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Thulium doped germanate glasses and fibres for 2 µm lasers and amplifiers

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Outline

Motivation - Lasing application in the 2 µm wavelength regions

Germanate glasses

Thulium ions

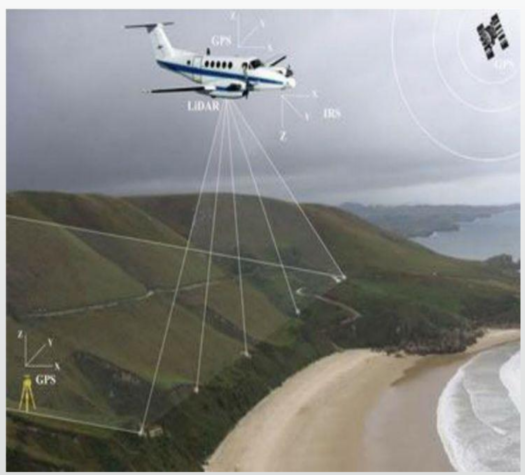
Glass Fabrication and characterization

Fibre development and characterization

Conclusion and outlooks

Motivation - Lasing application in the 2 µm wavelength regions

- Medical/Biochemical Applications (laser imaging, laser surgery..)
- Pump sources(mid –infrared lasers, optical parametric oscillators..)
- LIDAR (LIght Detection And Ranging, for cars, airports…)
- Gaz sensing systems ,
- And many others…



Germanate glasses

	Glass Transition Temperature Tg (°C)	Phonon energy (cm^{-1})	Transmission (µm)	Refractive index	Suitable for emission at
Phosphates	~500	1300	0.2-2.5	1.51	1 µm & 1.5 µm
Germanates	~500	**950**	0.3-4	1.65-1.9	1.5 µm & 2µm
Silicates	~500	1000-1100	0.3-3	1.50-1.8	1, 1.5 & 2µm

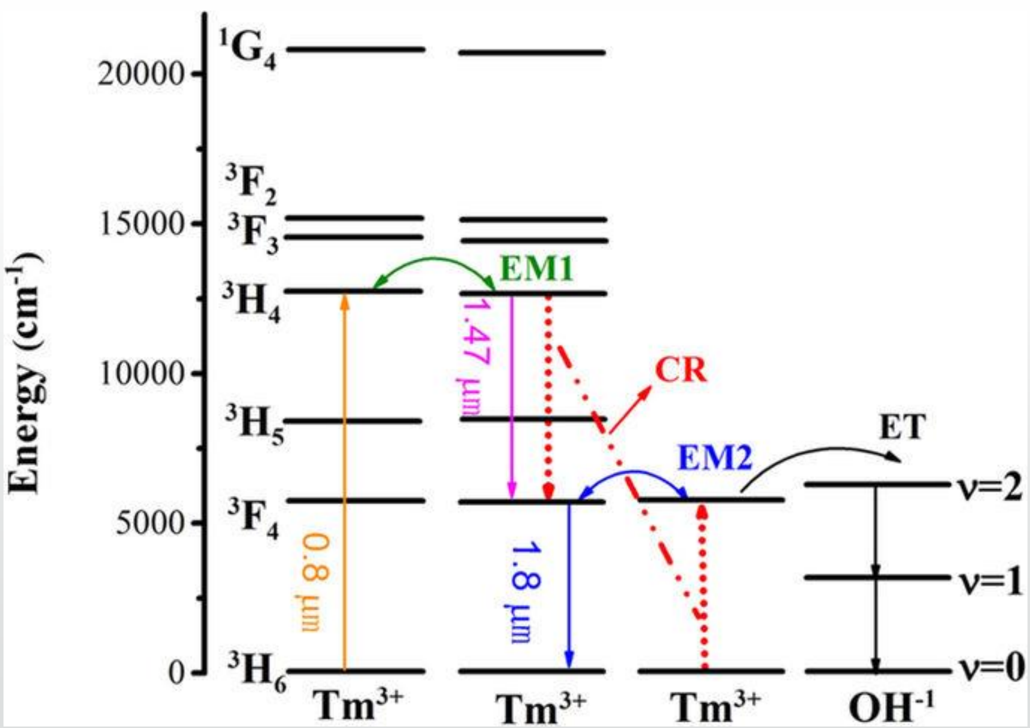
lower phonon energy

↓

decreases the probability of non-radiative relaxation and increases the Tm^{3+} luminescence at 2.um

Tm^{3+} for 2um emission

	Wavelength of emission(nm)	Transition	Type of transition
Tm^{3+}	1700-2015	$^3F_4 \rightarrow {}^3H_6$	3-level



Thulium lasers have the great advantage that the Tm^{3+} ions can be directly excited with commercially available laser diodes around 800 nm or 1550-1600 nm lasers.

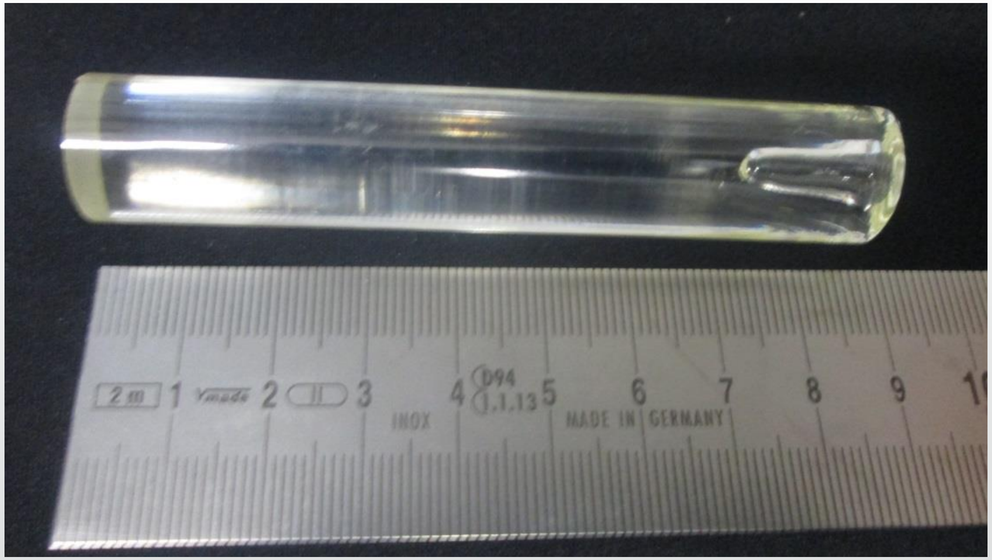
Xin Wen et al, nature, scientific reports
6, 20344,(2016)

Glass Fabrication

Melt-Quenching Technique

GeO_2-PbO-ZnO-Na_2O-Nb_2O_3-SiO_2-Al_2O_3

- Precursors: 99.9 %
- 40 g batches
- Pt crucible
- Melting Temperature (1250°C), O_2/N_2 gases, (<1ppm in H_2O) at 2 L/min)
- Annealing Temperature(480°C, 5 hours)



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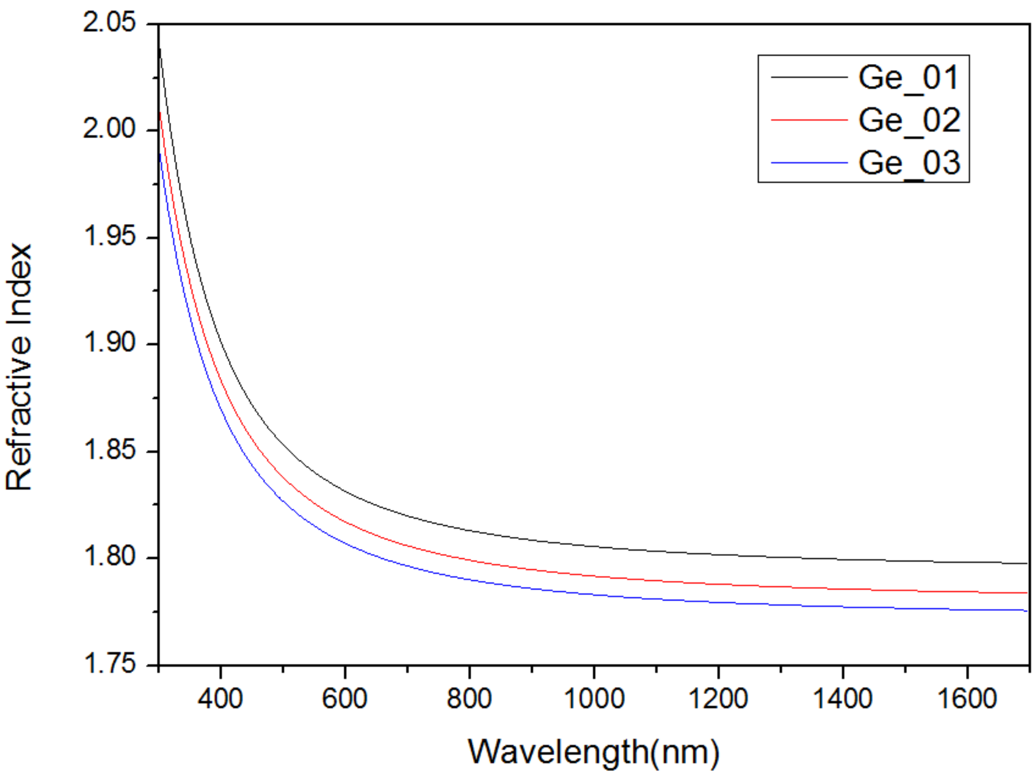
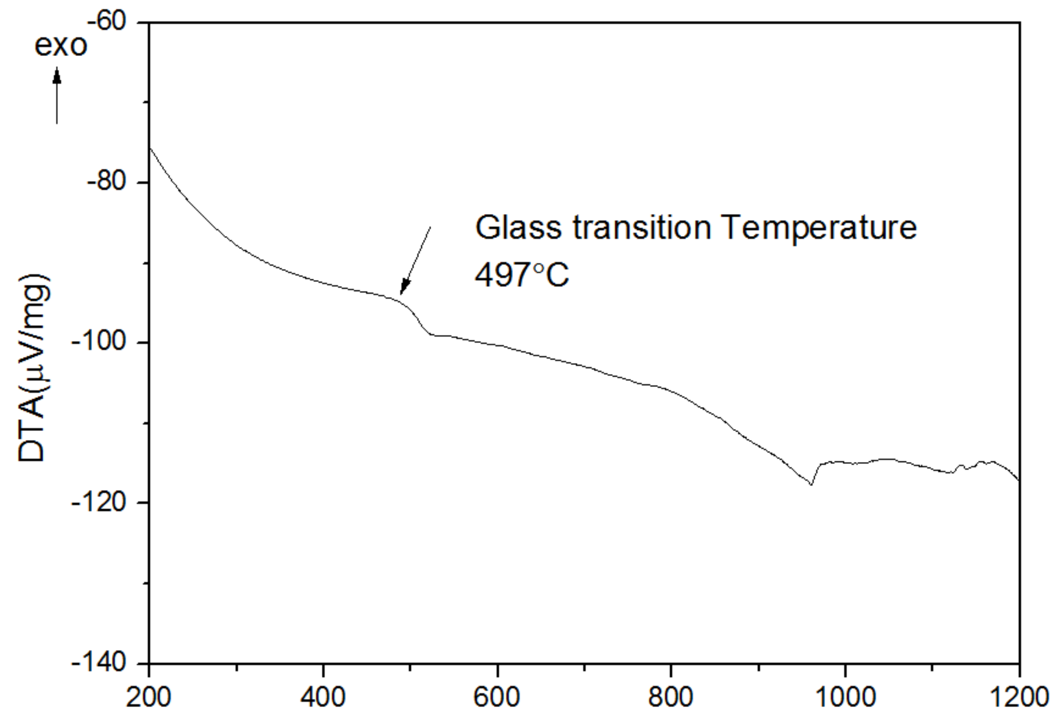




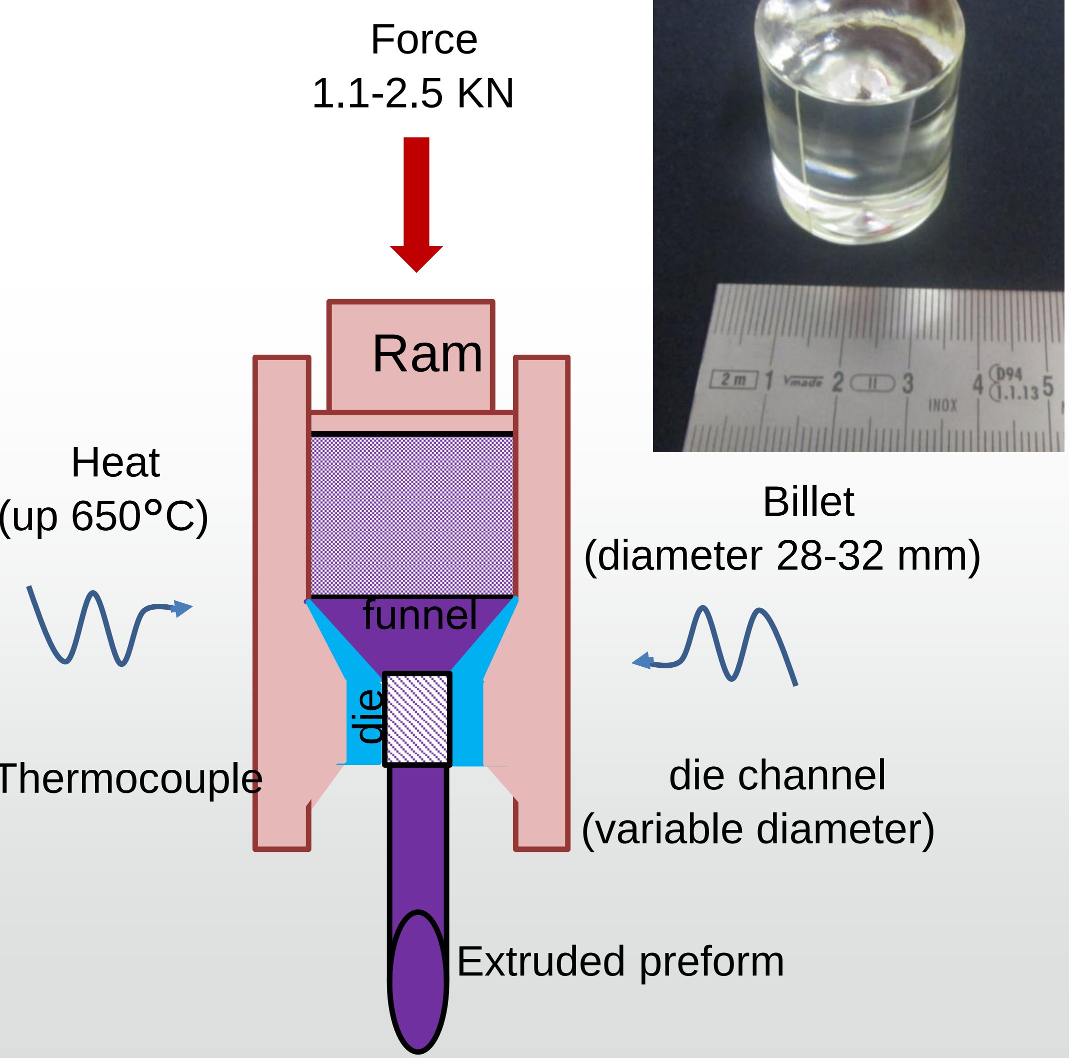
DTA curve for sample Ge_01(core)

Glass composition	Tg ± 3 (°C)	Tx ± 5 (°C)	n at 632.8 ± 0.001
Ge_01 (core glass)	497	758	1.827
Ge_02 (cladding glass)	503	761	1.813
Ge_03 (cladding glass)	506	754	1.803
Clad 3:SF6 SCHOTT	423	-	1.799

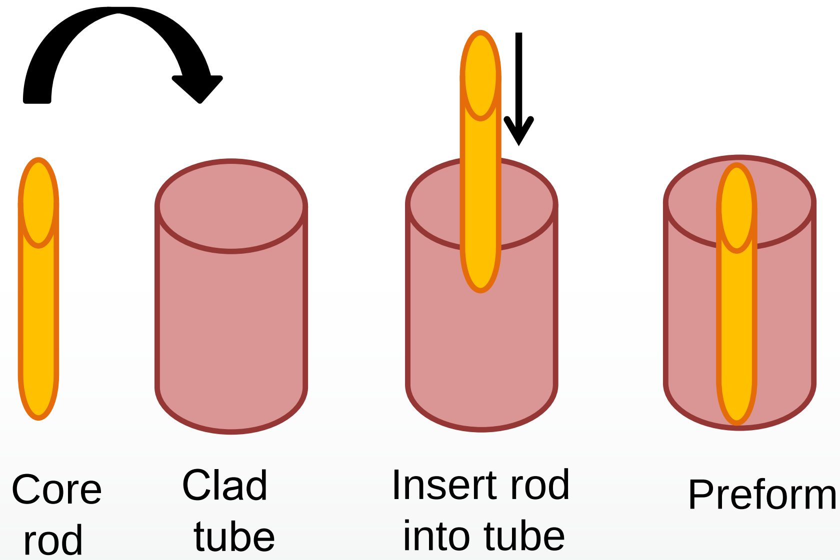
Glasses suitables for manufacturing glass lasing structures able to handle high average powers

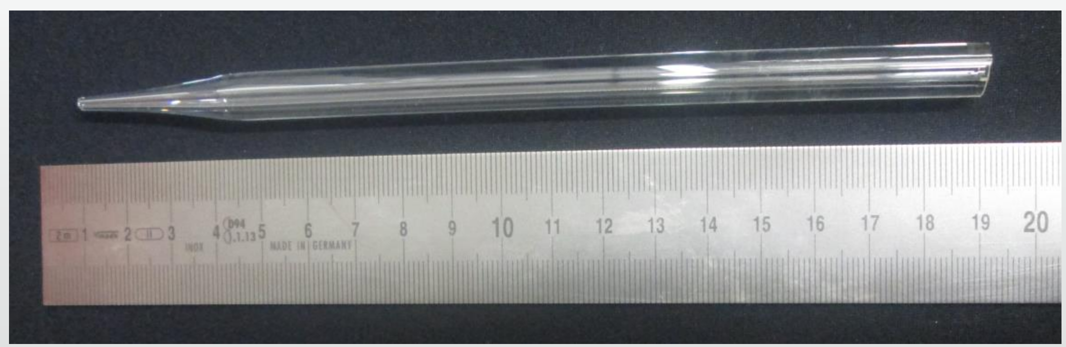
Fibre development

Extrusion Process

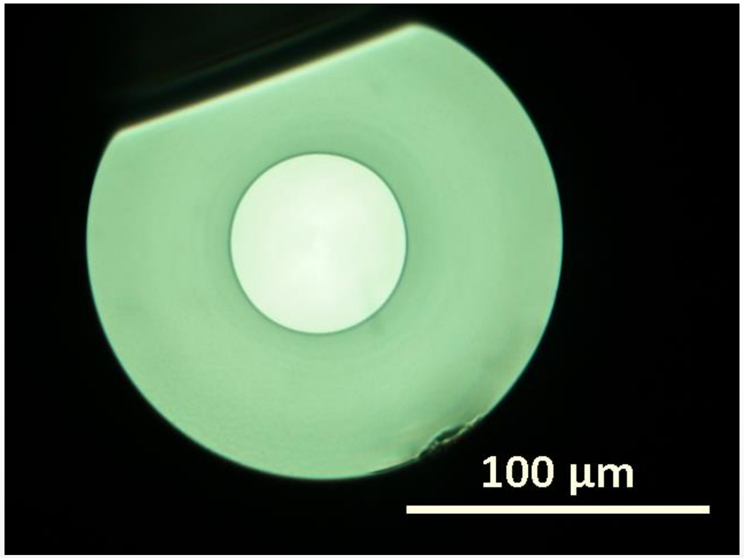


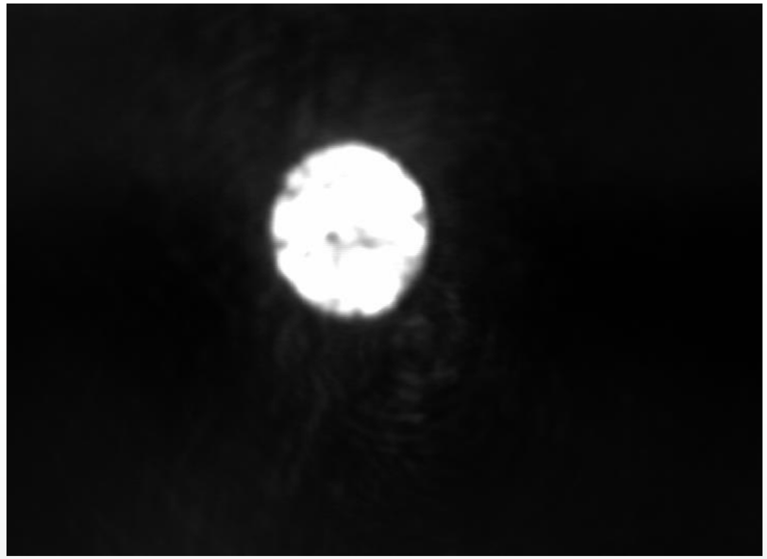
Rod-in-Tube Technique





Fibre Characterization





Fiber Core/Clad	Ge-01/SF6
$\varphi_{ext}(\pm 1\mu m)$ Ø$_{ext}$	157
$\varphi_{core}(\pm 1\mu m)$	60
Numerical Aperture (NA)	0.32

Transmission micrograph of fibre made from Ge_01 core glass and SF6 glass cladding

Near field imaging of a laser (λ=1.55 μm) through a 4.6 m long Ge_01/SF6 fibre section

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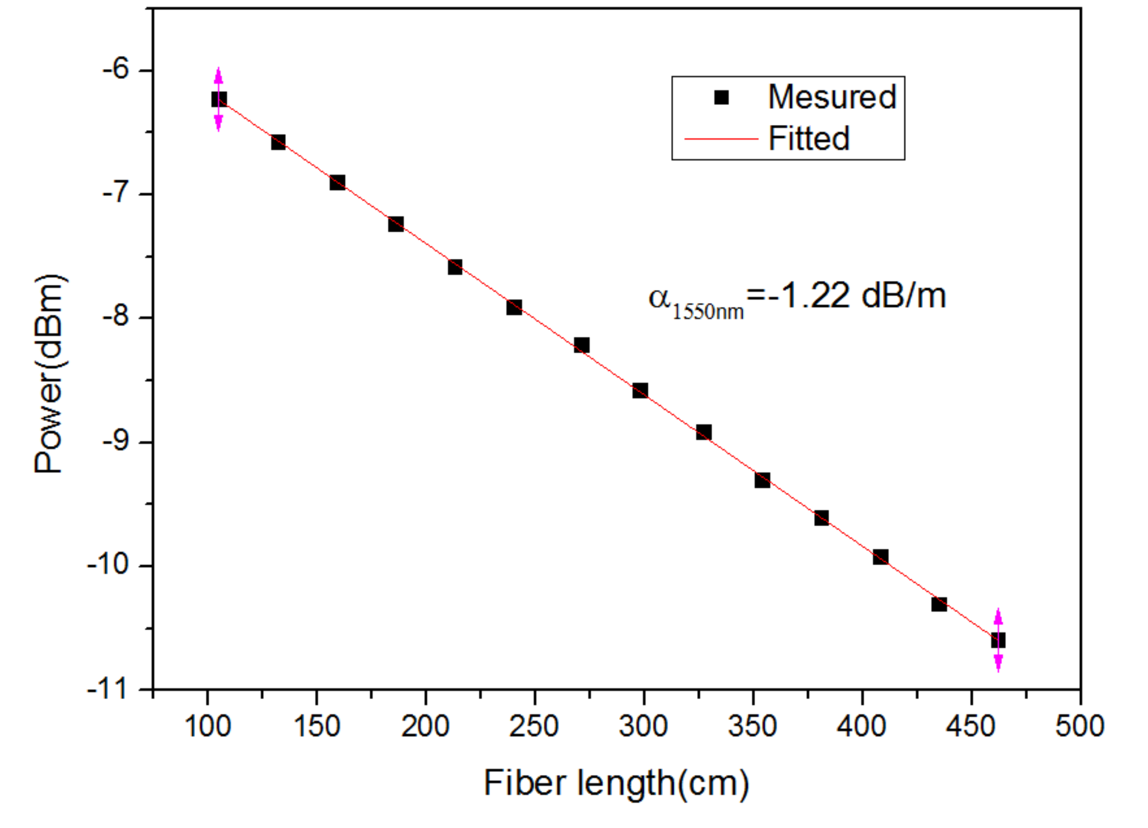
Fibre Characterization

Cut-back measurement
at λ=1550 nm using a length of 382 cm.



Losses (dB/m)	**1.2 dB/m**

Absence of cristallization(otherwise high value)

the glass is able to withstand the double thermal cycle necessary for fibre fabrication without crystallising

Development of large core SM fibre

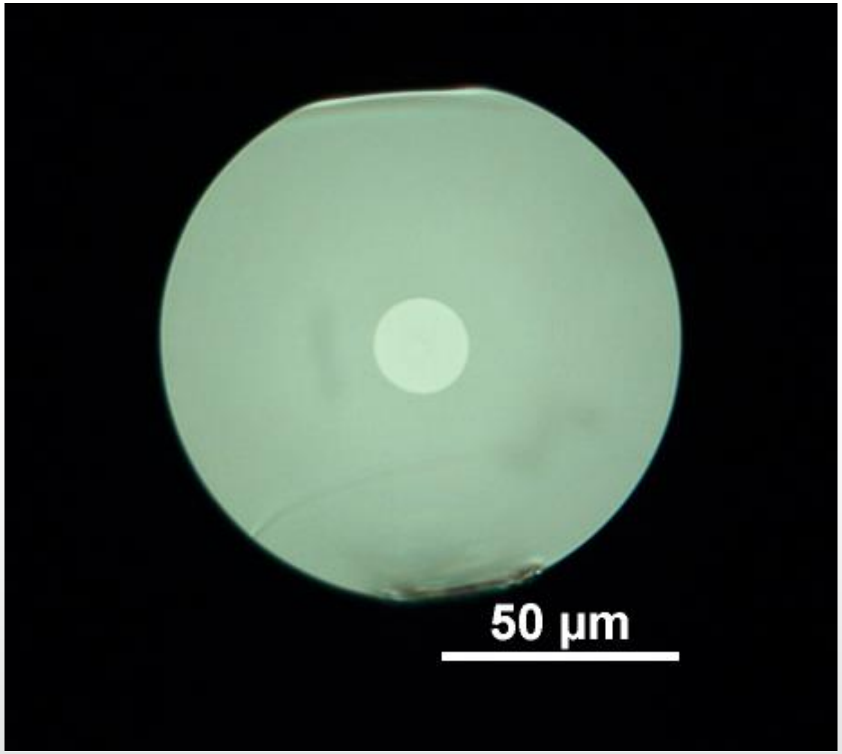
	Ge_04	Ge_05
Tg(± 3 ℃)	485	489
n at 632.8 ± 0.001	1.825	1.827

$\Delta n = 0.002$

NA=0.07

=> SM operation fiber with a large core diameter(20 um at λ =2 um)

Large core SM fibre - Characterization



Fiber Core/Clad	Germanate
$\varphi_{ext}(\pm 1\,\mu m)$	110
$\varphi_{core}(\pm 1\,\mu m)$	20
Numerical Aperture (NA)	0.07

Conclusion

- Three thermally compatible germanate glasses in the systemGeO_2-PbO-ZnO-Na_2O-Nb_2O_3-SiO_2-Al_2O_3, were developed
- Theses glasses, possessing a high temperature transition, makes them suitable for high average power amplifier and laser applications
- One of theses glasses was successfully drawn into fiber using an SF6 as a clad
- A second fiber was developed using a core and a clad fabricated both with melt-quenching method, with the final aim to develop large core SM fibre for highly compact lasers and amplifiers operating in the 2 µm region

On going & future work

- Remove OH- content in glasses to achieve excellent luminescence property
- Absorption, emission spectra, lifetime measurements →Cross sections and gain properties
- Double clad optical fiber, with SF6 or an other commercial glass as a second clad

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Thank You For Your Attention

Special Thanks to:

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