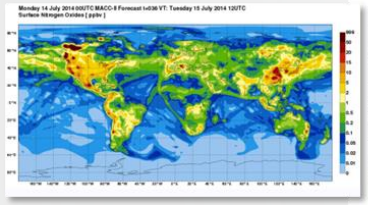
COST TD 1401, WG2 meeting, 8th of February 2018

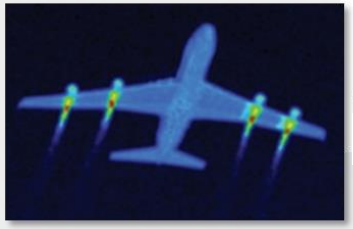
Efficient very-large-mode-area thulium doped fibre laser for 2 µm operation

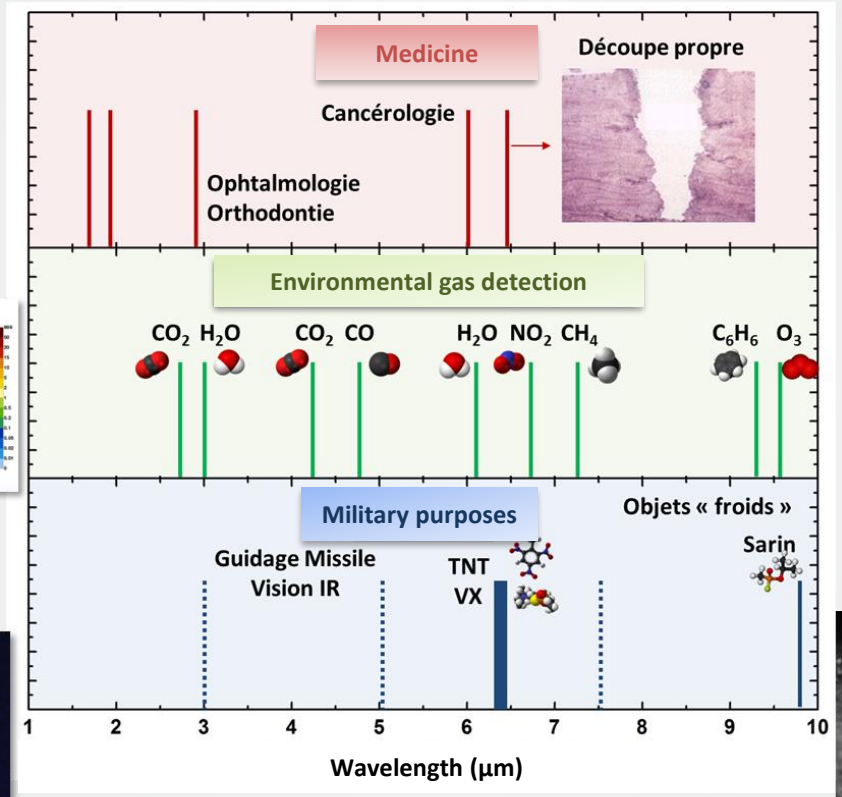
- Stacks of mid-IR laser sources
- Previous achievements
- Synthesis of a VLMA Tm-doped fibre
- Laser results and prospects

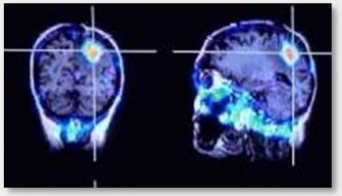
Dia Darwich, Romain Dauliat, Mostafa Sabra, Baptiste Leconte, Raphaël Jamier, Jean-Louis Auguste, Anka Schwuchow, Kay Schuster, Eric Lallier, and Philippe Roy

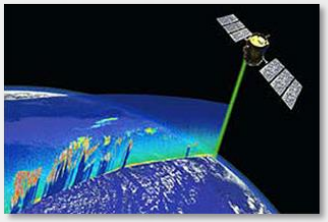
Stakes of mid-IR sources











Current technology: CO2 and quantum cascade laser

Route to mid-IR sources

STRATEGIES

- **Monochromatic laser sources at 2 µm = Eye-safe wavelength range**

Climatology / LIDAR

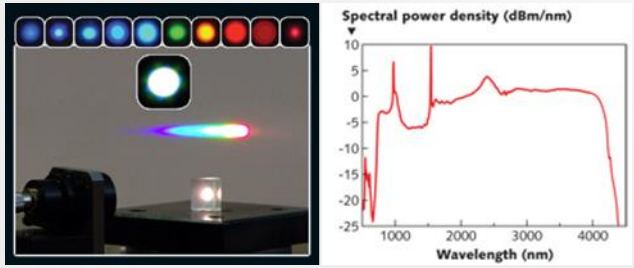
Ophthalmology

Host matrices

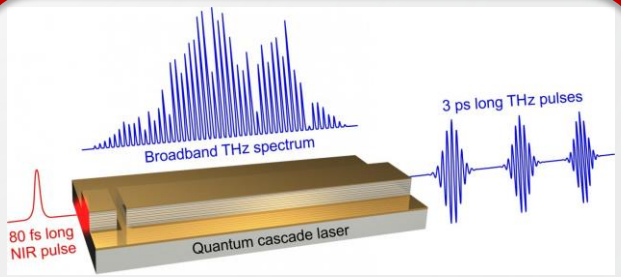
Tm_2O_3:SiO_2
Ho_2O_3:SiO_2
Tm_2O_3: Ho_2O_3: SiO_2

Er:ZBLAN

- **High peak power for frequency conversion to mid-IR**



Mid-IR supercontinuum



Terahertz waves

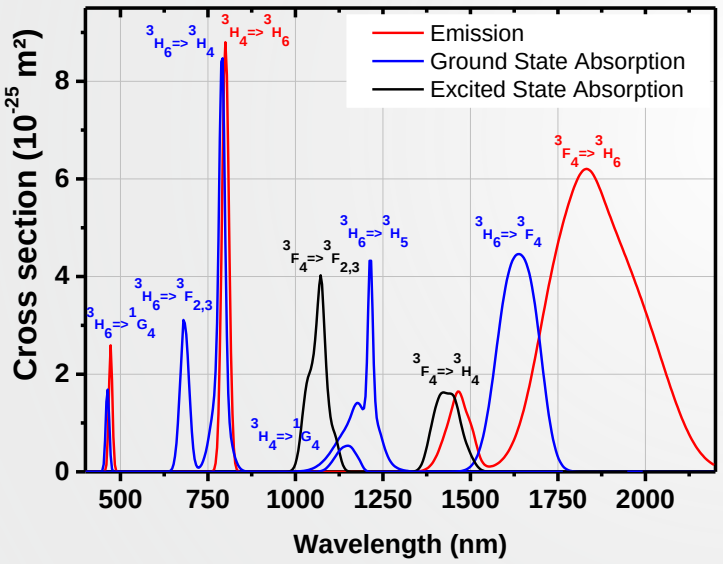
=> Next talk

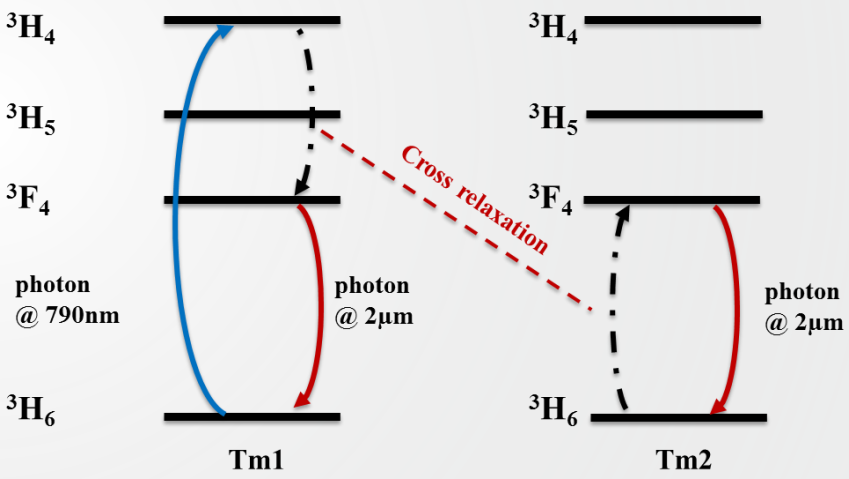
2 µm fibre laser

CHALLENGES

- **Moderate efficiency compared to Yb-doped laser**

=> Need to favour the cross-relaxation mechanism



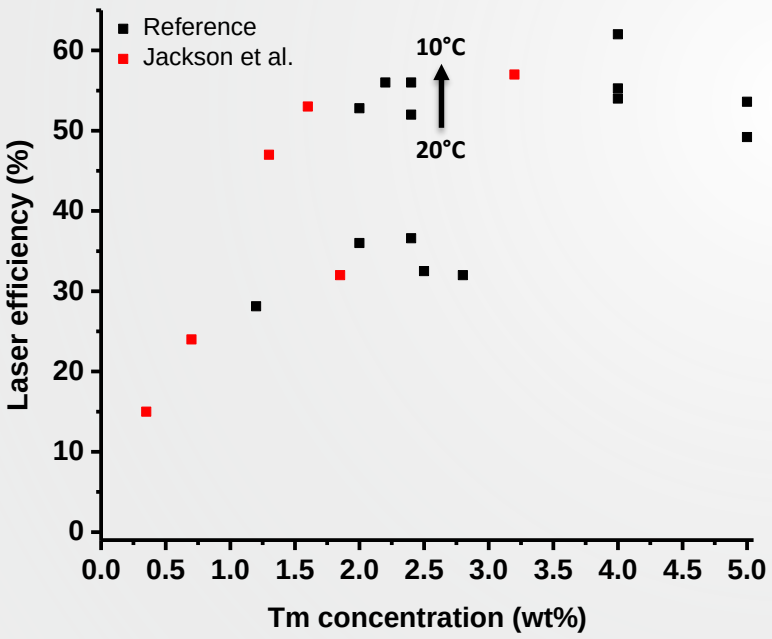


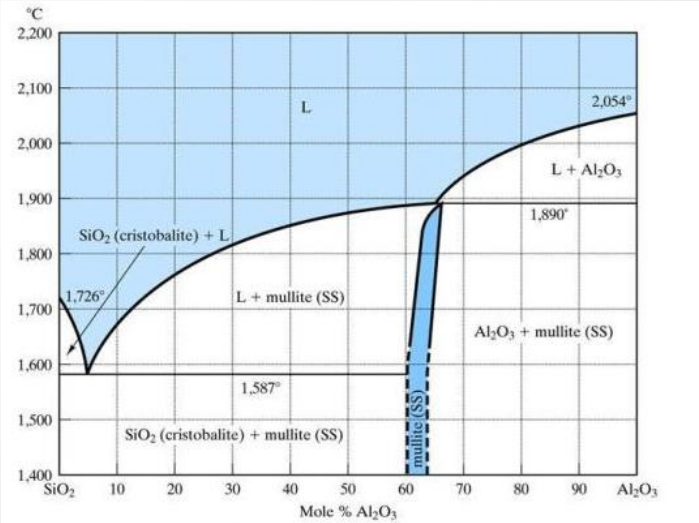
=> Efficiency can be as high as 80%

Defining an adequate material composition

GLASS MATRIX

- Host matrix: Aluminosilicate for solubility of Re_2O_3
- Tm_2O_3 introduced in large amount to favour ions proximity and cross relaxation
- Al_2O_3:Tm_2O_3 <-> 10:1 => Risk of phase separation





Al_2O_3 –SiO_2 phase diagram

Mullite is an intermediate compound with ideal stoichiometry $3Al_2O_3 \cdot 2SiO_2$

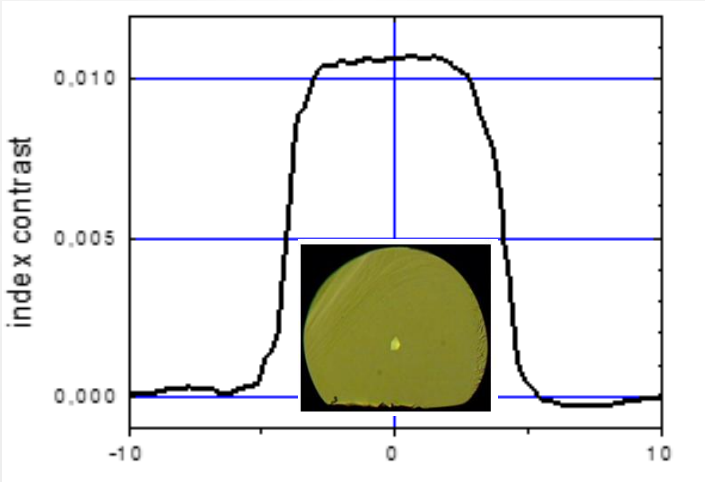
Material validation

FABRICATION OF STEP-INDEX FIBRES

- **1st composition of interest**

Fibre n°493

0.3 mol % Tm_2O_3
3 mol % Al_2O_3



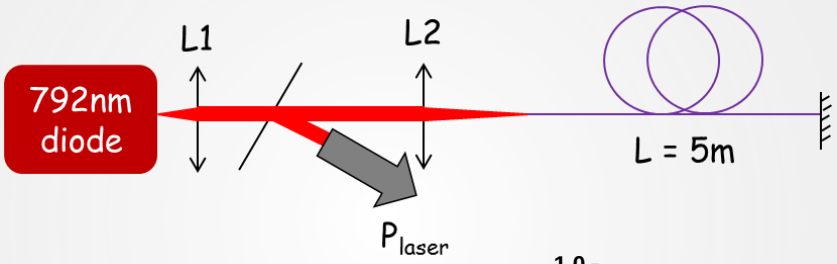
Core dimensions: 7*9 µm
Clad dimensions: 122*146 µm

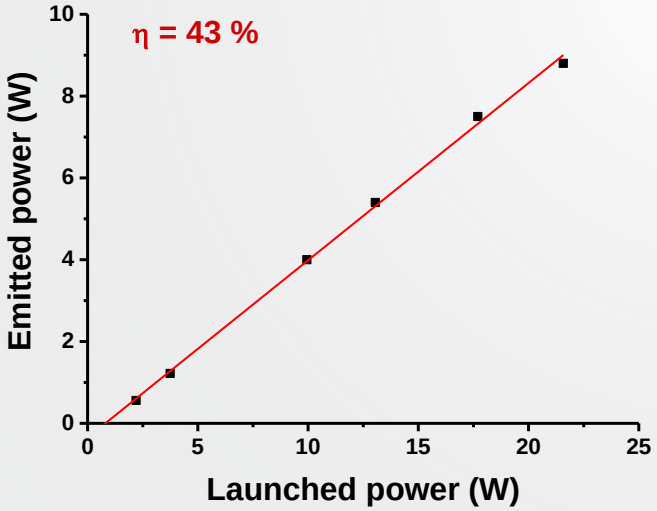
D-shape
=
Improves pump absorption

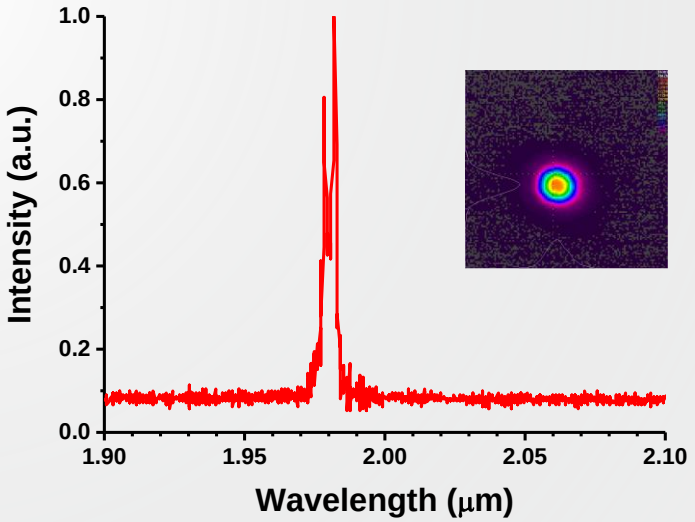
Fibre lasers

DETERMINATION OF THE LASER EFFICIENCY

- **Fibre 493:** ~9 µm core / 122*146 µm clad – 5 dB/m abs. @ 792 nm







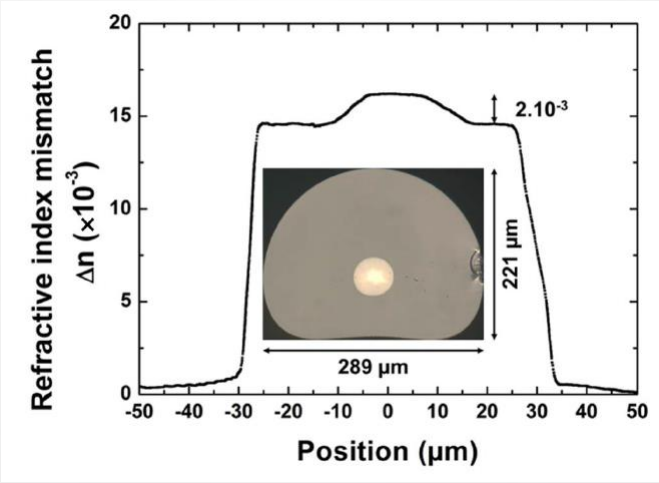
Material validation

FABRICATION OF STEP-INDEX FIBRES

- **2nd composition of interest**

Fibre n°985

0.3 mol % Tm_2O_3
6 mol % Al_2O_3



Core dimensions: 18 µm
Clad dimensions: 221*289 µm

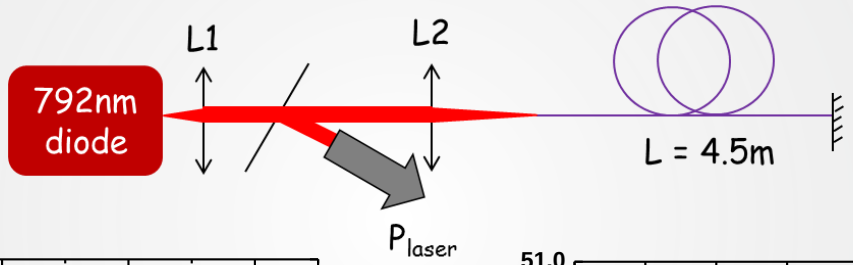
D-shape
=
Improves pump absorption

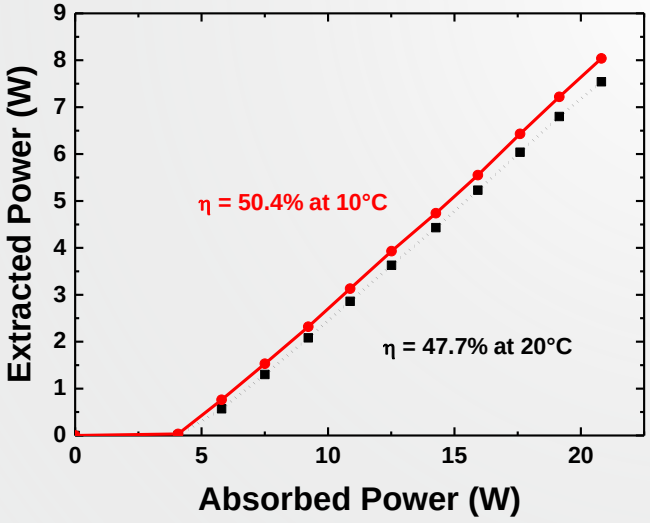
Part of this work, achieved by Dia Darwich, has been supported by a STSM in April 2016

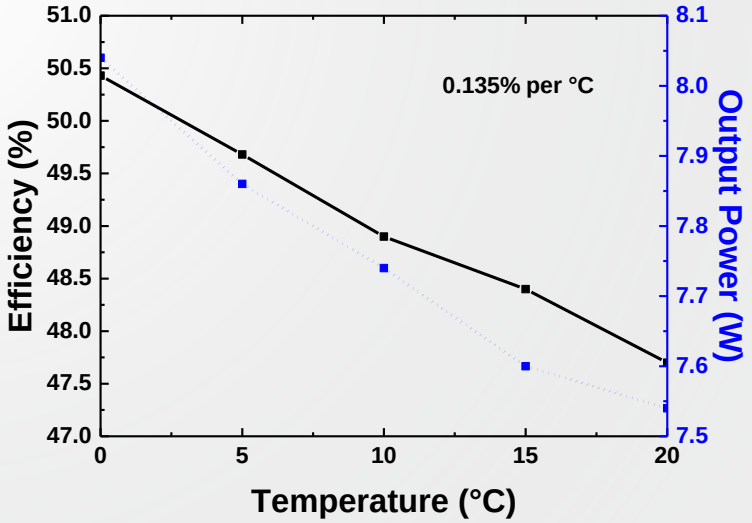
Fibre lasers

DETERMINATION OF THE LASER EFFICIENCY

- **Fibre 985:** ~18 µm core / 221*286 µm clad



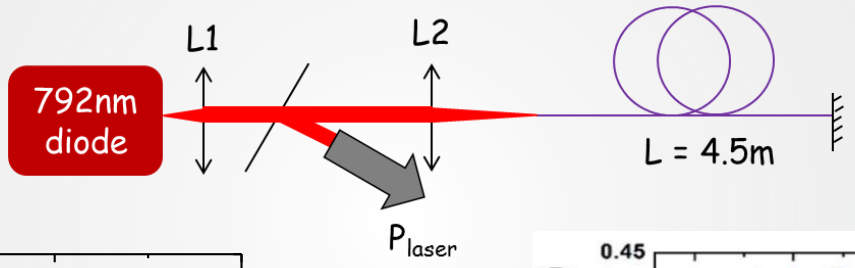


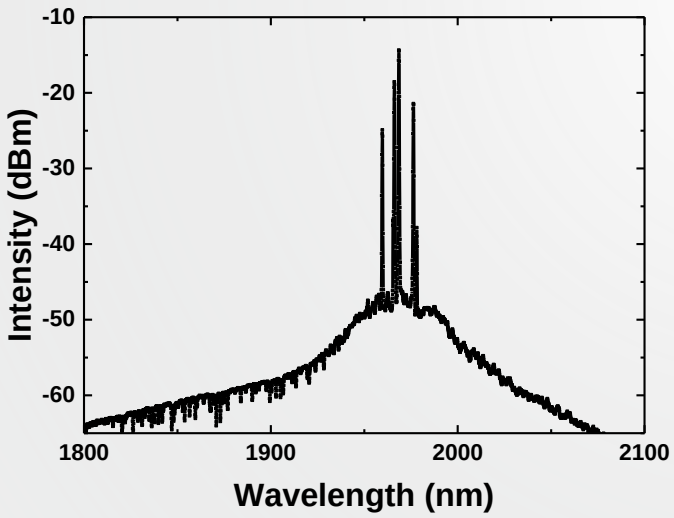


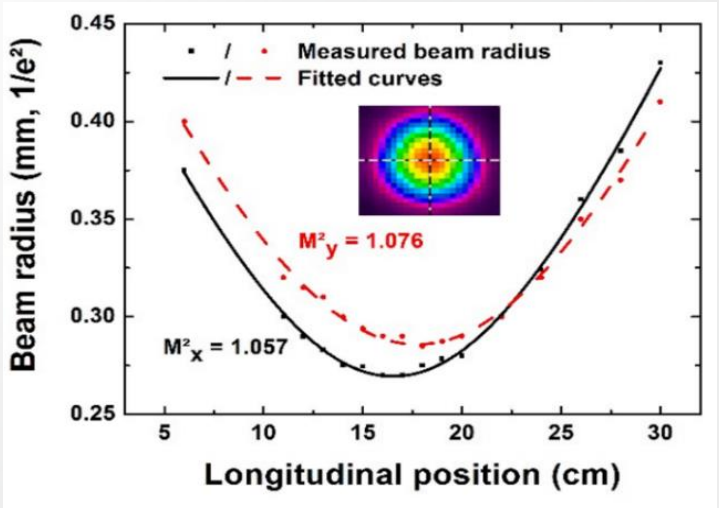
Fibre lasers

DETERMINATION OF THE LASER EFFICIENCY

- **Fibre 985:** ~18 µm core / 221*286 µm clad





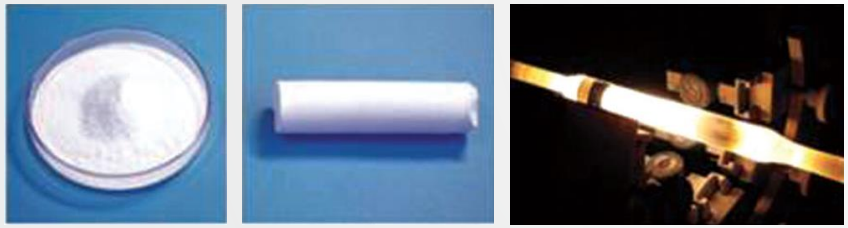


Towards VLMA fibres

CHALLENGE

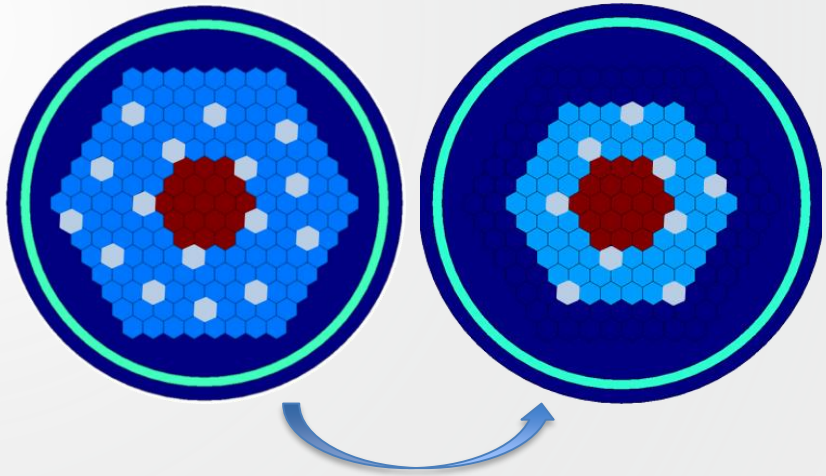
- **Producing a singlemode VLMA fibre**
- **CVD techniques offers a limited control over the refractive index and so on the core size**
- **Our proposition: Repusil + Cladding-reduced Fully Aperiodic LPF**

Repusil synthesis technique



Langner et al., PW (2012)
Schuster et al. Adv. Opt. Techn. 3(4)(2014)

Fully-Aperiodic Large-Pitch-Fibre



- **An index matching between the active core and the passive cladding is mandatory**

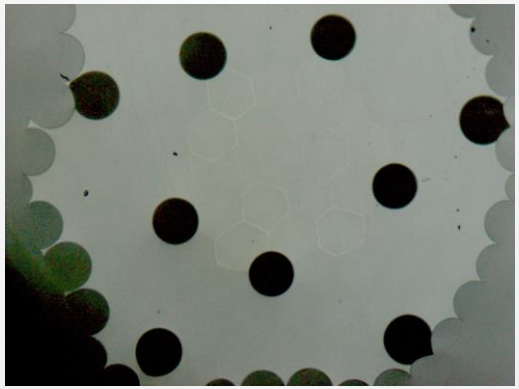
Synthesis and fibre fabrication

MATERIALS

- Core material: 0.3 mol% Tm_2O_3 + 3 mol% Al_2O_3
- Clad material: 3.7 mol% Al_2O_3

Stack

Microstructured cane



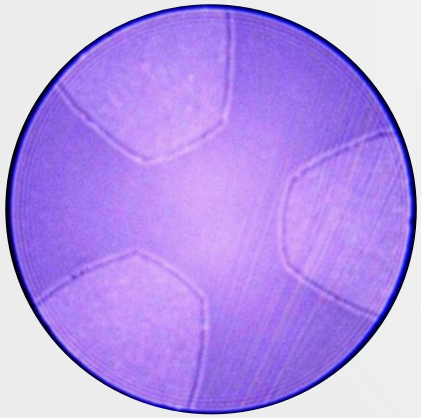
Rod-type FA-LPF

Control of the index matching

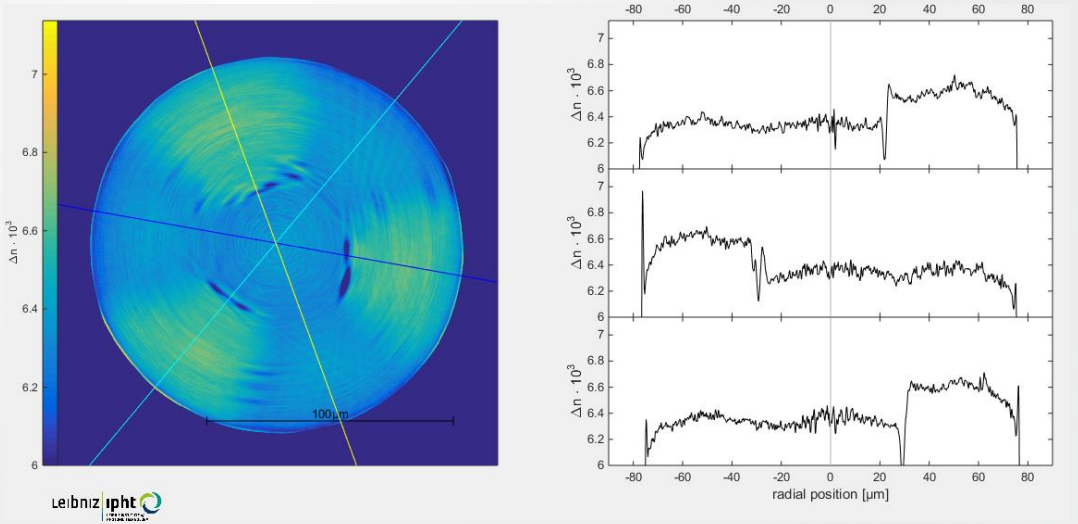
PROTOCOL

- **Drawing of a « test fibre »**
- **Mapping the refractive index mapping using a commercial IFA device**
- **Performing a statistical analysis for improving the measurement accuracy**

« Test fibre »



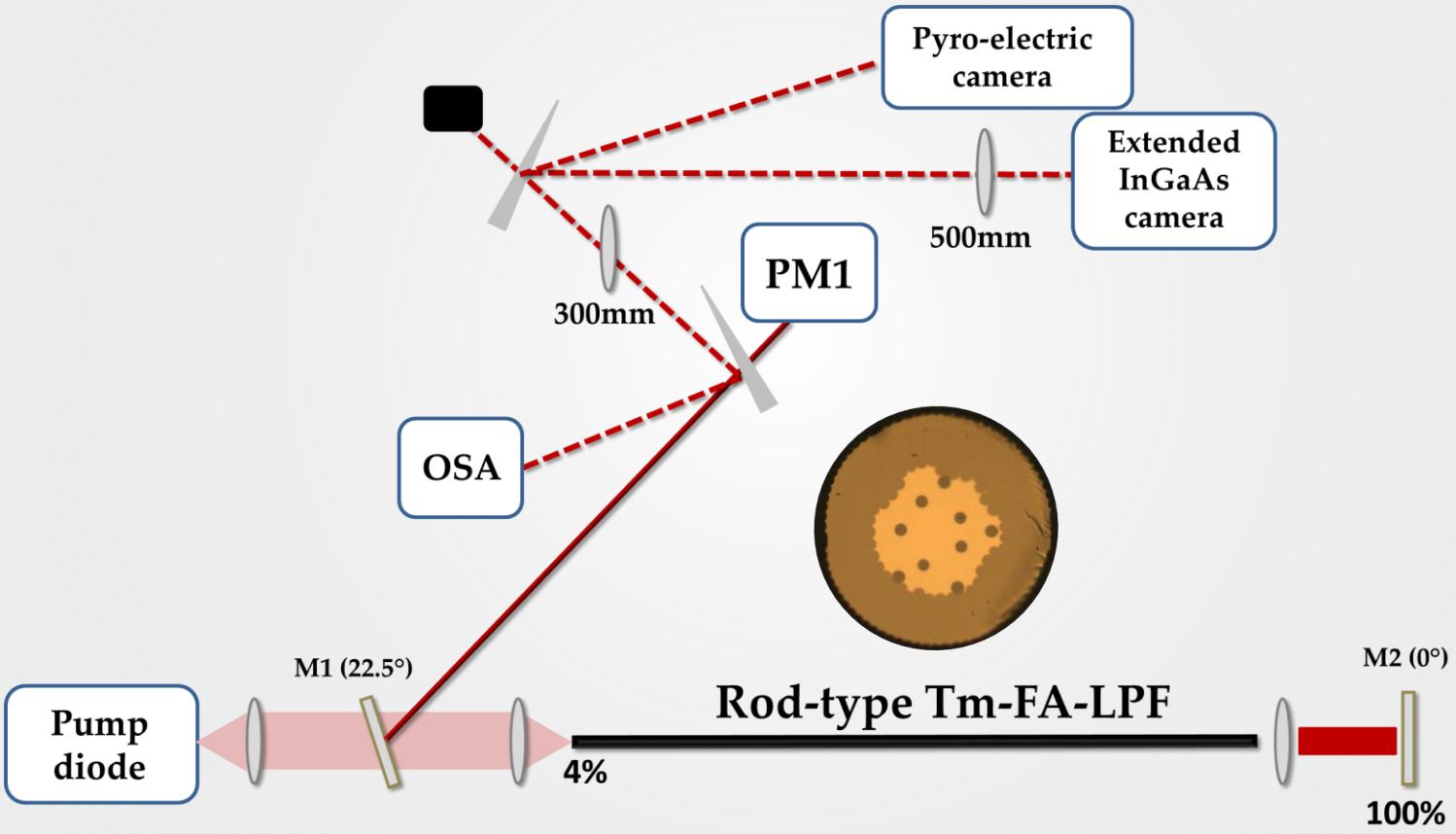
Refractive index mapping



$\Delta n \sim 30.10^{-5}$

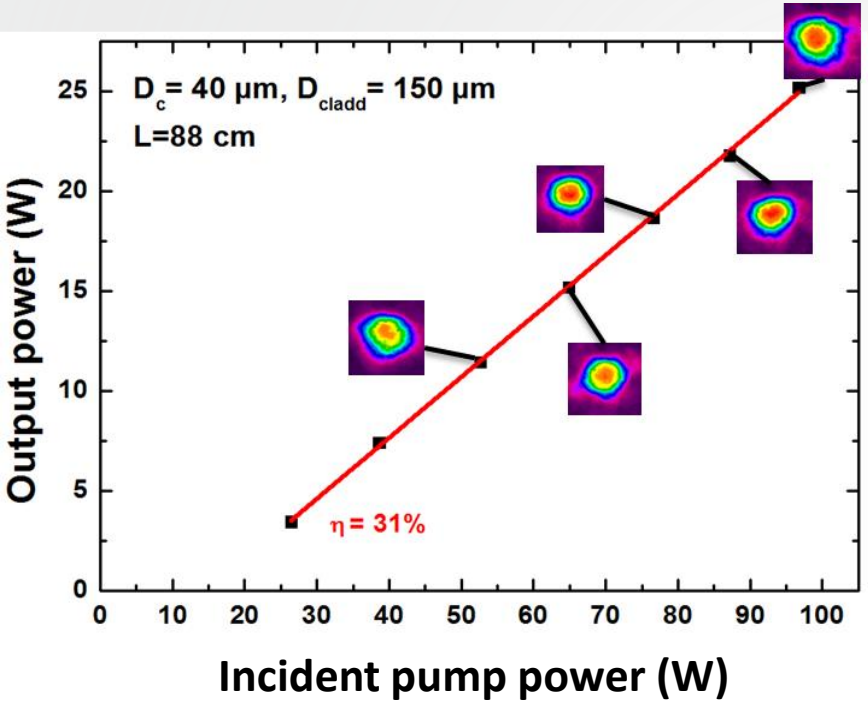
Tm-doped FA-LPF for 2 µm operation

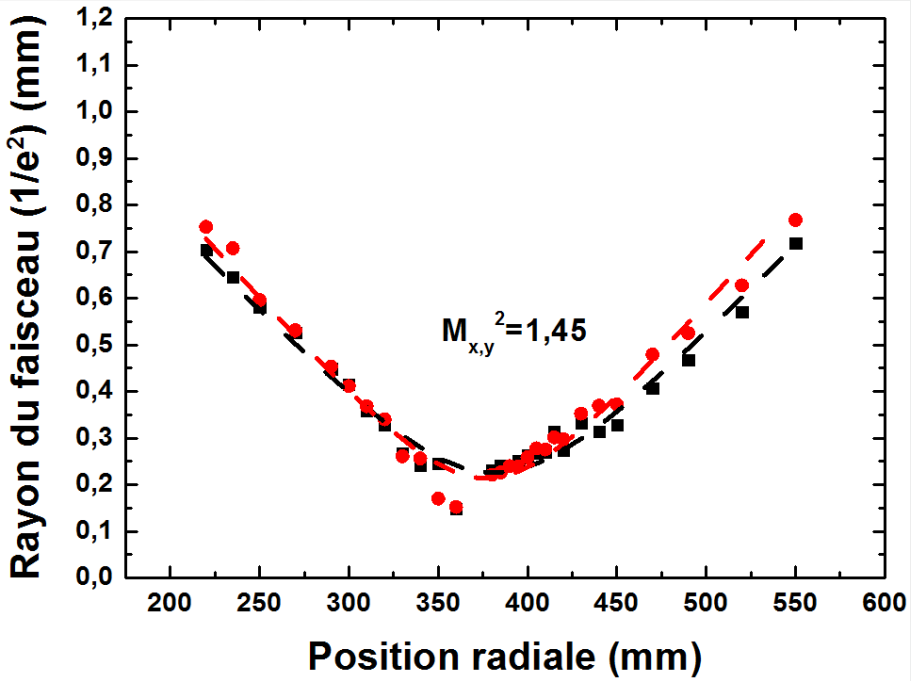
LASER SETUP



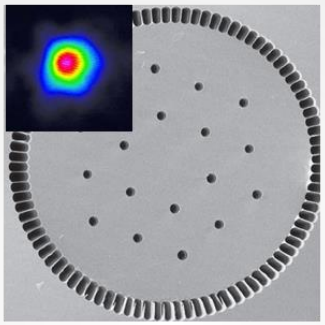
Tm-doped FA-LPF for 2 µm operation

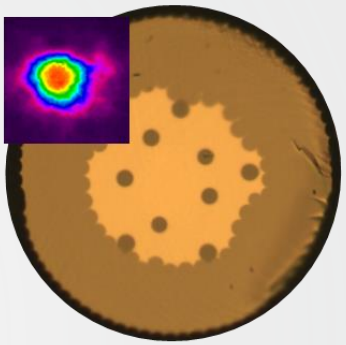
LASER RESULTS





Tm-doped FA-LPF for 2 µm operation





Thulium concentration	0,415mol% Tm_2O_3	0,3mol% Tm_2O_3
Core diameter (µm)	81	40 / 48
MFD (µm)	60	35 / 40
Efficiency (%)	33	31 / 36,5
M^2	< 1,5	< 1,45 / ??

F. Jansen et *al*. Opt. Lett., 37(21), 2012

Conclusions & Prospects

CONCLUSIONS

- **Study of glasses composition for maximizing the cross relaxation**
- **Step index fibres: efficiency reaching up to 50%**
- **Influence of the temperature on the efficiency confirmed**
- **Fabrication of the first Tm-doped FA-LPF satisfactory**

PROSPECTS

- **Drawing fibres with larger dimensions**
- **Building a Q-switch laser**
- **Use this fibre as amplifier for Terahertz generation**

Acknowledgements

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Acknowledgement for:

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Martin Lorenz / Adrian Lorenz: Accurate refractive index measurements