Optoelectronics Research Centre

European Commission

UNIVERSITY OF Southampton

Tellurite glasses and fibres for the development of coherent Mid-IR supercontinuum source

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Motivations

Mid-IR applications (1 μm to 5 μm)

i. Chemical sensing – molecular fingerprint

ii. Medical applications – OCT

ii. Mid-IR LIDAR systems

Mid-IR light source technologies

i. Rare-earth ions doped crystal/glass

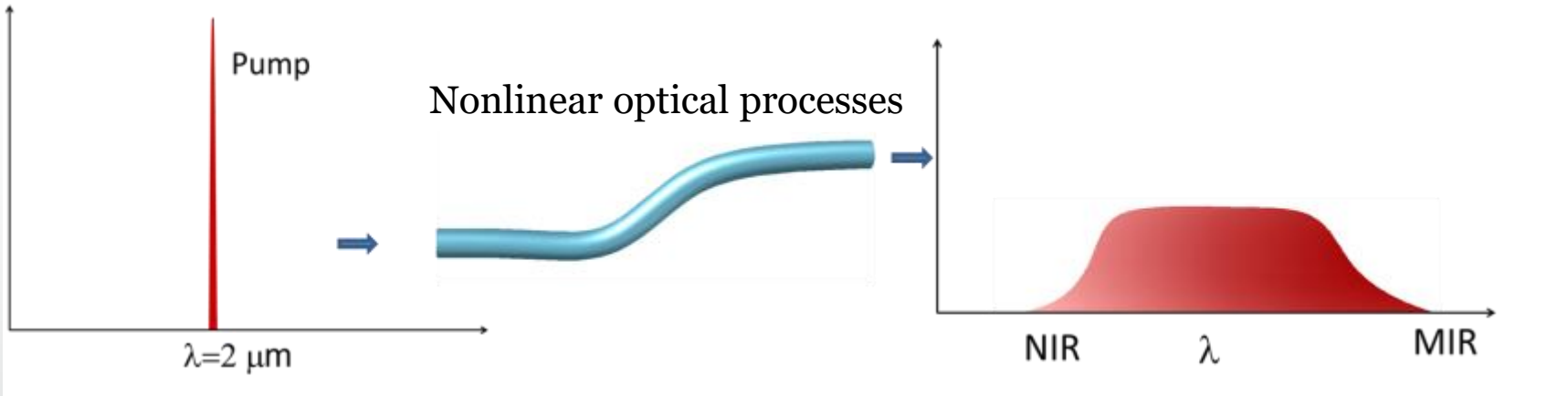
ii Optical Parametric Oscillators/Amplifiers

iii. Quantum cascade lasers

iv. Supercontinuum sources

Supercontinuum sources

Narrow bandwidth and highly coherent laser light converted into a broad spectrum by exploiting the non linear properties of the medium



MIR Supercontinuum sources in soft glass fibers

	n_2 (m^2/W)	ZDW
ZBLAN	3×10^{-20}	1.68 μm
Tellurite glass	30×10^{-20}	2.2 μm
Chalcogenide glass	$>300 \times 10^{-20}$	>4 μm

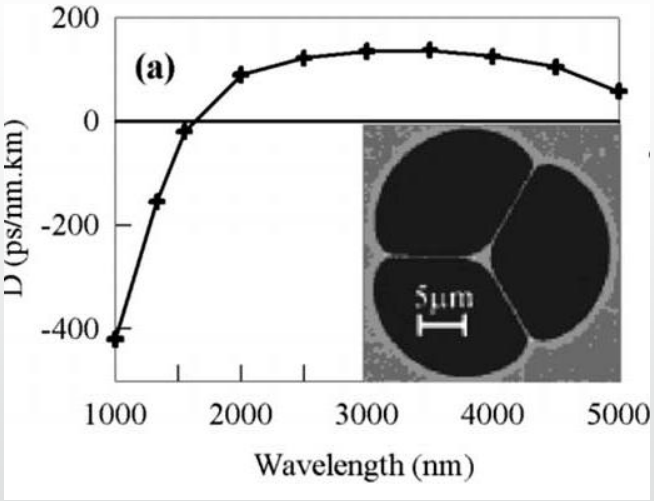
λ_{pump} / ZDW & fibre dispersion profile

Dynamic and efficiency of SC generation

MIR Supercontinuum sources in soft glass fibers

Mature and "low" cost 1.5 μm and 1.9-2 μm pulsed laser technologies (Er^{3+} and Tm^{3+} -based)

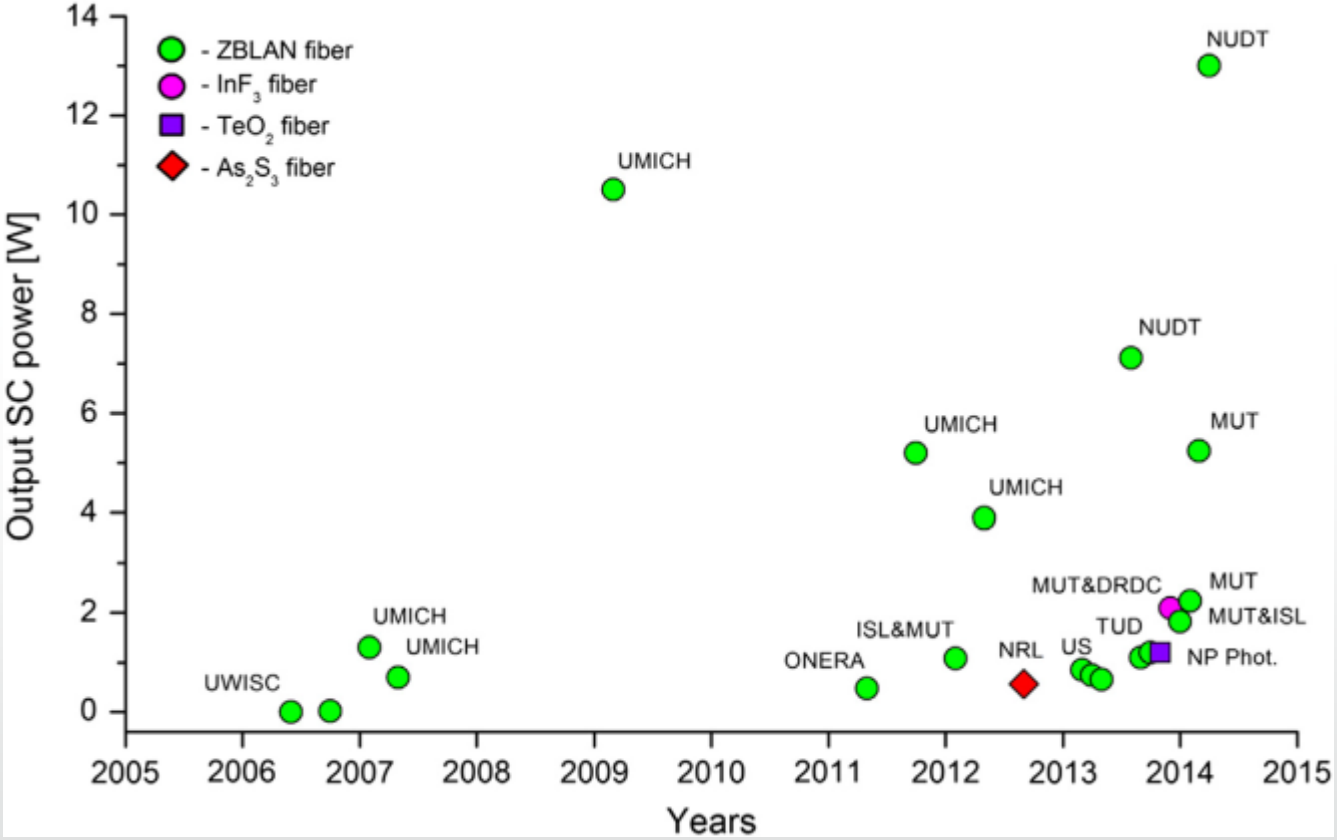
Fiber dispersion engineering for TeO2 and chalcogenide fibers



- Microstructure control difficult
- Poor environmental stability
- Integration challenging

MIR Supercontinuum sources in soft glass fibers

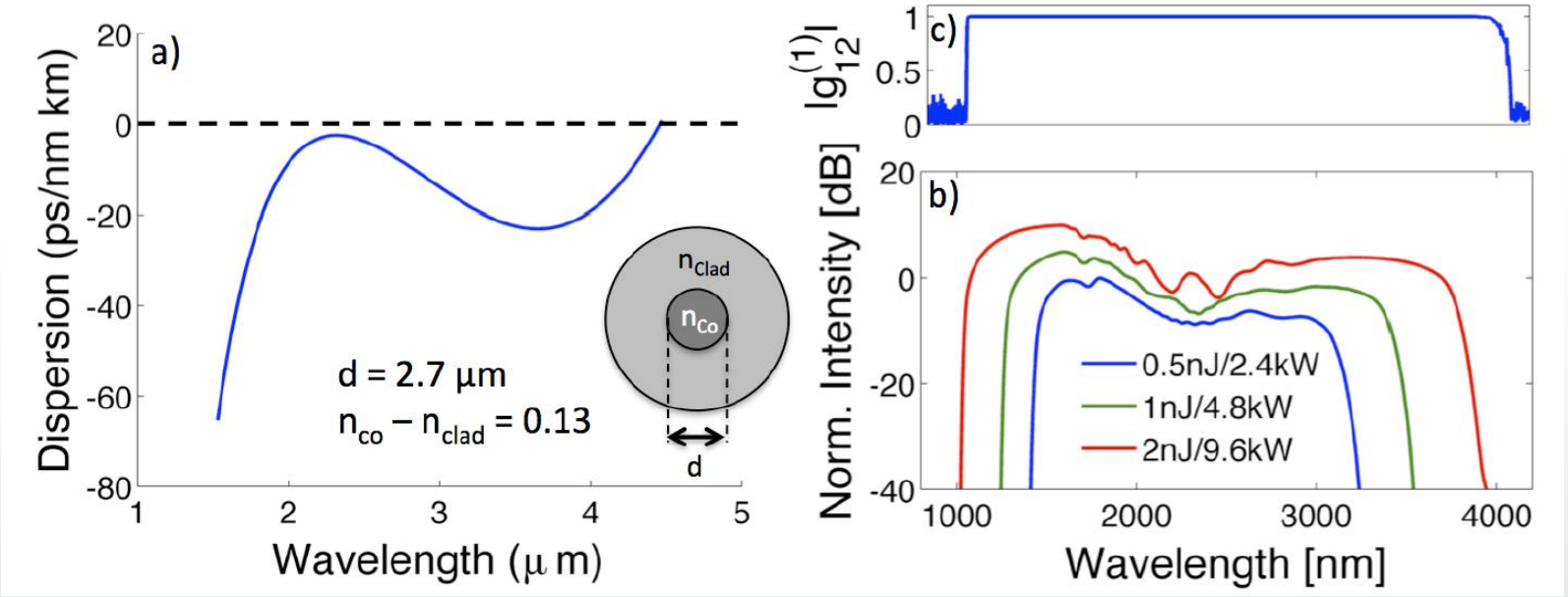
ZBLAN fibre most successful => quality of fibre critical



J. Swiderski, Progress in Quant. Elec., 38, 2014, pp 189-235

MIR Supercontinuum sources in soft glass fibers

Dispersion engineering in high index contrast all solid fiber



Heidt et al., *conference proceeding of OSA meeting "Speciality Optical Fibers",* ***2012***.

Objective

Development of TeO_2 fibre for high power SC

- Step index fibre for fabrication control and integration
- high NA for dispersion engineering

No exotic fibre structure => back to material engineering…

New TeO_2 glass for SC generation

Glass development specifications:

1. Improved thermo-mechanical properties / TZN glass
2. Higher nonlinear refractive index / TZN glass
3. Mid-IR absorption edge 4.5 μm (=TZN)
4. Low OH group content (= loss around 3 μm)

Approach:

1 Suitable intermediate elements for improving glass stability

2&3 Highly polarisable element for improving nonlinearity

3&4 Glove box controlled melting atmosphere (H_2O < 0.3 ppm)

3&4 <2-3 mol% fluoride precursor for removing OH groups

New TeO2 glass for SC generation

Melting procedure

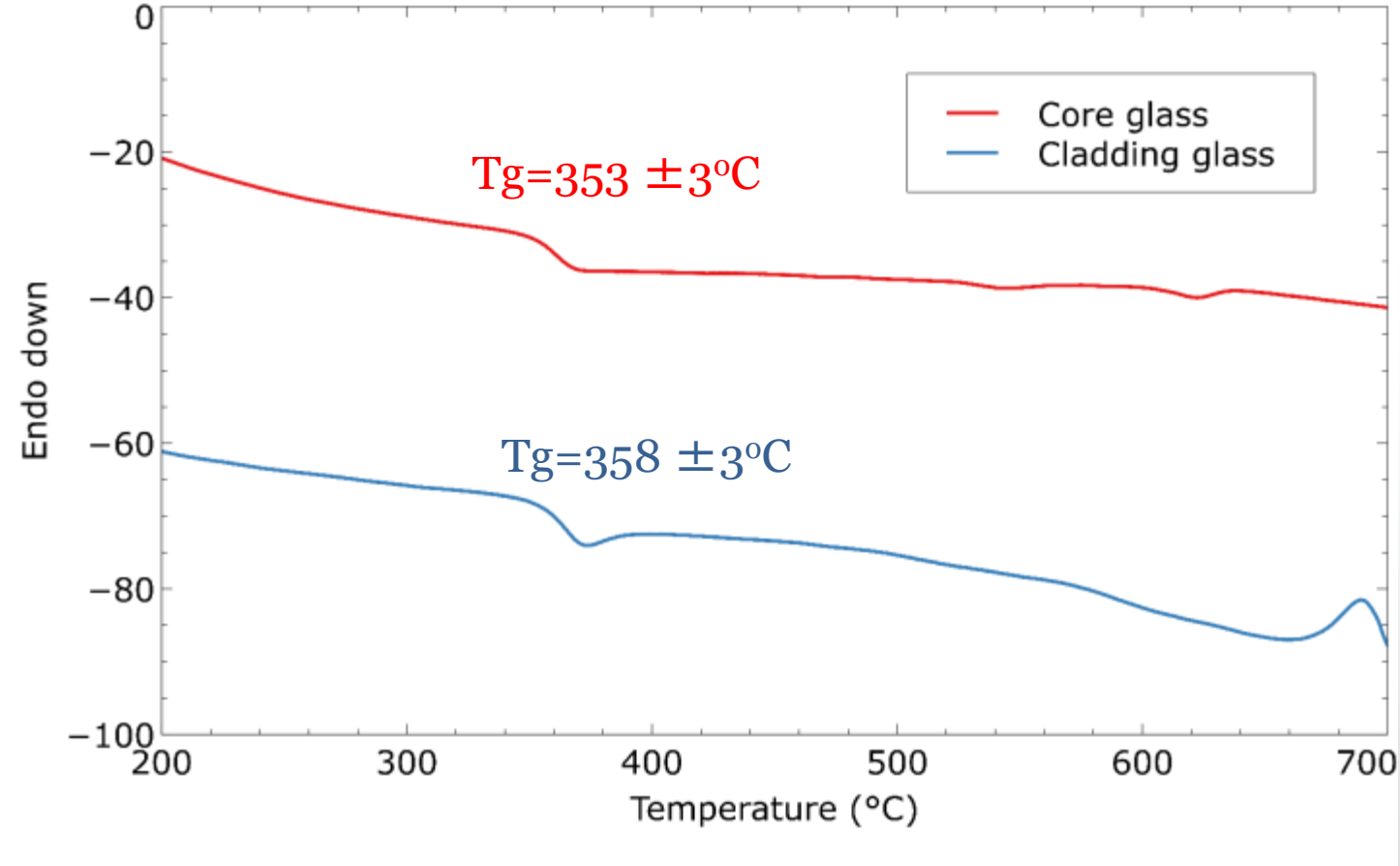
- Precursor: +99.99%
- Au crucible
- Glove box dried air (<0.1 ppm H_2O)
- Melting temperature: ~830°C

Cladding glass composition

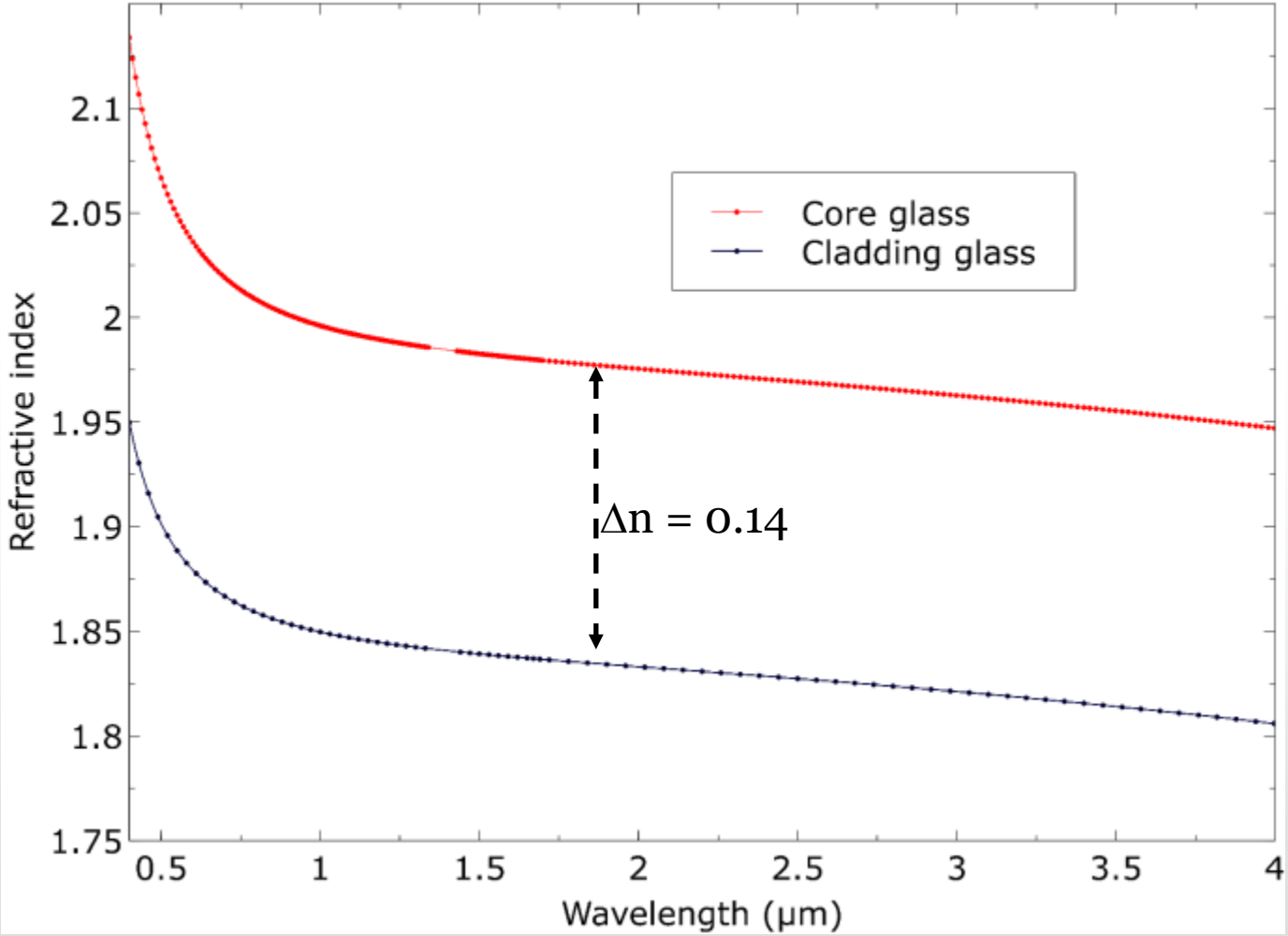
- 25% of TeO2 substituted by GeO2
- 9% of ZnO by Na_2O

New TeO2 glass for SC generation

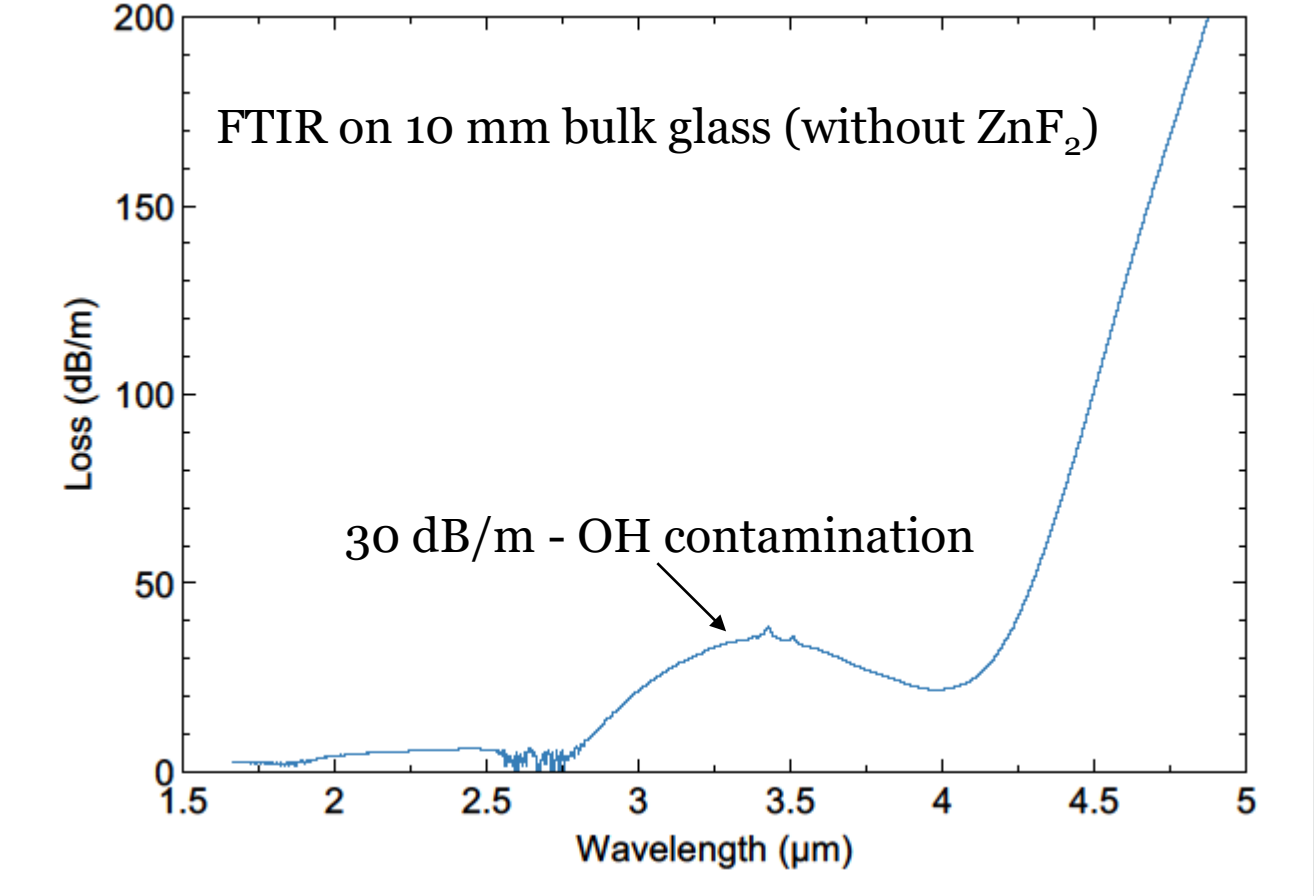
after 27 glass compositions…



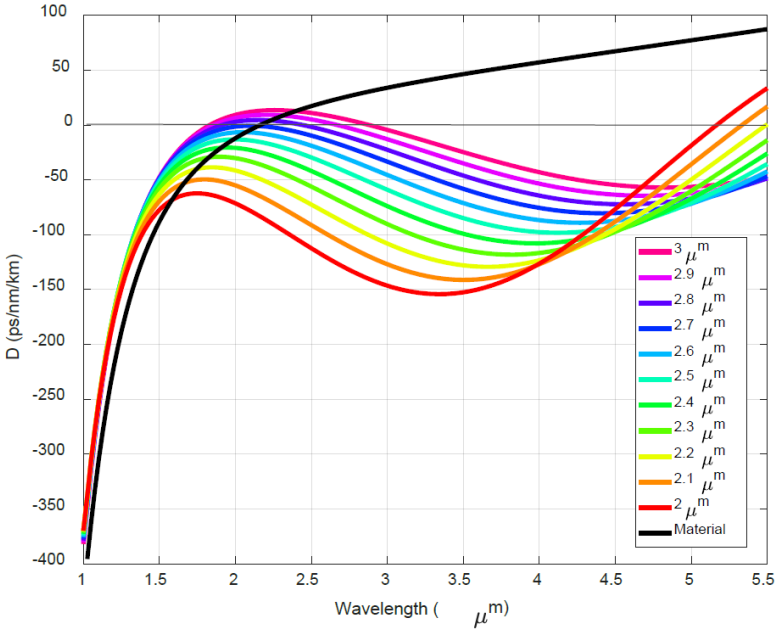
New TeO_2 glass for SC generation

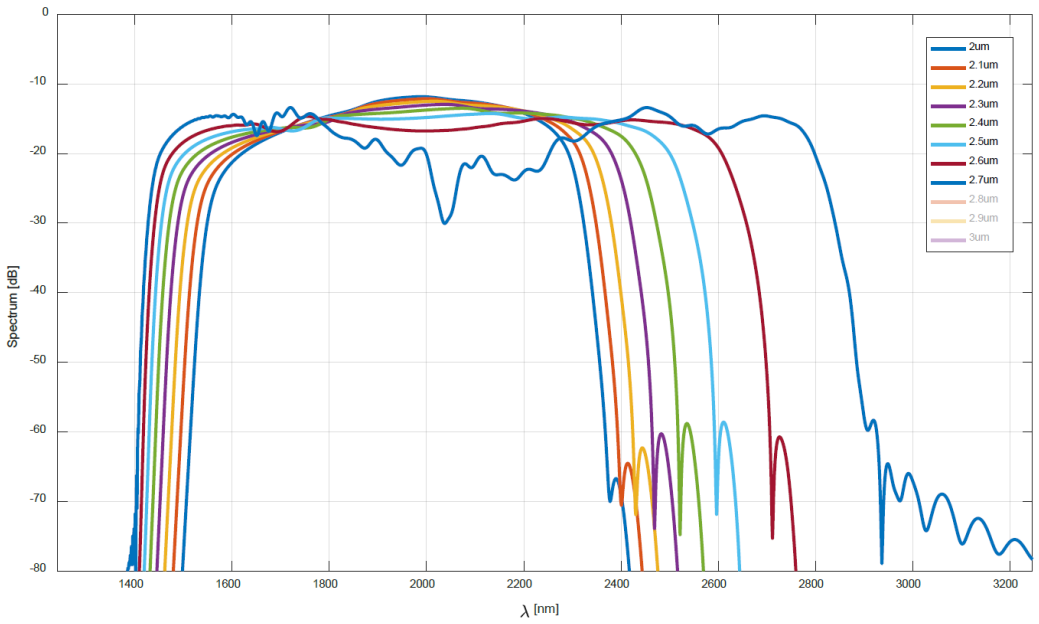


New TeO_2 glass for SC generation



Fibre design for coherent SC





Core diameter 2 μm to 2.7 μm for coherent SC in 20 cm long TeO_2 fibre

Fibre fabrication

Possible techniques:

- Suction casting
- Built-in-casting
- Direct rod-in-tube for control of fibre geometry.
  Impact on losses?

Fibre 1. Large core (50 μm) fibre – for preliminary tests
- Core glass rod by casting (ø12mm diameter) => cane
- Cladding tubes rotational casting

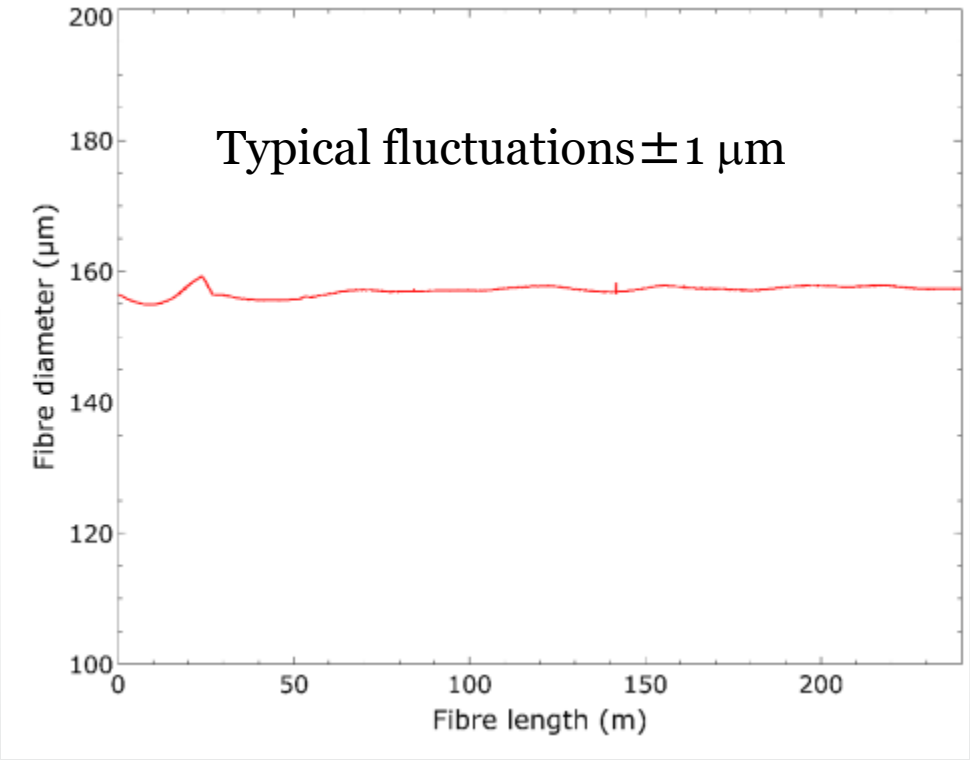
Fibre 2. Small core (2.75 μm) fibre - Double sleeving procedure
- Core glass rod by casting (ø12mm diameter) => cane
- Cladding tubes made by extrusion

Fibre 1 - Cladding tubes by rotational casting

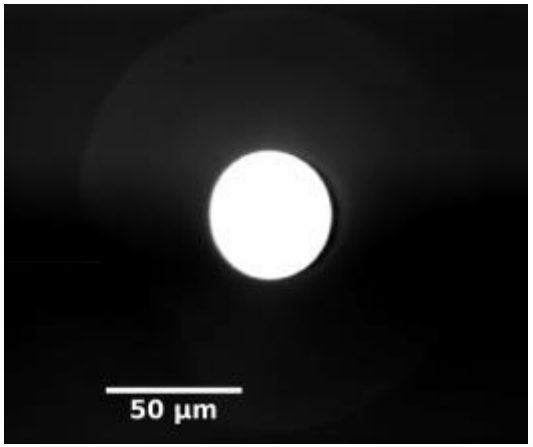
2000 rpm from liquid state

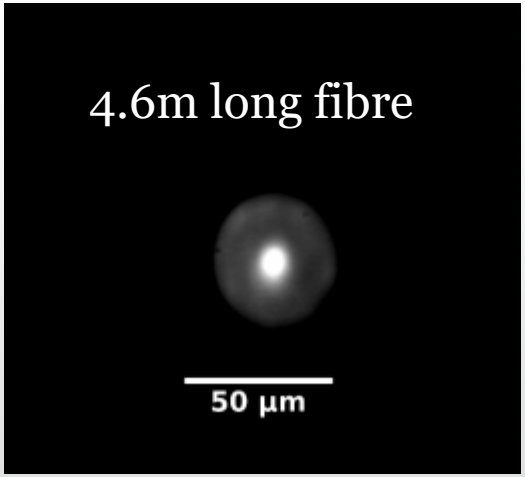
OD 12 mm /ID 4 mm to 8 mm

Fibre drawing

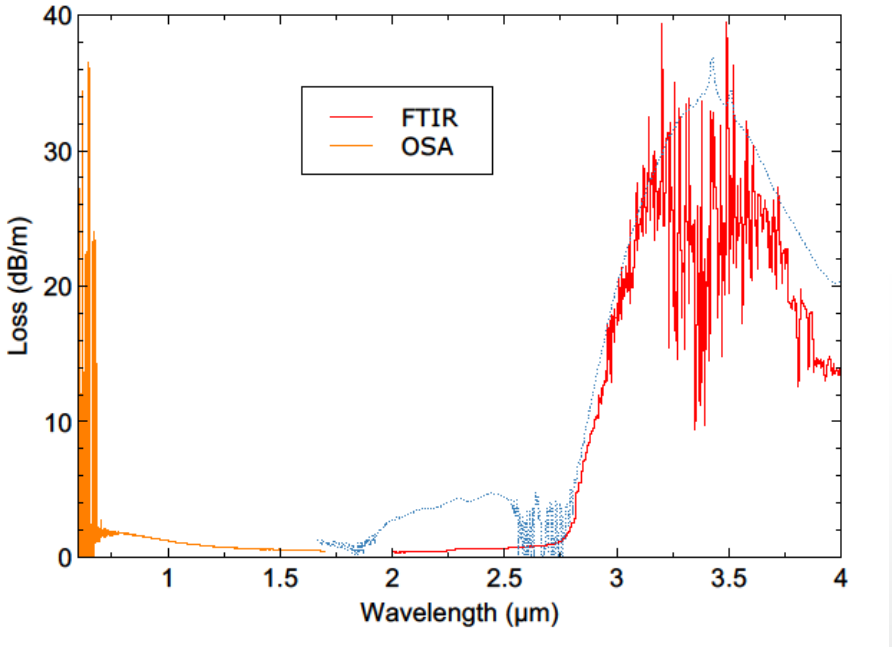


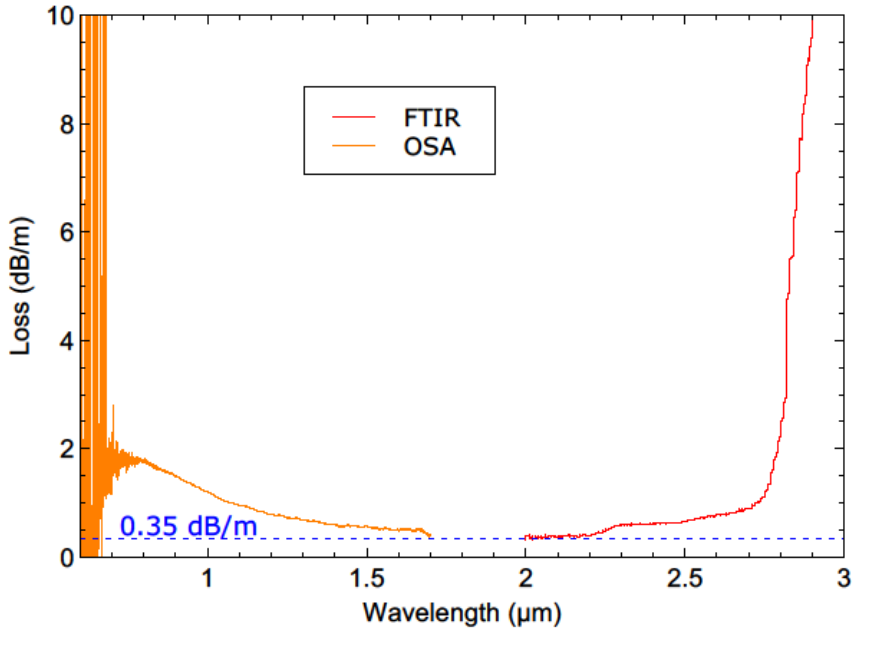
Near Field - Fibre 1





Fibre 1 - losses



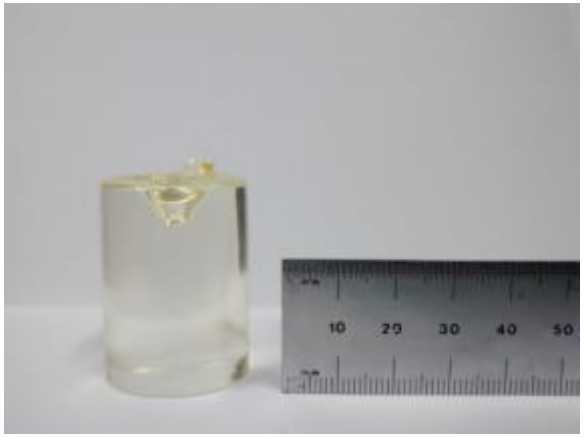


Near field observations + low loss level => good quality TeO2 fibre

Fibre 2 - Extrusion of cladding tube

Synthesis of cladding glass billet

Ø 28 mm × 40 mm



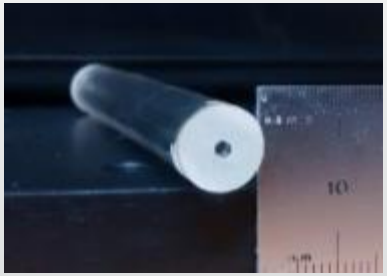
Extrusion process

405 °C

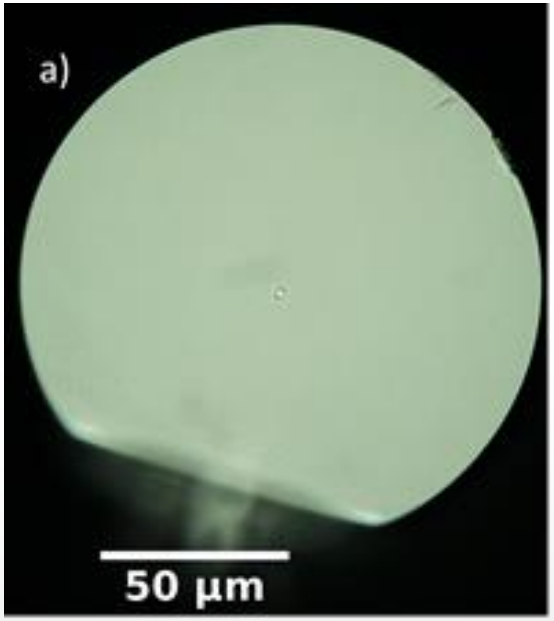
0.1 mm/min ram speed

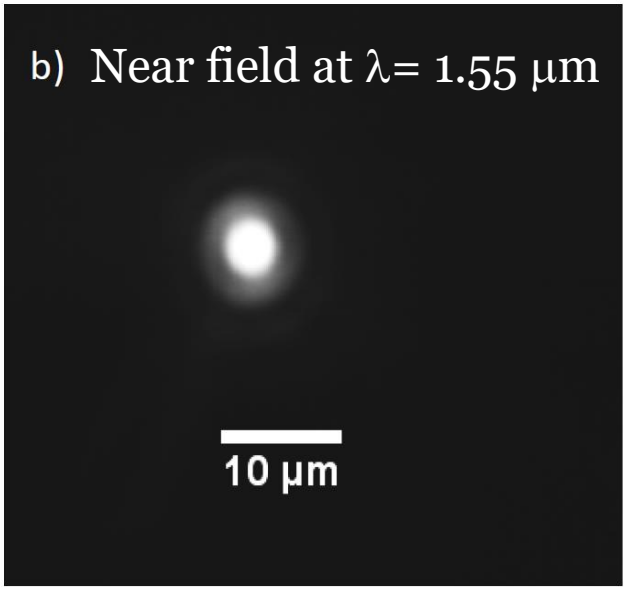
1.41 kN force

Clad tube with high OD/ID ratio (10 mm /1.8 mm)



Fibre 2

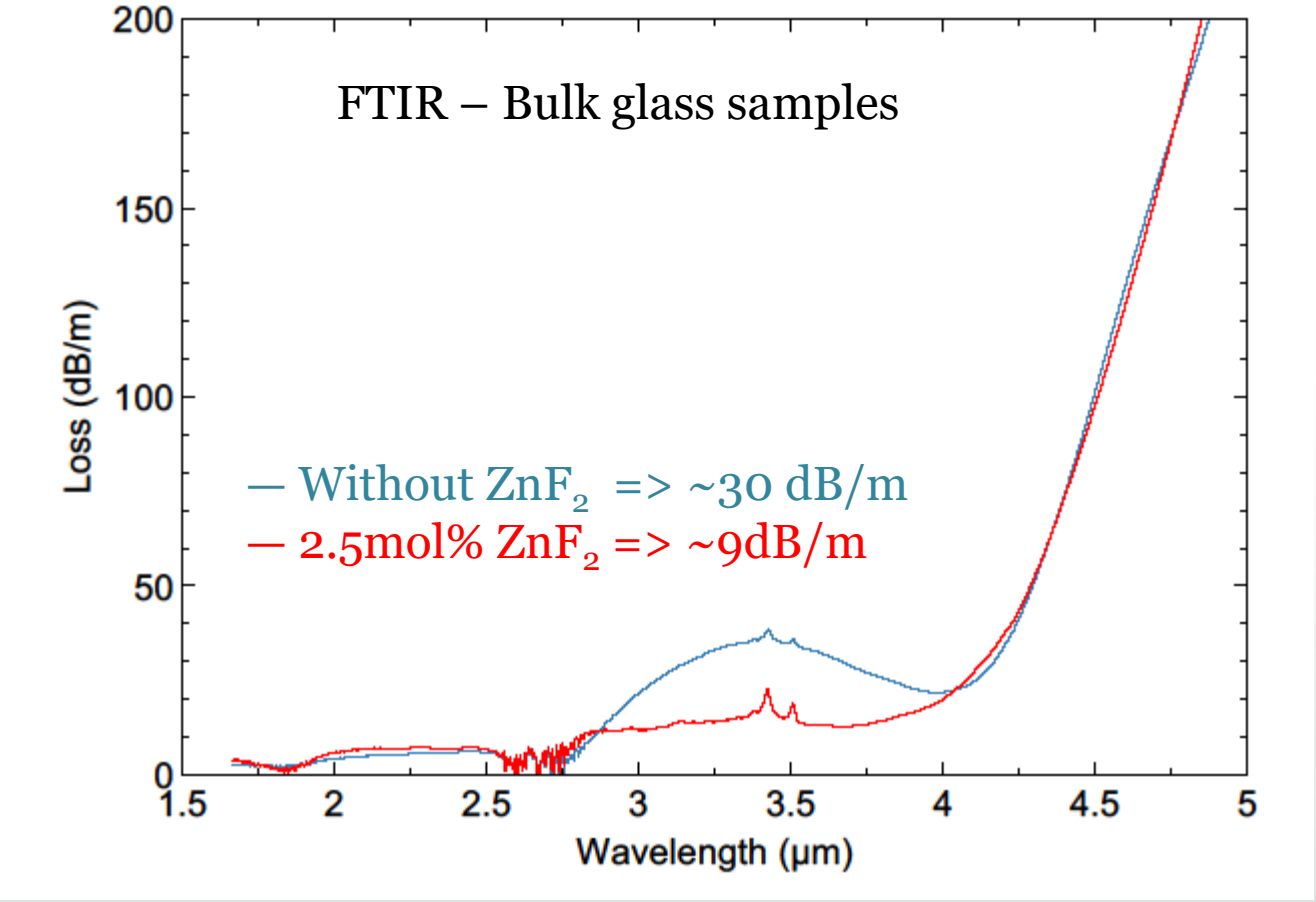




Losses at 1.55 µm = 2.56 dB/m in 2.75 µm core

Acceptable attenuation level for short length device (~10-20 cm)

Reducing OH content



Conclusion

- Development of improved TeO2 glass specifically designed for SC generation in Mid-IR

Glass label	T_g (° C) ± 3 °C	T_x (° C) ± 3 °C	$\Delta T=T_x-T_g$ ± 6 ° C	n@2 µm ± 0.001
TBG_1 (core)	353	575	200	1.975
TBG_2 (clad)	358	625	245	1.833

- Development of clad class offering high NA and compatible for fibre fabrication

Low loss & High quality fibre fabricated. Losses low enough?

Ongoing and future work

- SC generation experiments in fabricated fibres
- OH reduction in glass => low loss fibre across whole MIR

Undergoing fibre fabrication

Acknowledgement

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Thanks to the organizers & thank you for your attention

New TeO_2 glass for SC generation