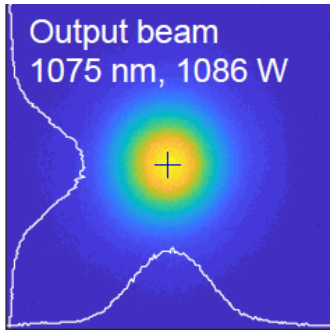


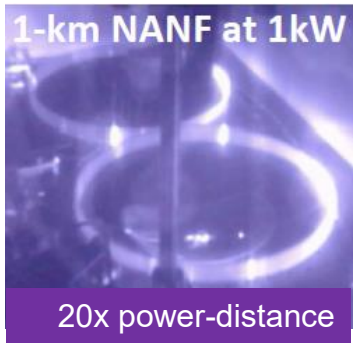


25x delay stability

Power delivery

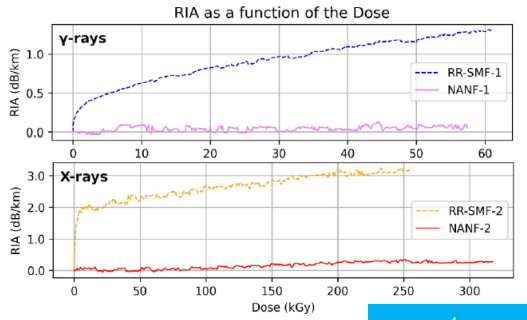






20x power-distance

Space photonics



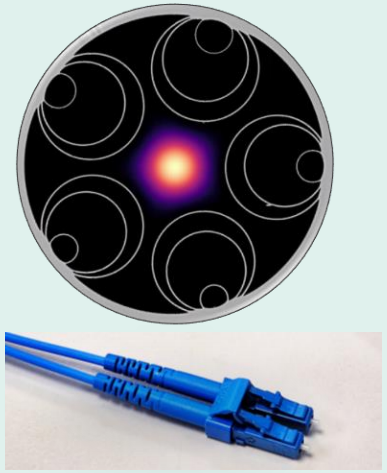
10^4x rad-hardness

Summary: Hollow Core Fiber Connectivity Solutions

Technology Description

- **Low-loss**, **low-latency** fiber for ultrafast transmission
- Focus on **AI-data center**, **metro** and future **6G** networks
- **Record low loss** HCF extends transmission lengths
- **Multiple vendors** exploring novel HCF designs
- **Patented H+S HCF-SMF connector** enables robust connectivity solutions portfolio

Illustration



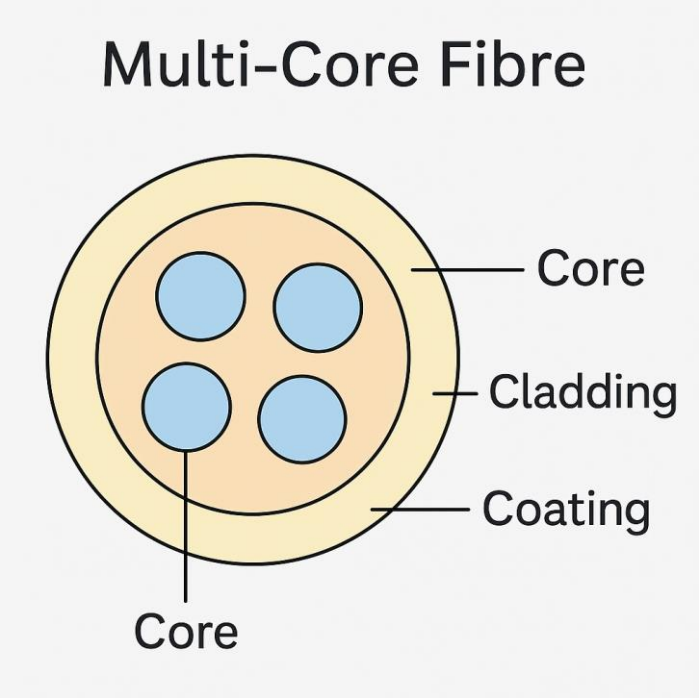
Use case / Customer

- Creating end-to-end low-latency data center networks enables **sustainable differentiation**
- Enables **amplifier-free** metro links
- First applications deployed in DC interconnect networks
- Potential for efficiency benefits in **AI supercomputing**
- **Exploitation beyond DC** in timing, sensors, A&D…

USPs

- **Free-space** transmission speed with the flexibility of fiber
- **Standards-compatible** HCF connector allows simple integration with existing singlemode fiber systems
- **Removes** glass **nonlinearities** to create high power links
- Highly stable delay for **precision time** distribution
- Enables **quantum coexistence** with classical comms

What about Multi-Core Fiber?



Why Multi-Core Fiber is useful

Massive capacity increase
Instead of pulling separate fibres, one Multi-core fibre can deliver similar capacity.

Better space efficiency
Ideal where ducts, conduits, or subsea cables are space-limited.

Lower cost per bit (long term)
Shared cladding and installation reduce physical infrastructure overhead.

Energy efficiency
Fewer fibres → smaller cables → reduced amplification and cooling needs.

Key technical challenges

Inter-core crosstalk
Light leaking between cores must be minimised using core spacing and trench designs.

Fan-in / Fan-out devices
Special components are needed to connect MCF to standard single-core equipment.

Ecosystem maturity
Transceivers, splicing, and monitoring tools are still evolving.

Still need *'adaptor'* to connect to high speed 400G, 800G, Terabit transceivers

steve.jones@hubersuhner.com

+44 7900 881729

Steve Jones | LinkedIn

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Connecting – today and beyond