A Bright COST Action

"Laser Material and Components Challenges"

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Chair of COST Action MP1401

"Advanced fibre laser and coherent source as tools for society, manufacturing and lifescience"

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Summary

- Introduction
  - Who we are
  - Were we are here
  - Why we are “bright”?
- Roadmap
- Challenges
- Conclusions

Thanks to


Dr. Maurizio Ferrari and Dr. Kay Schuster

Chaired and Organized this meeting



Dr. Virginie Nazabal (WG1), Prof. Angela Seddon (WG2), Prof. Marian Marciniak (WG2)

Swansea University

Materials, Physical and Nanosciences Domain

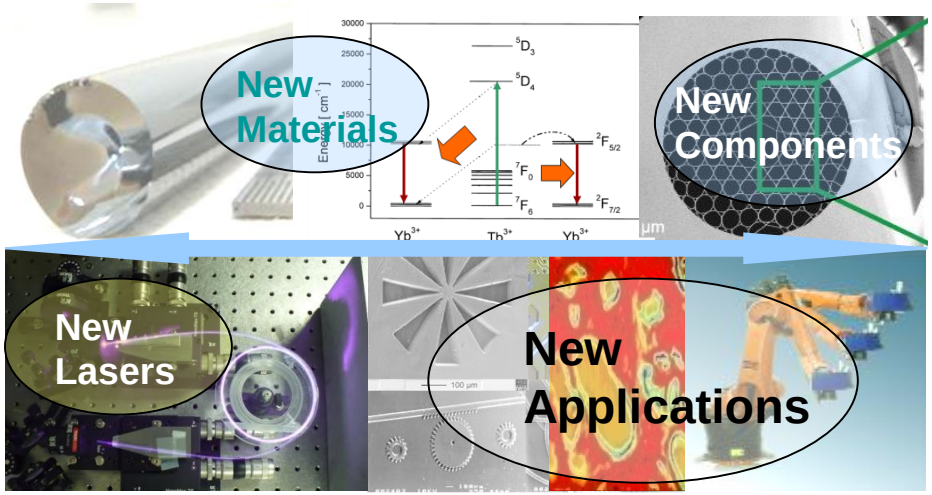
COST Action MP1401

Advanced Fibre Laser and Coherent Source as tools for Society, Manufacturing and Lifescienc

EAGLES, Trento 18-10-2016 WG1 Topical Meeting

Objective

The aim of the Action is to provide the first arena for fibre lasers where experts in fundamental material sciences, established laser and component groups, fibre laser manufacturers and end-users will be able **to actively interact, share know-how and focus on common goals.**

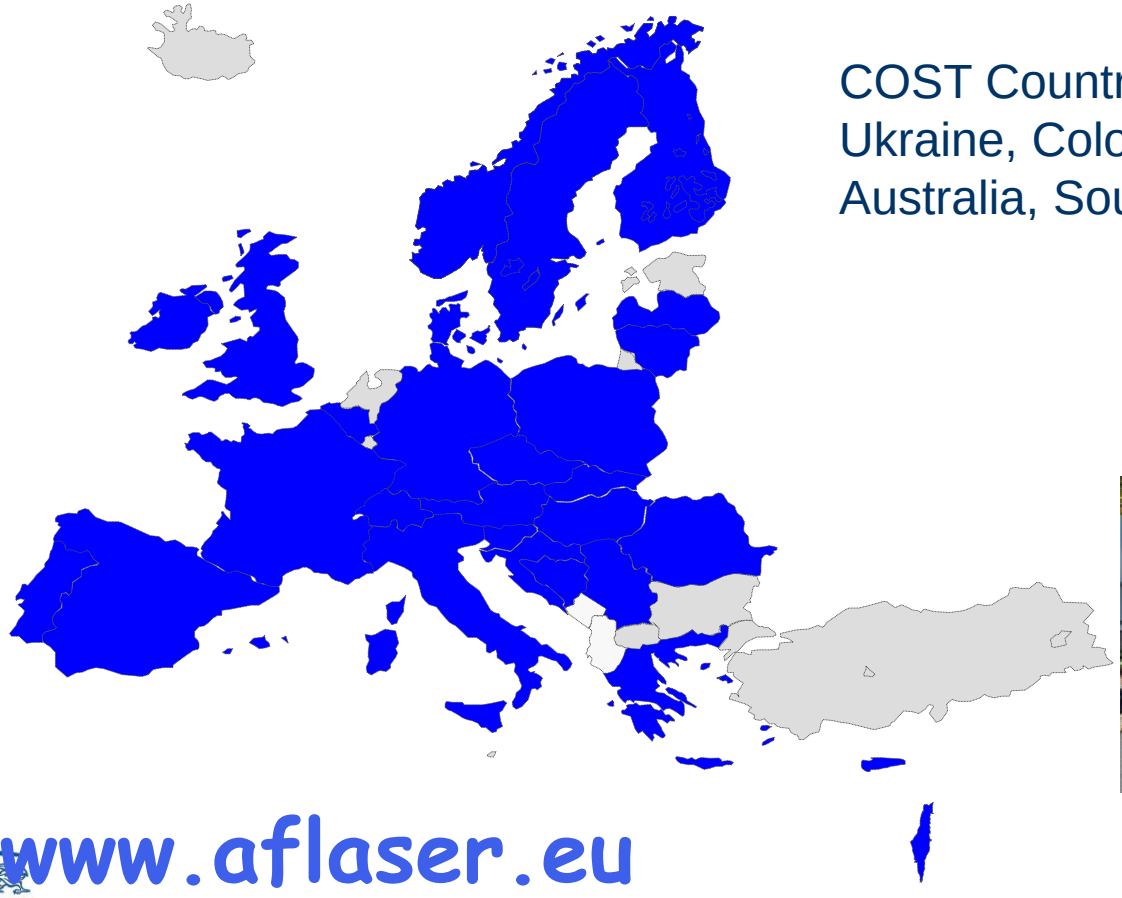


WG1	Materials, Fibres, Components and Technology
WG2	New laser , amplifier devices and coherent light sources
WG3	Applications
SIG1	techno-economical aspects

COST MP1401

MP1401 Advanced fibre laser and coherent source as tools for society, manufacturing and lifescience

COST is an H2020 EU Network to support scientific cooperation
From 12/2014 to 12/2018



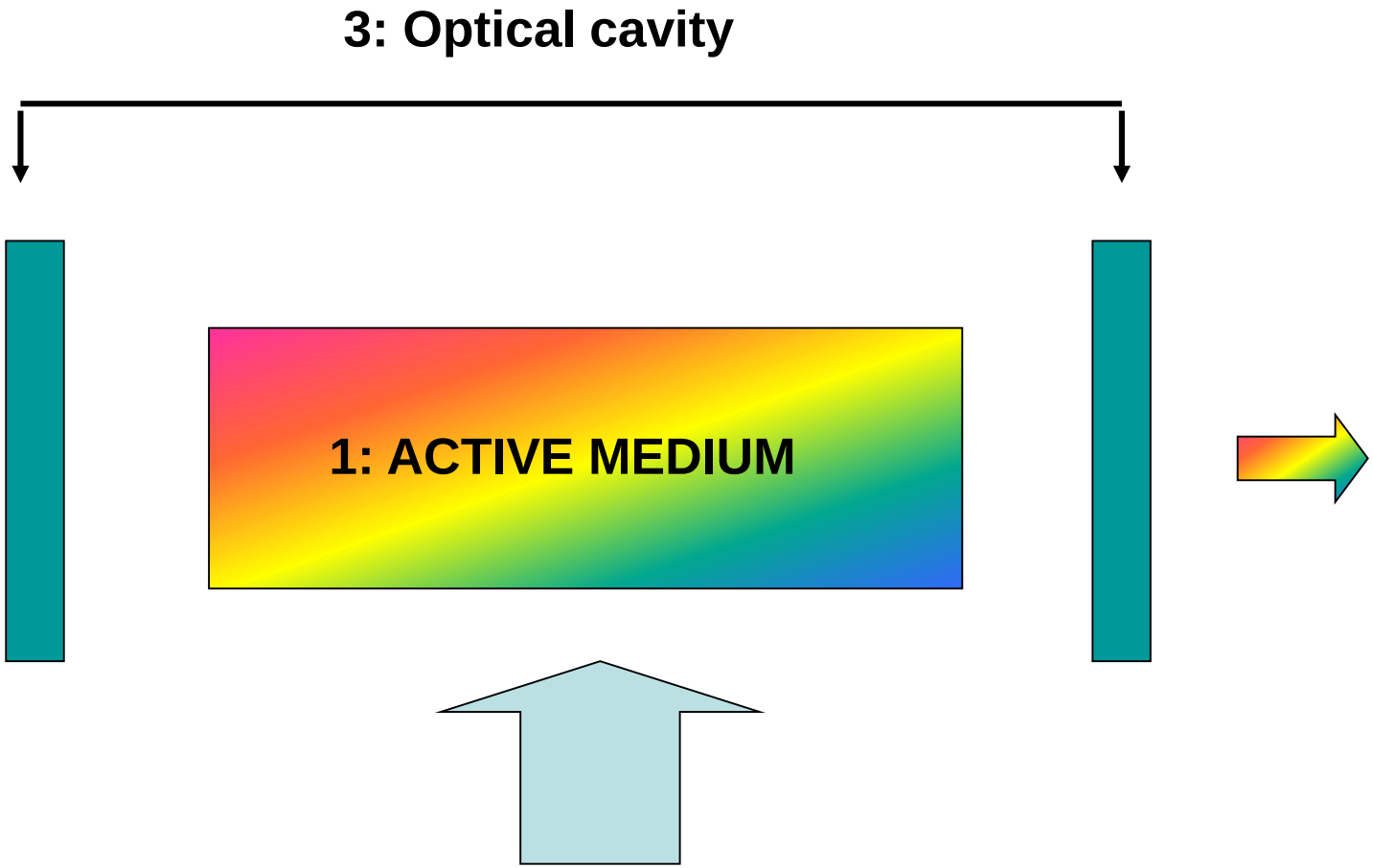
COST Countries : 28 + Russia, Armenia, Ukraine, Colombia, Brazil, Jordan, US, Australia, South Africa.

Participants:
130 Institutions,
260 Researchers

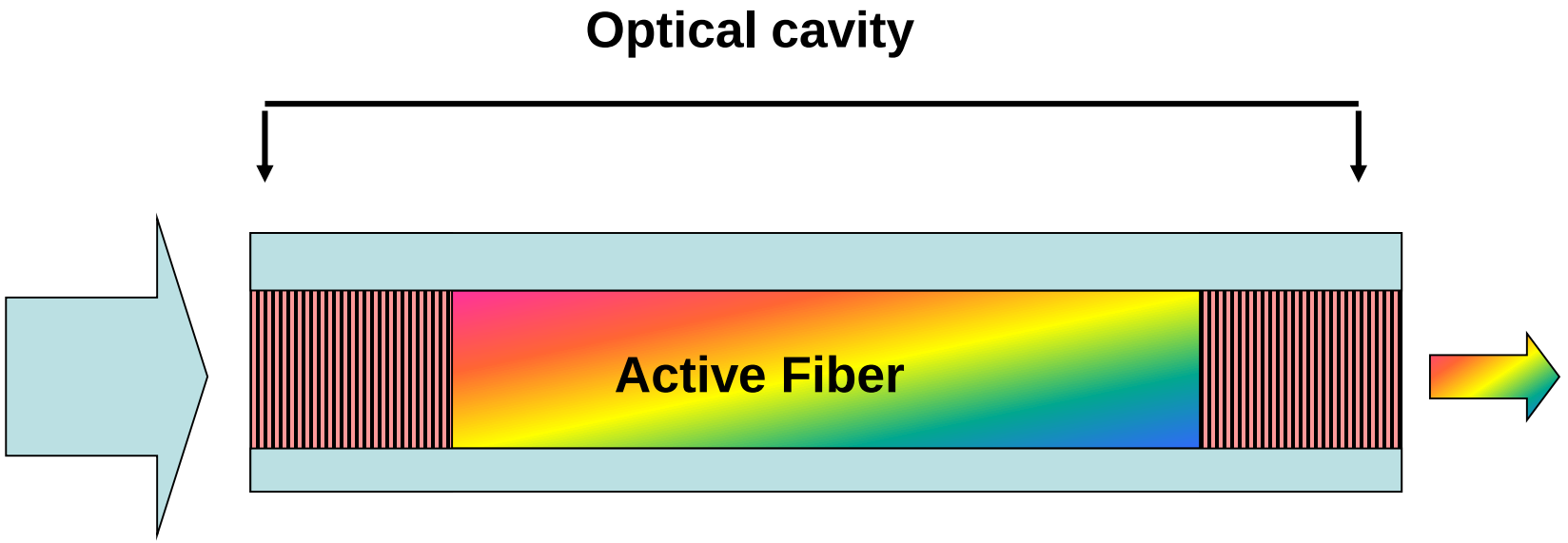
Dresden meeting at IWS Fraunhofer

www.aflaser.eu

Elements of a laser



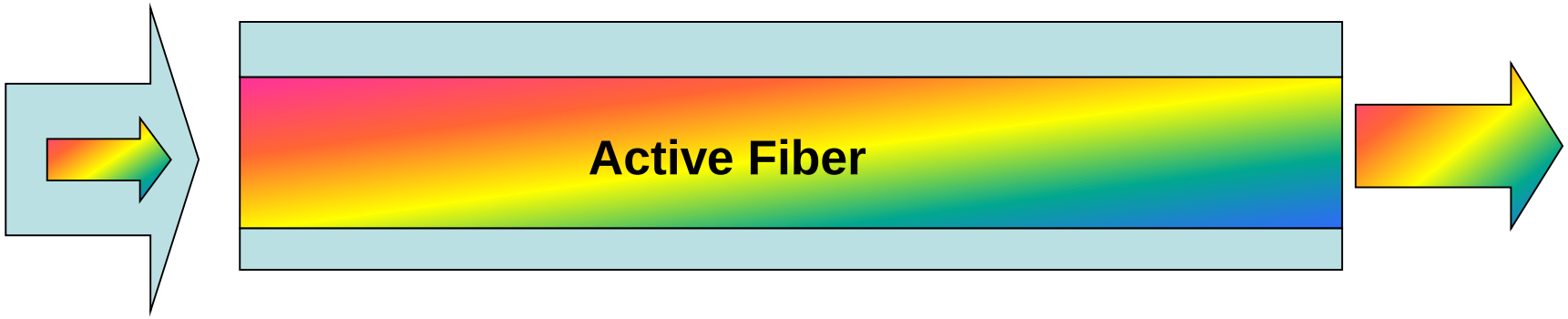
Elements of a fiber laser



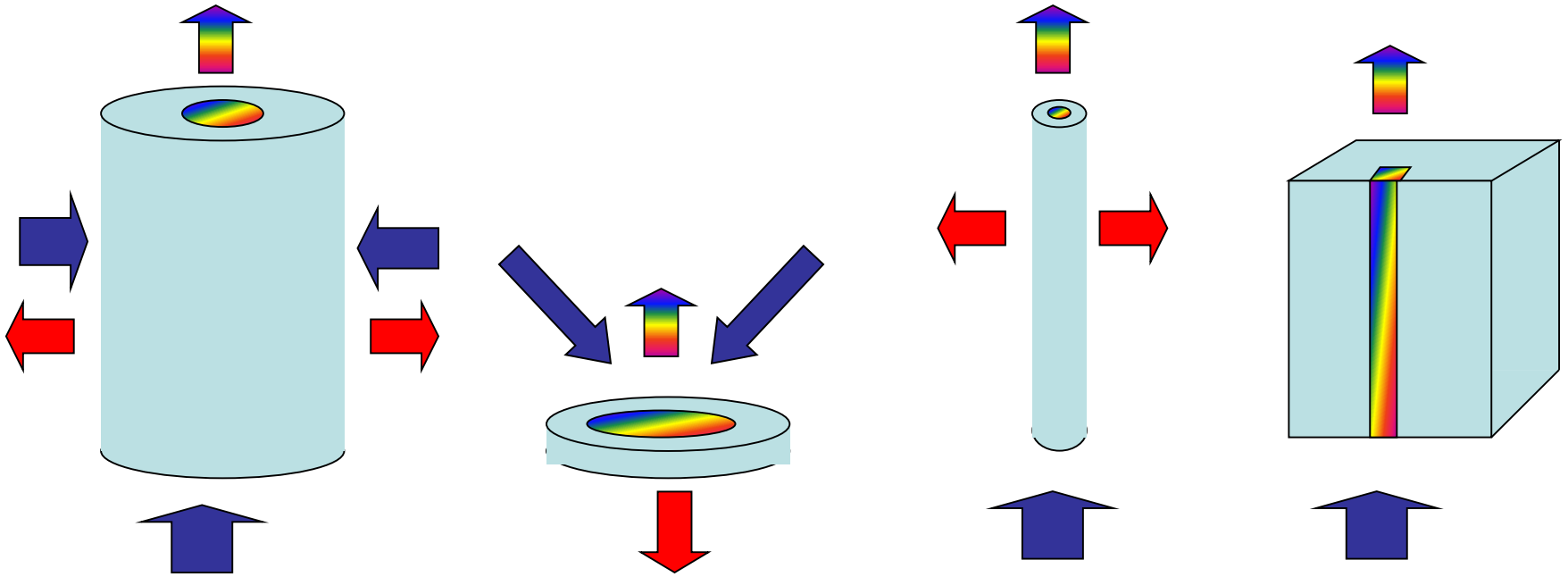
Excitation mechanism

Elements of a fiber amplifier

Excitation mechanism



Type of lasers



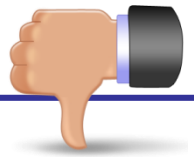
Rod laser

Disk laser

Fiber laser

Waveguide laser

Why fiber devices?



Fiber lasers/devices:

Structural integration (fiber splicing)

High-gain (long interaction distance)

Compactness, robustness and reliability

Design flexibility and manufacturability

High efficiency (up to 40% electric-to to-optical))

High surface/volume ratio (**good thermal management**)

Diffraction-limited operation at multi-kW output powers

Photonic structures

Exploitation of **non-linear effects**

Fiber lasers/devices:

Need of tailored glasses

Glasses are very different each other!

Relatively small core size

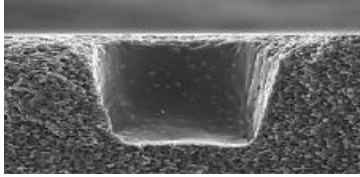
Constrain on power density (optical damage, non-linear effects (Raman, SBS, ASE))

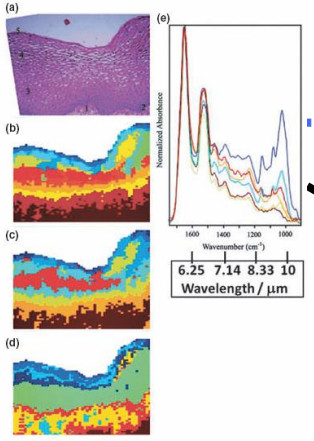
Constrain on pulse energy (~mJ)

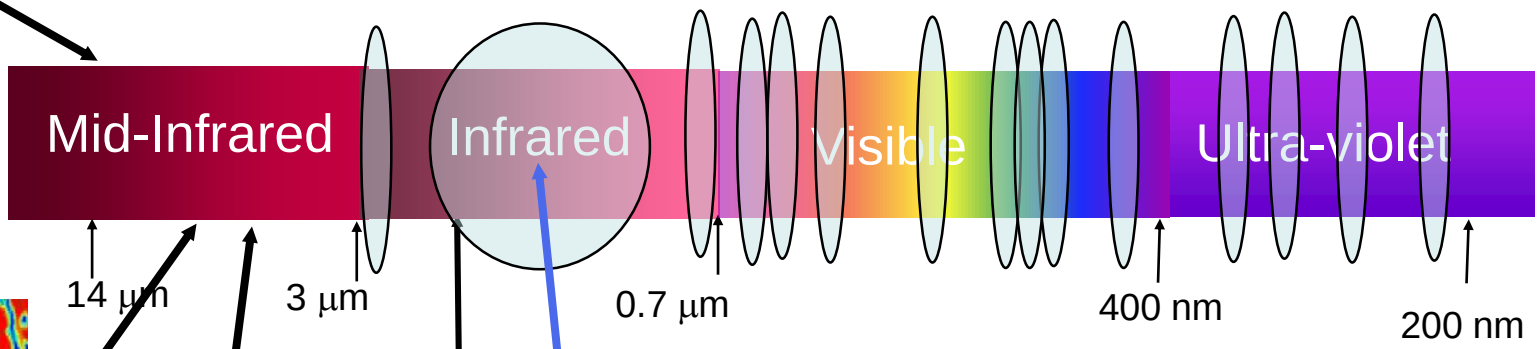
Limited amount of “all-fiber” components

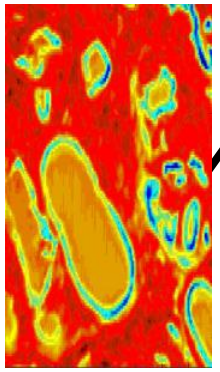
Were we are here

Lasers with direct emission



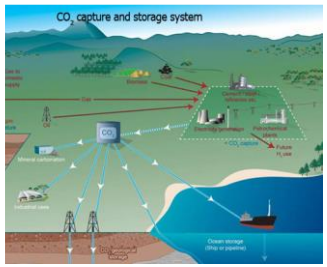


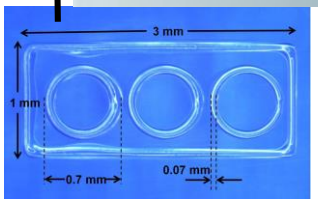


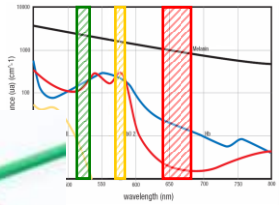


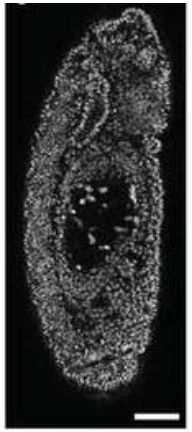
Cancer

Healthy







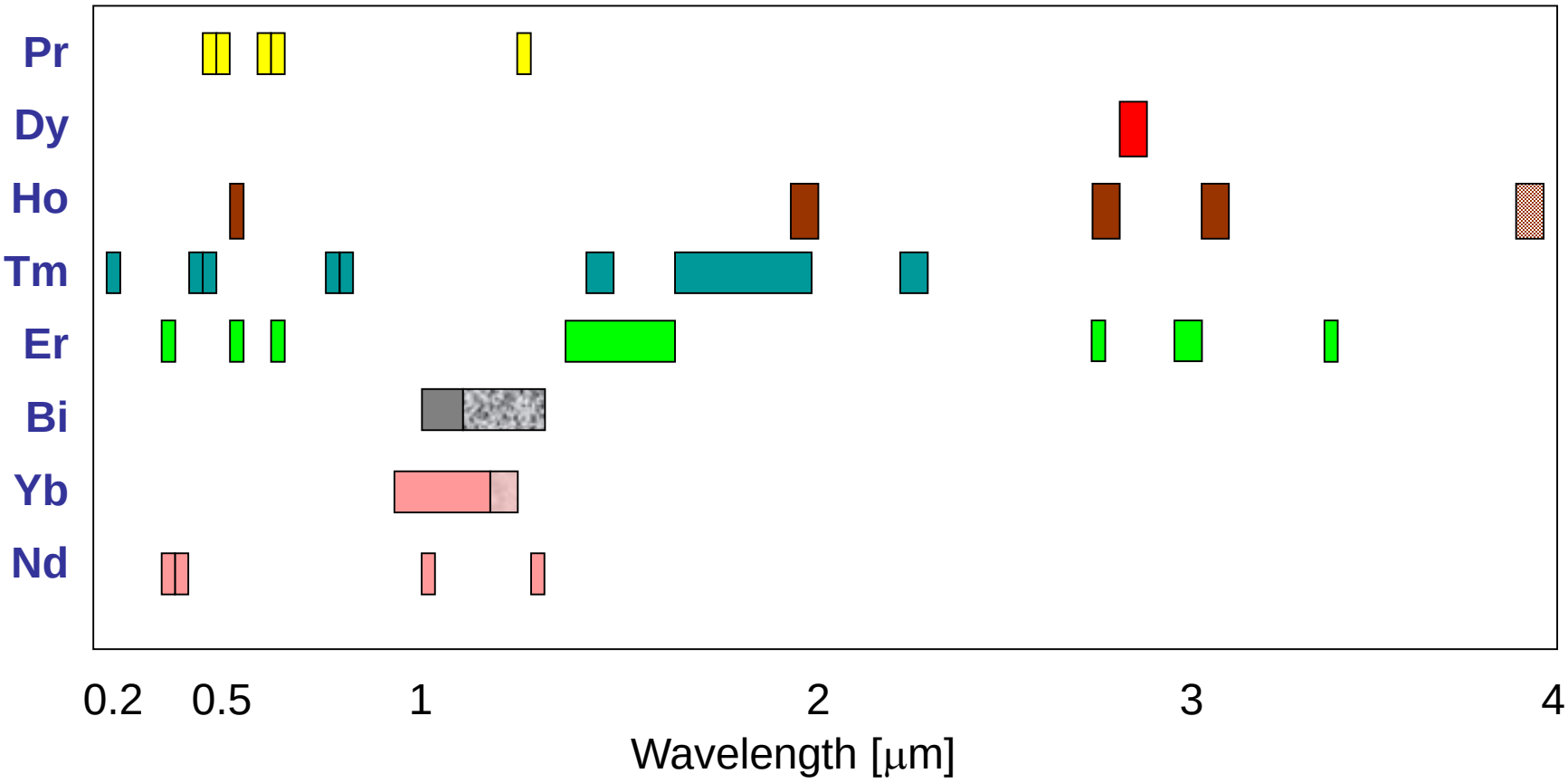


MIR: “Fingerprint region”: interaction sensitive to 3D structure. In-vivo diagnostics (cancer), Soft material processing,

IR: advanced manufacturing

UV/visible: address fundamental science, imaging, diagnostic and medical treatment, manufacturing

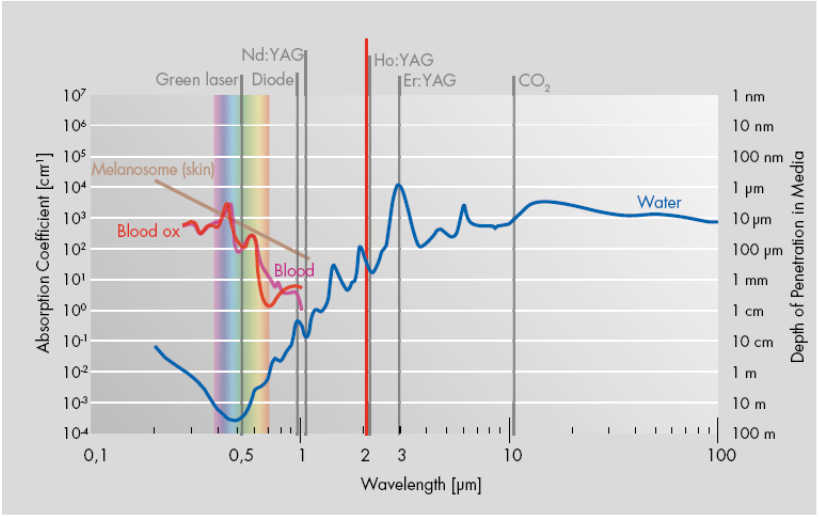
Emission Wavelength

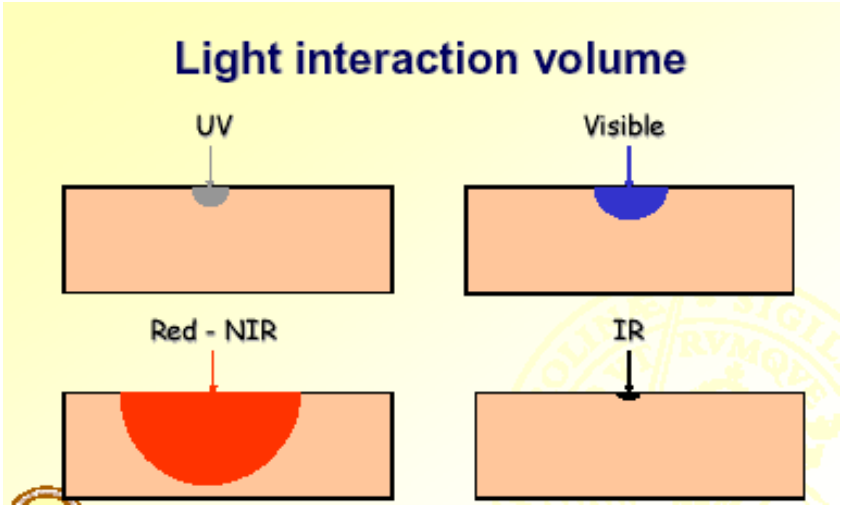


FILL MISSING WAVELENGH INTERVALS

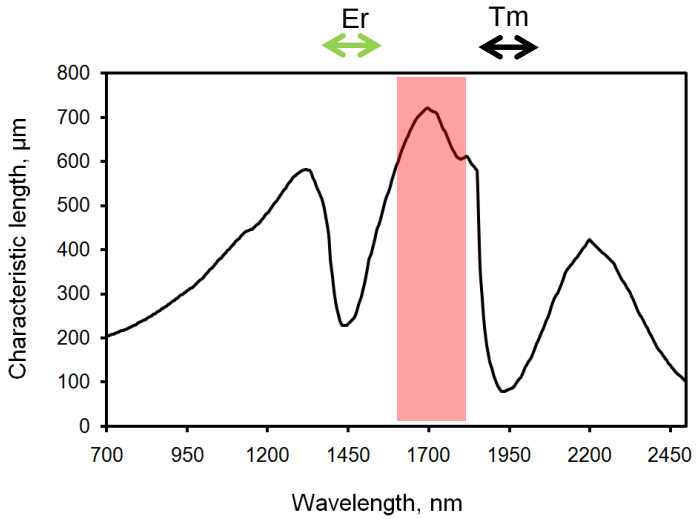
Why Optimum Wavelength is important

Absorption depth





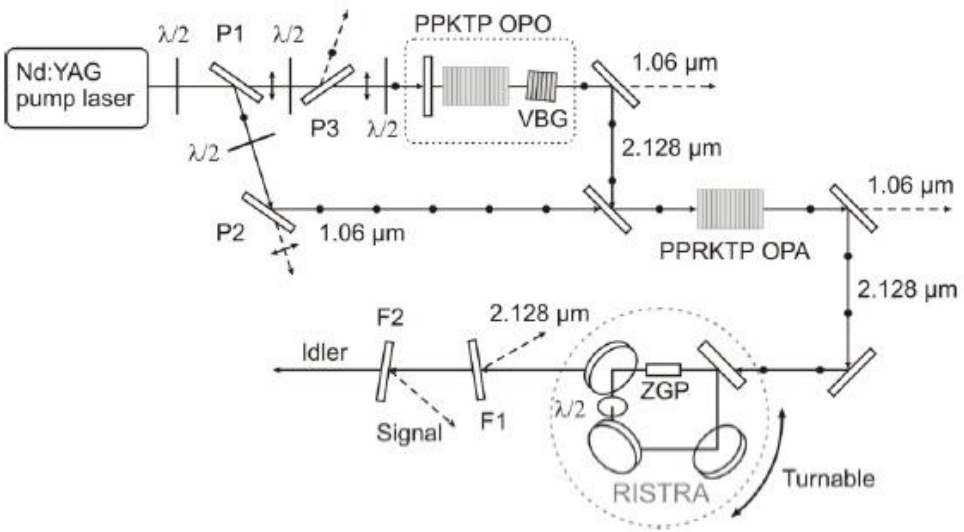
Optimum spectral window for deep bioimaging lies around 1700 nm.

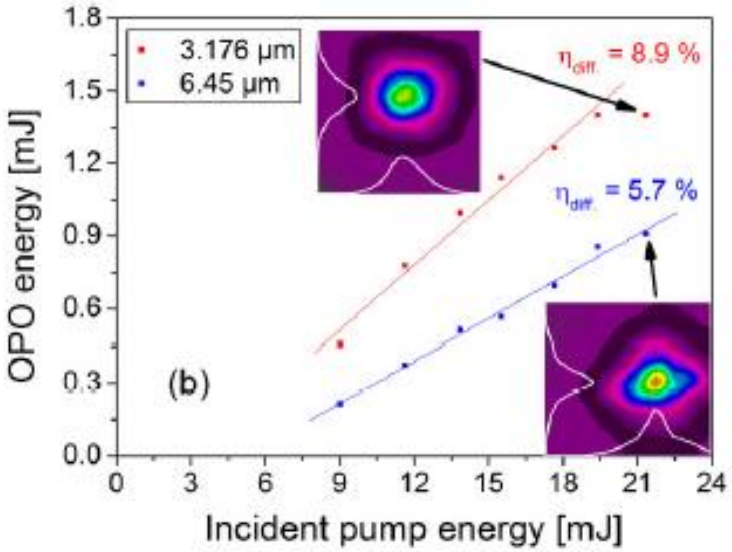


It is determined by a trade-off between tissue scattering and absorption (dominated by water in the NIR).

Optimum spectral window from
1650 nm to 1800 nm.

Sub-micron brain surgery



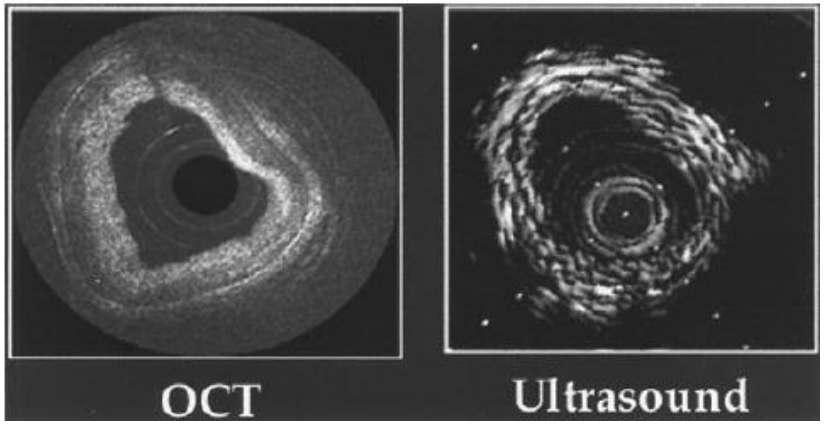


V. Pasiskevicius, KTH, Sweden: MISURG project

Why we are bright

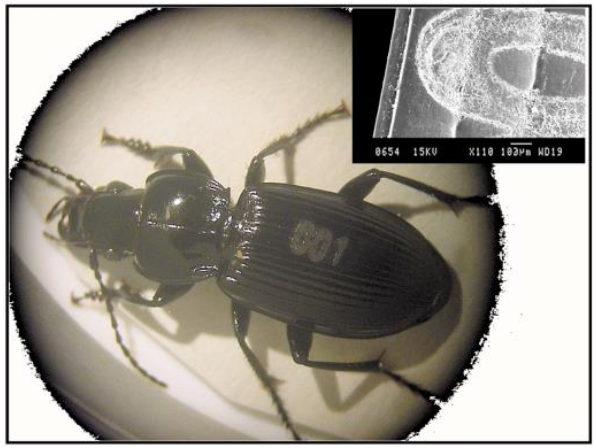
30 kW welding of steel.

several tens of mm



Blood vessel imaging

customized ear implant



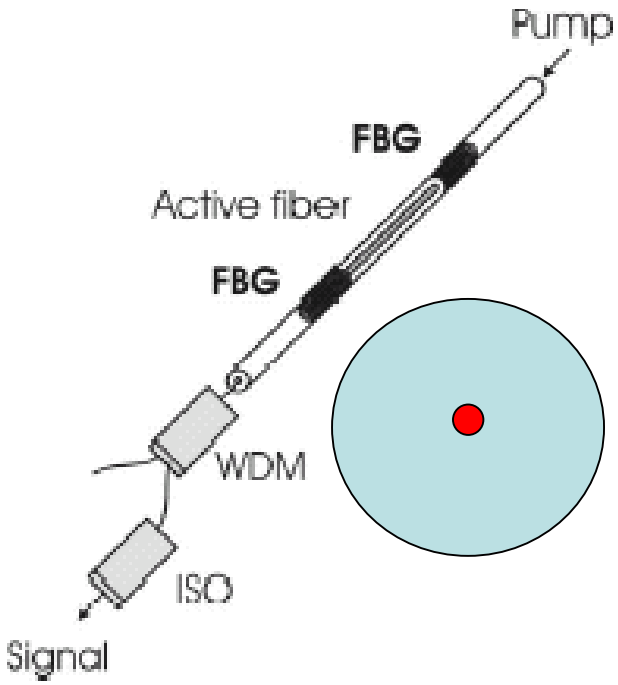
marking of beetles

Cleaning and restoration

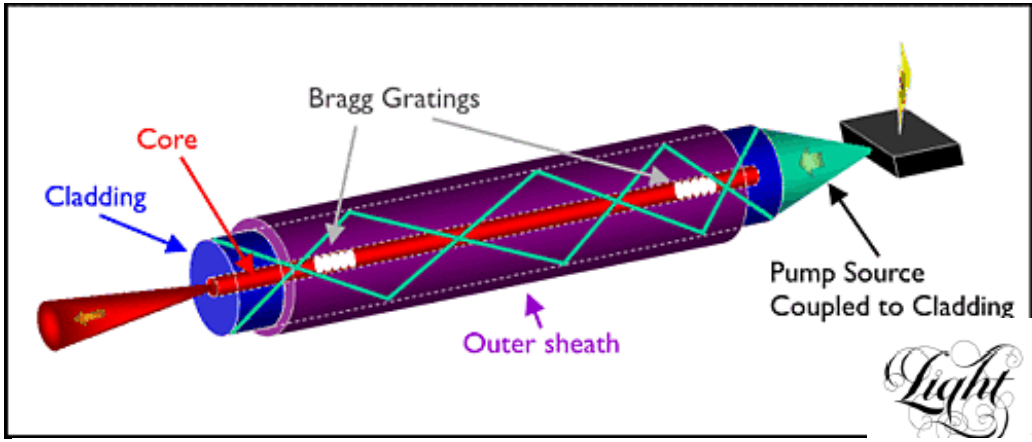
Art Work

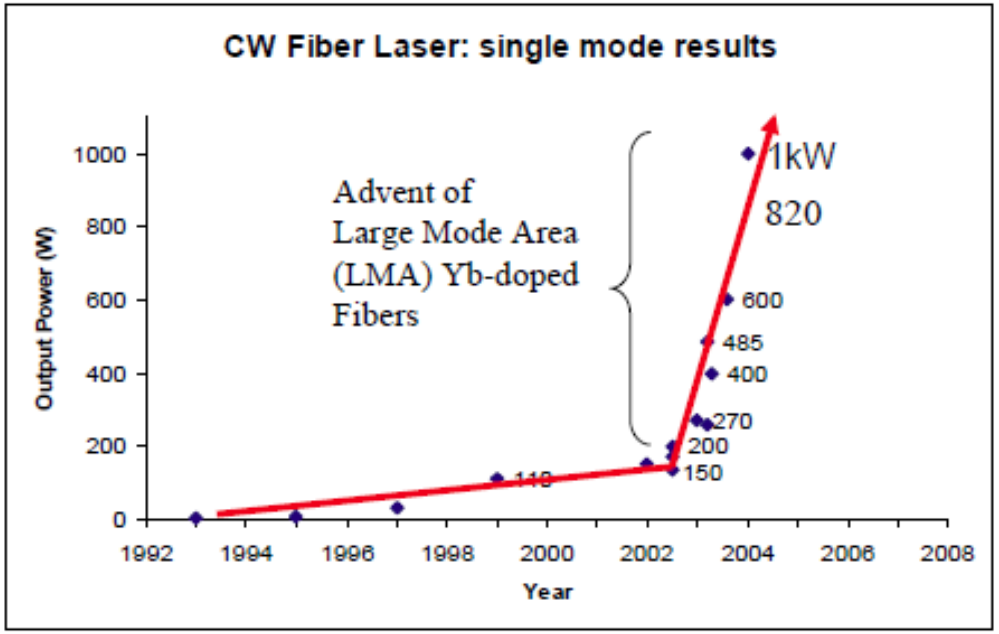
Fiber

Single-mode fiber (core pumped) are telecom type.

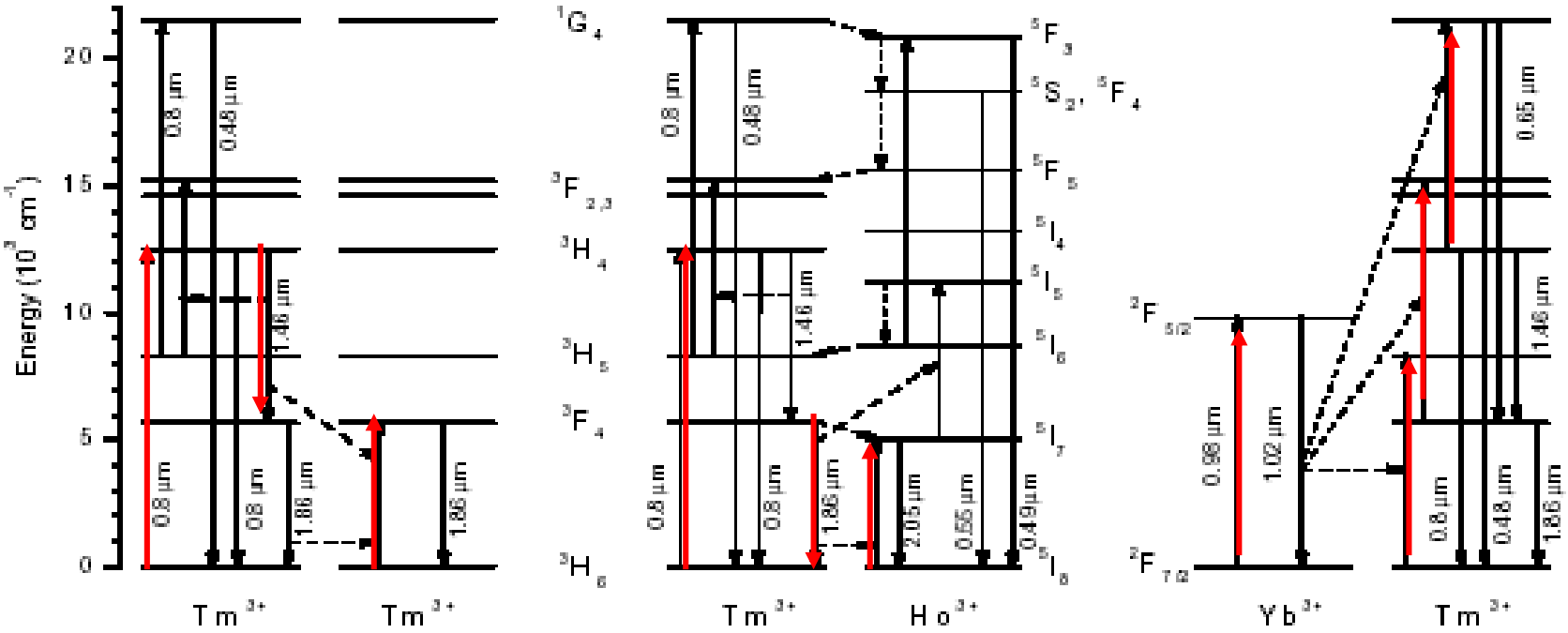


High-power: Double cladding pumping





ACTIVE IONS – Pumping Schemes



Cross-relaxation

Tm

Energy transfer

Tm:Ho, Yb:Tm, Yb:Er

Soft-Glasses

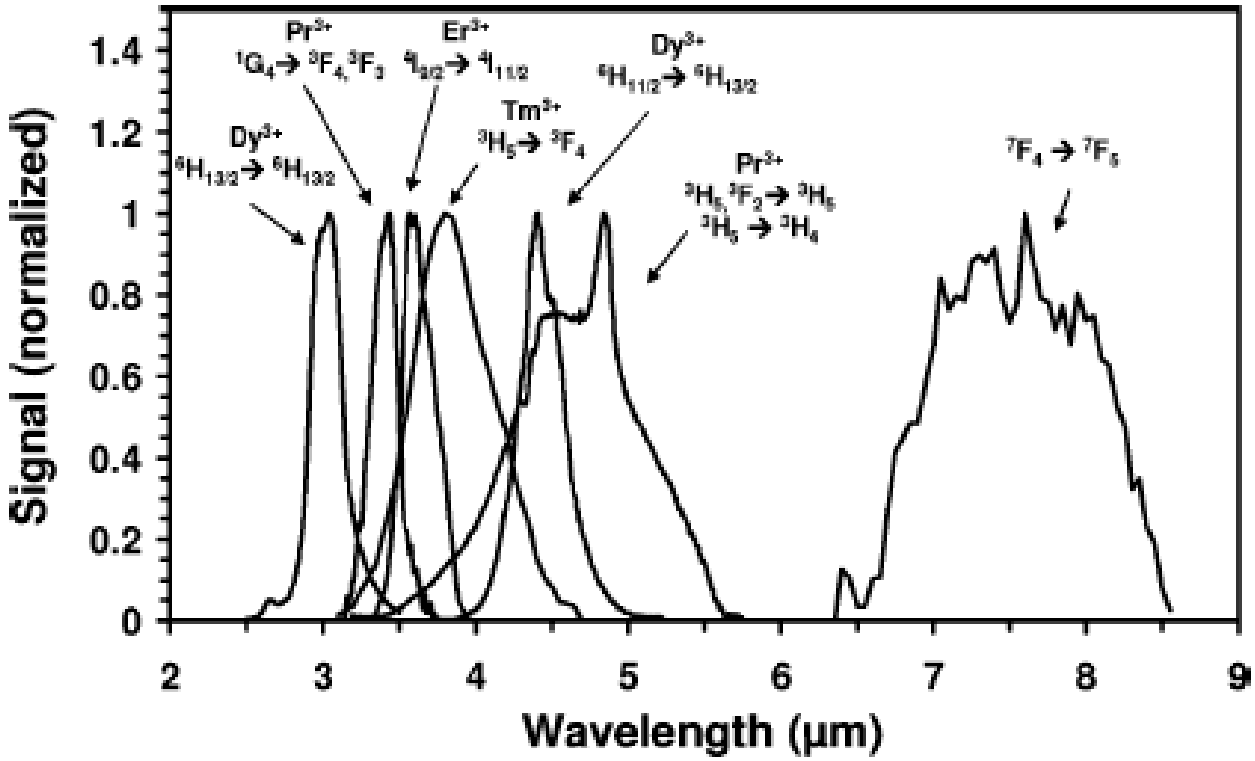
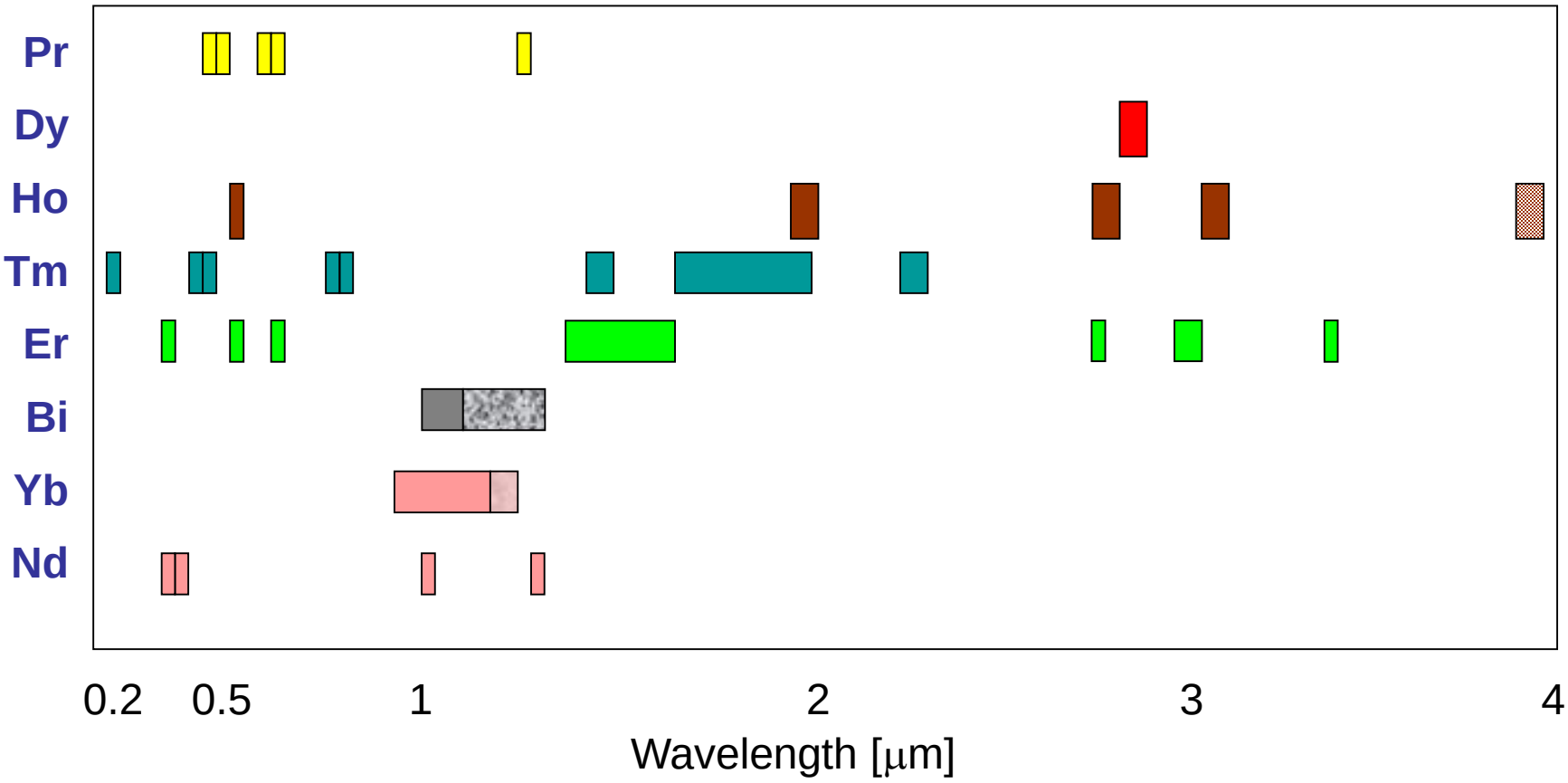


Fig. 4. Rare-earth-doped chalcogenide (Ge–As–Ga–Se) glass IR transitions within the 2–5 μm atmospheric transmission window. Also shown is the $\sim$8 μm transition of Tb^{3+}.

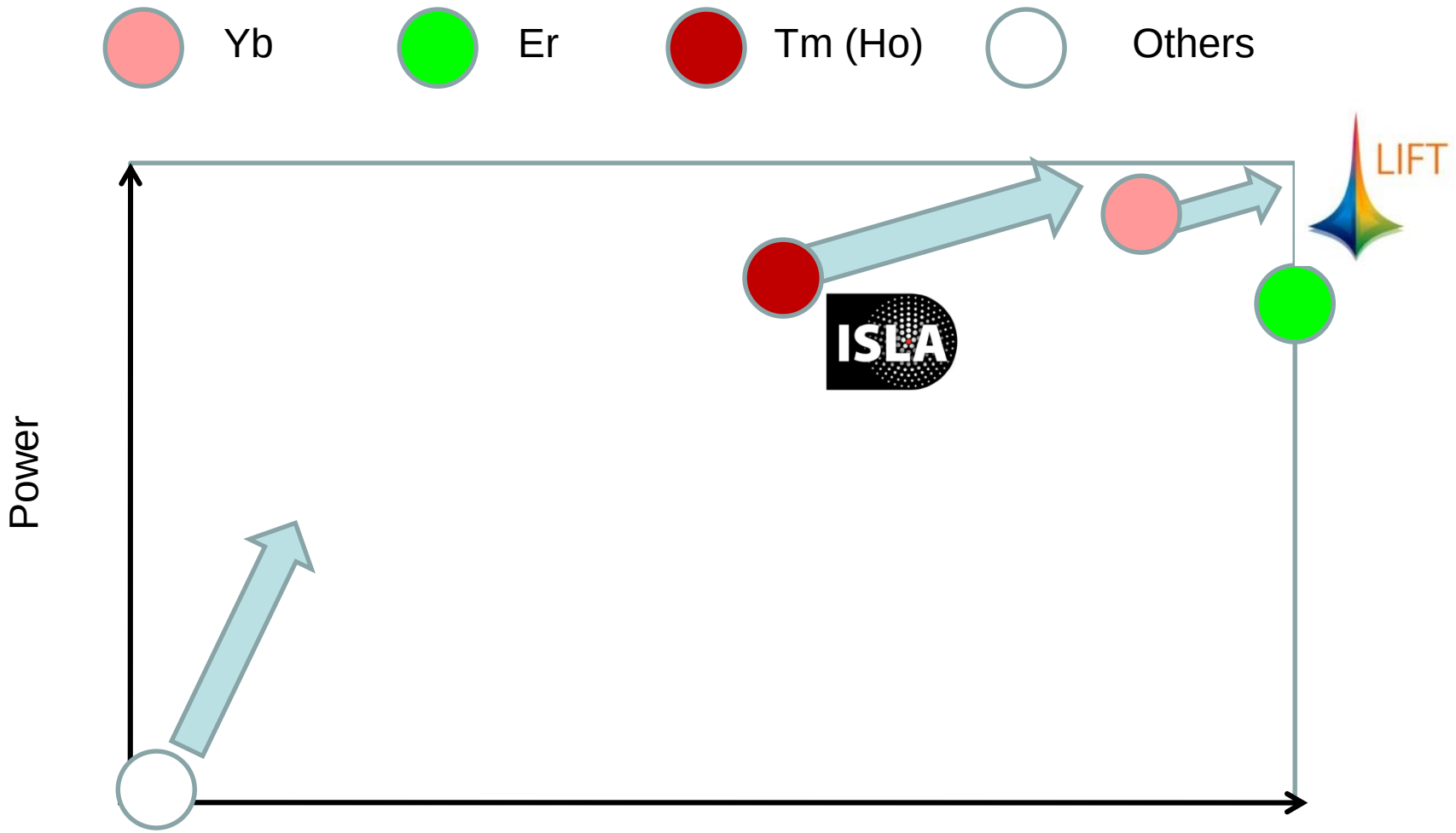
But we should be more bright....

But we should be more bright....

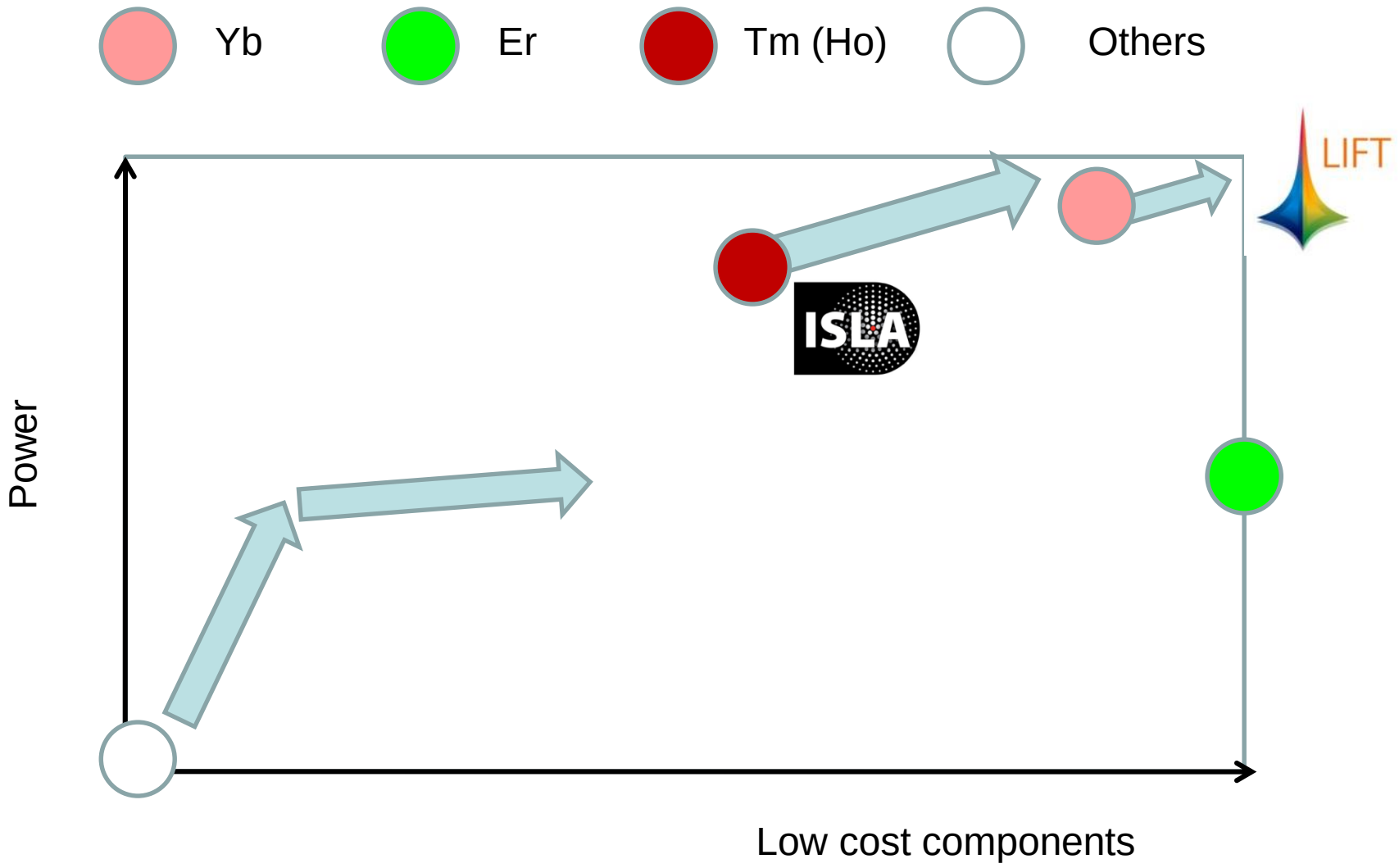


Challenges for Material Scientists and Fiber Scientists

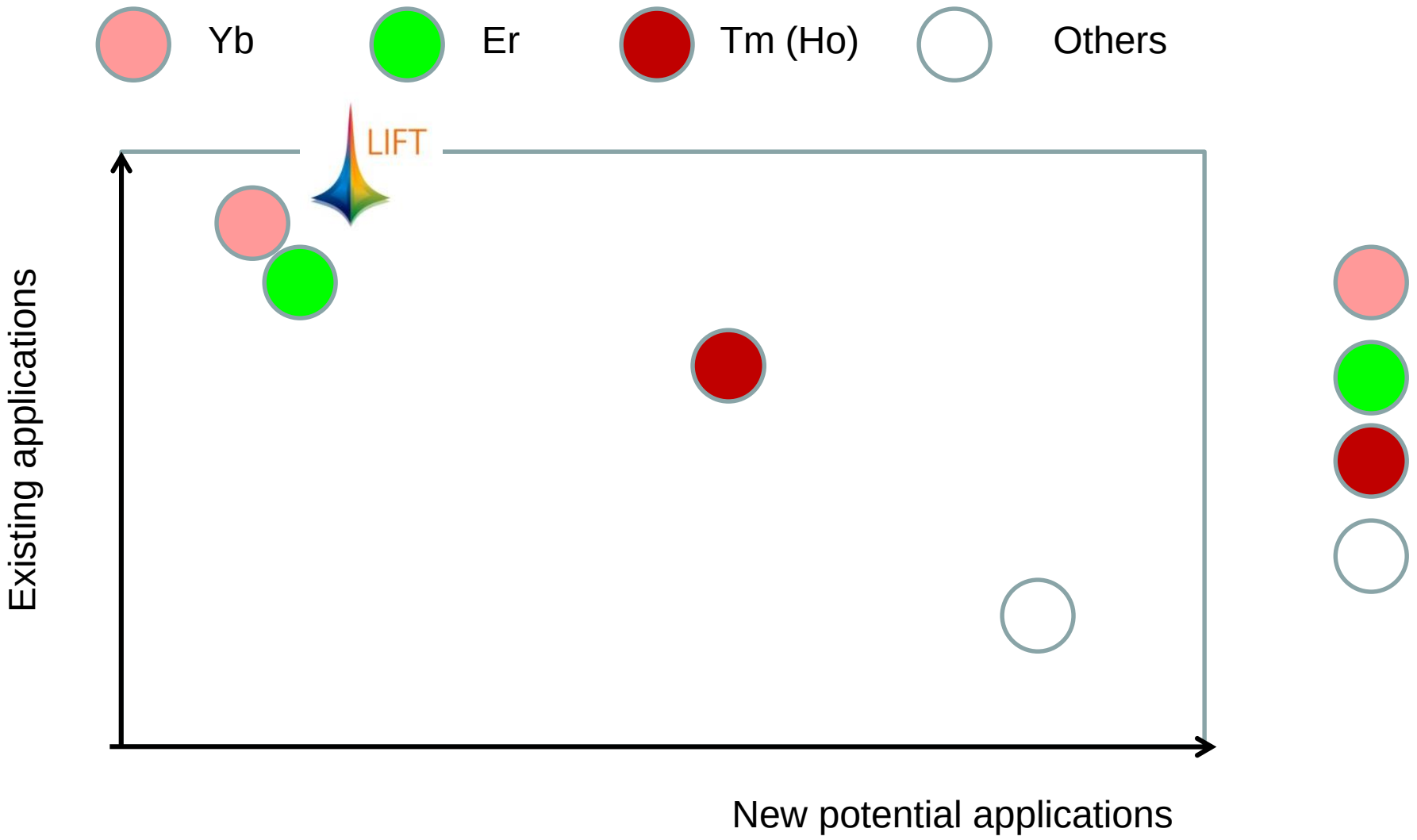
Were we are


Yb
Er
Tm (Ho)
Others
LIFT
ISLA
Power
MINERVA
improved medical diagnostics
Low cost components
Components reliability

Were we are (applications)



Applications



Roadmap (how to achieve)

New and tailored glass hosts

New low cost techniques for fibre manufacturing

Develop high-quality fibre manufacturing technique for soft glasses

Develop new theoretical model and innovative pumping schemes

New mode-locking techniques

New second- third-order harmonic generation techniques

Available components

New pump diodes

Investigate light/matter (incl.tissue) interaction

Optimize process parameters for existing applications

Approach new applications

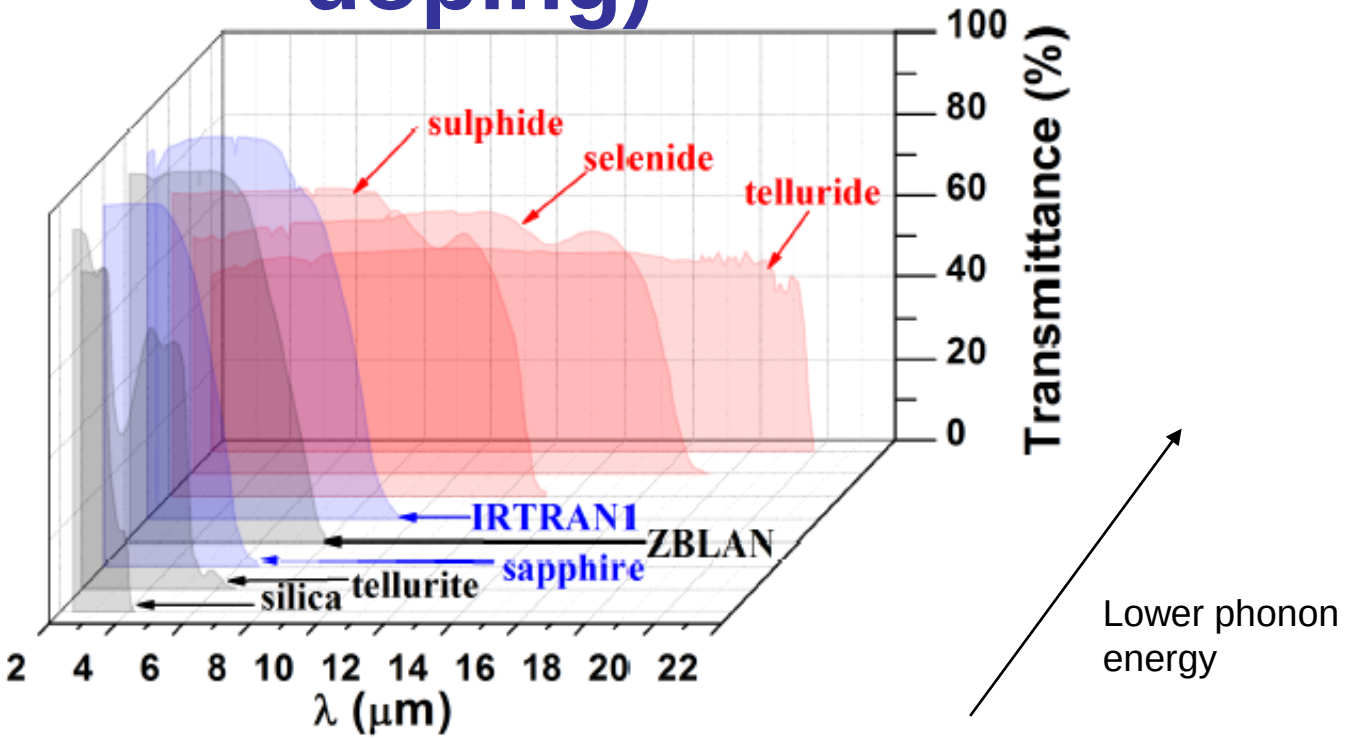
Joint specialist in a multidisciplinary effort (from material science to surgeons)

New generation of multidisciplinary Researchers

Example:
Glasses/Fiber for MIR

Glasses

PRO CONS (Thermal, splicing, doping)

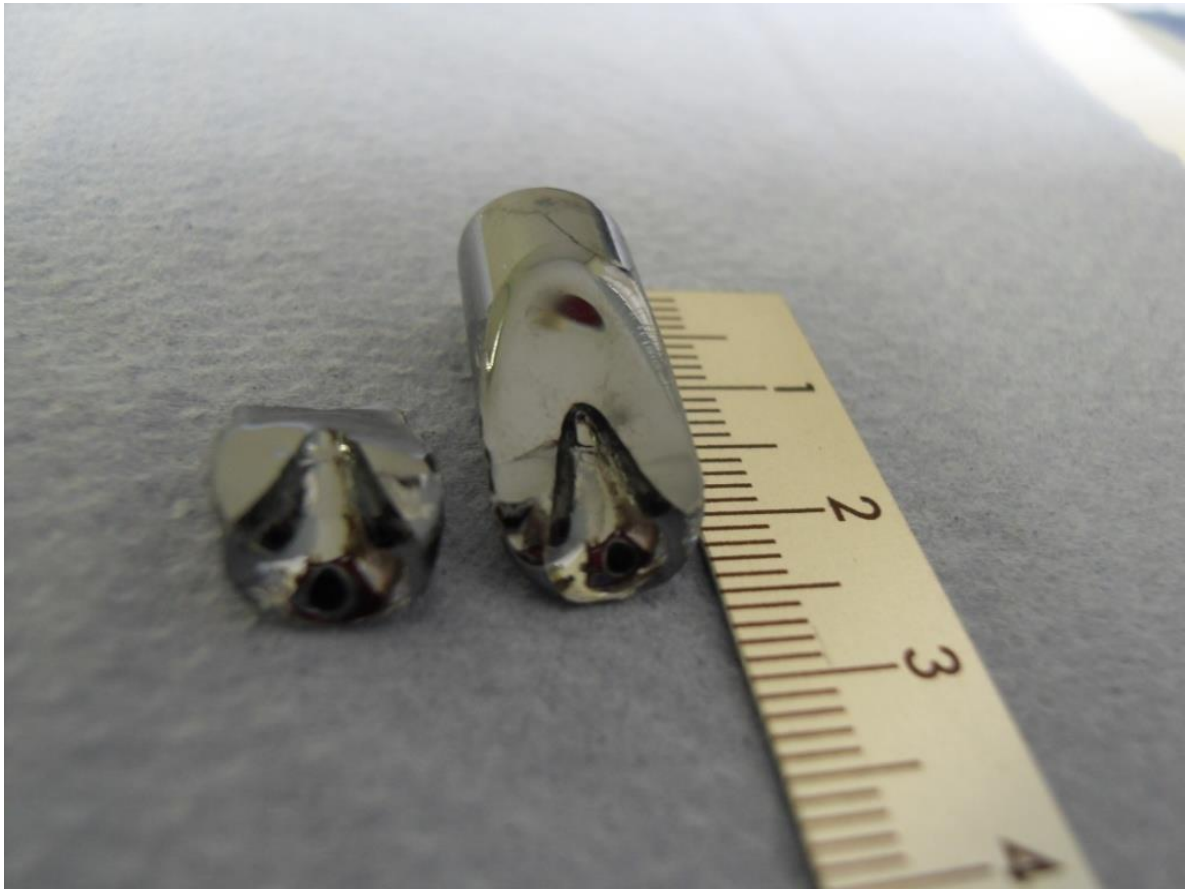


Jiri Orava, Tomas Kohoutek, A. Lindsay Greer, and Hiroshi Fudouzi, "Soft imprint lithography of a bulk chalcogenide glass," Opt. Mater. Express **1**, 796-802 (2011)

Fibre Fabrication

	Material quantity (active doped)	Purity / Fiber loss (active doped)	Homogeneity / Refractive index distribution	Doping elements
MCVD solution doping	☹ $\varnothing_{Core}$	☺ **5 dB/km**	☹ Layer structures, dip	😐 RE, Al, P, F, B, Ce
MCVD gas phase doping	😐 $\varnothing_{Core}$	😐 15 dB/km	☺ **Excellent homogeneity**	😐 RE (Yb, Tm), Al, (Ce)
REPUSIL Powder sintering technique	☺ $\varnothing_{Core}$	😐 15 dB/km	😐 Short-periodic index fluctuations	😐 RE, Al, F, B, Ce
Melt glasses (SAL)	☺ $\varnothing_{Core}$	☹ 500 dB/km	☹ Striae, RI fluctuations	☺ **RE, Al, P, F, B, Ce**

Soft Glasses

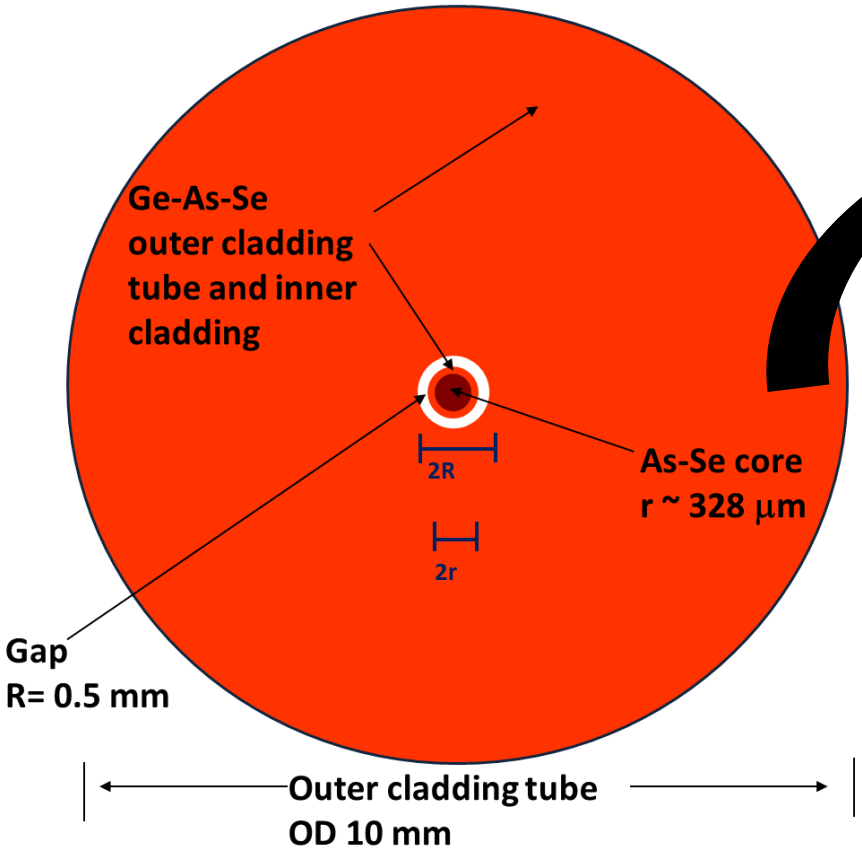


Glass code: ZQT 010 synthesised at UofN:

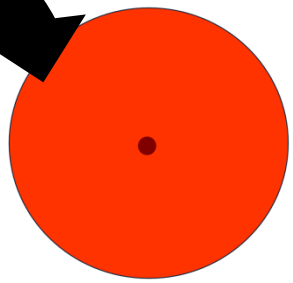
500 ppm Dy^{3+}-doped selenide chalcogenide glass

A. Seddon, Nottingham Uinversity

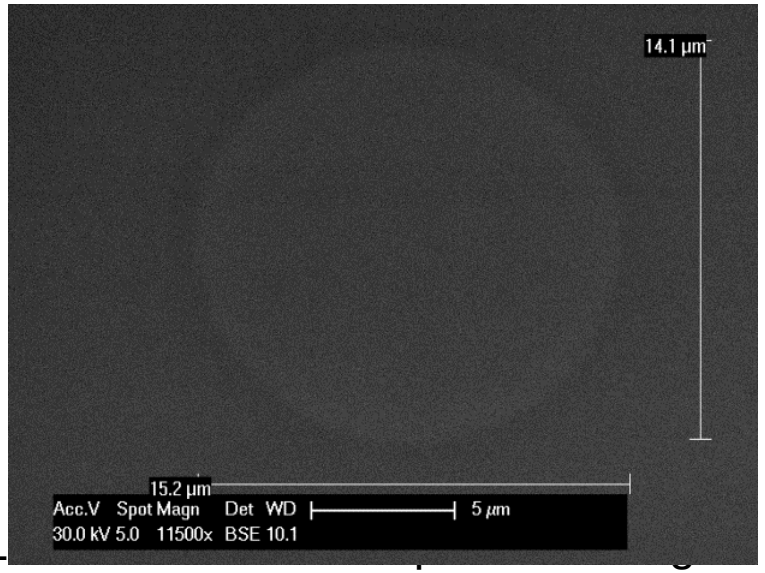
Schematic diagram preform, made *via* extrusion.

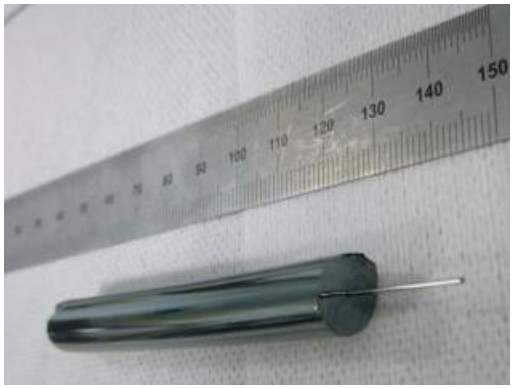


Drawn-down final-SC-fibre small-core



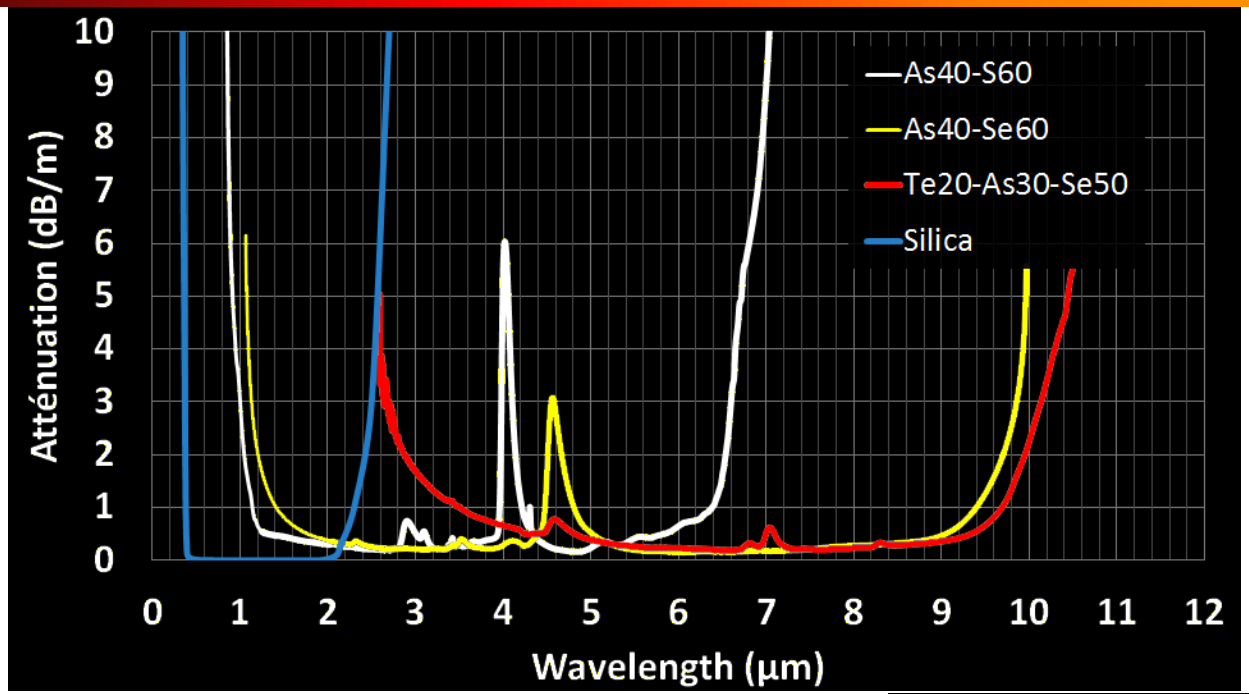
Core diameters aimed at: 10, 15, 20 μm





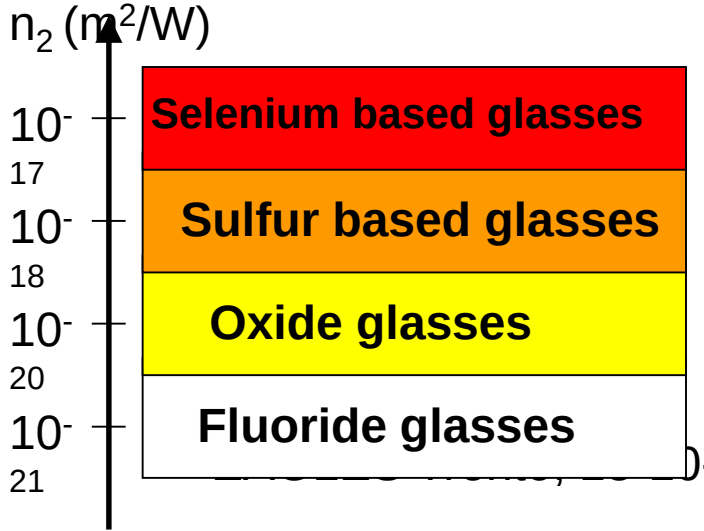
Petersen et al. NAT PHOTON 8 830-834 2014.

Interest of chalcogenide fibers



The transmission window can include the telecom wavelengths and the two atmospheric windows 3-5 µm and 8 - 12 µm

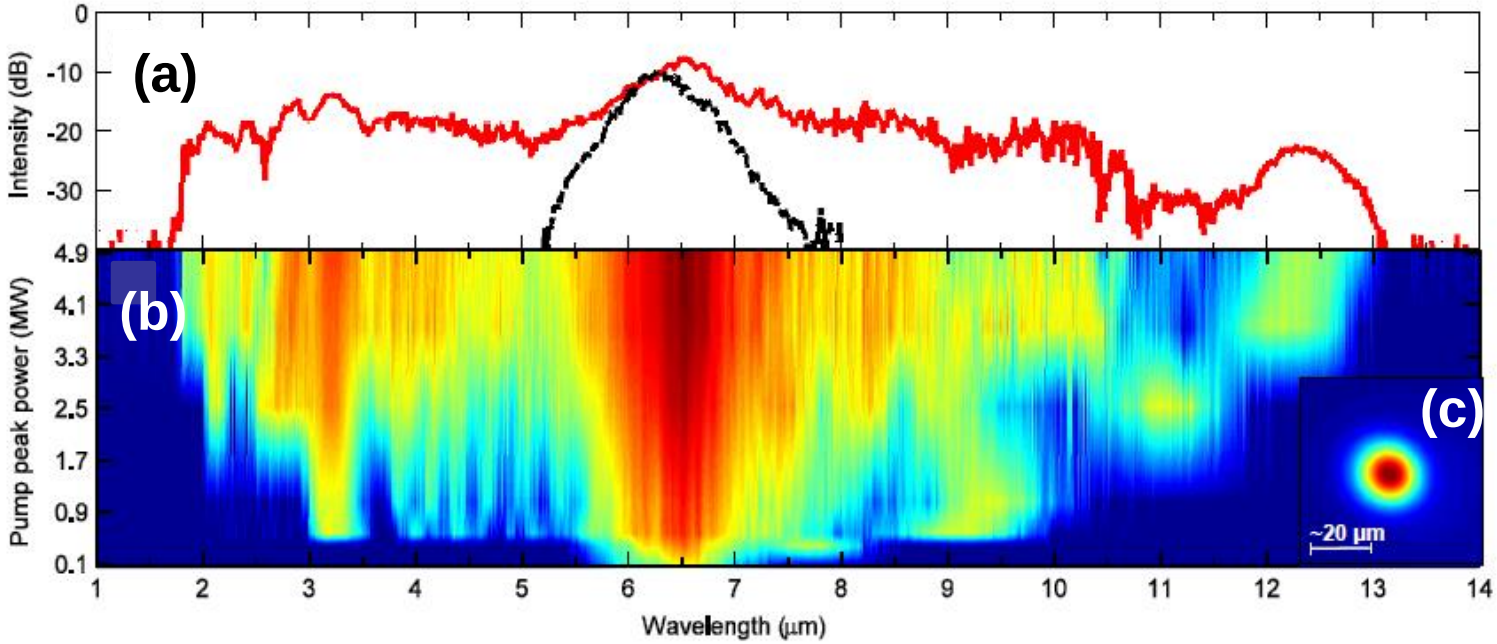
n_2 : The non linear refractive index



Glasses	Ratio n_2Glass / n_2SiO2 at 1.55 µm
SiO_2	1
As_2S_3	120-150
$Ge_{15}Sb_{20}S_{65}$	140
$GeSe_4$	400
As_2Se_3	550-650

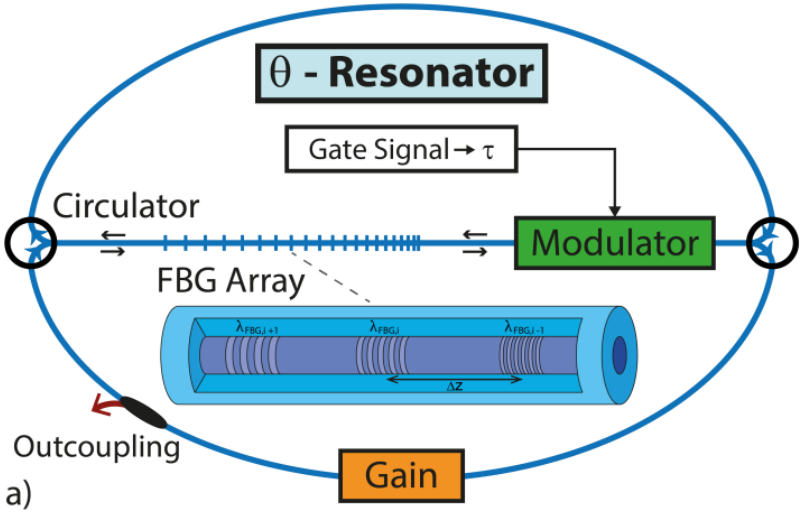
MINERVA
improved medical diagnostics

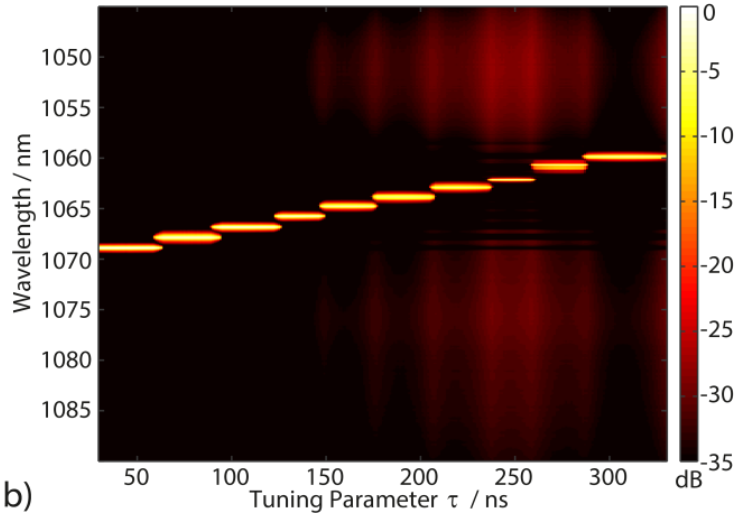
MIR-SC from 1.4 μm to 13.3 μm spectral range in fibre, to cover fundamental biomolecular absorption bands.



Petersen et al. NAT PHOTON 8 830-834 2014.

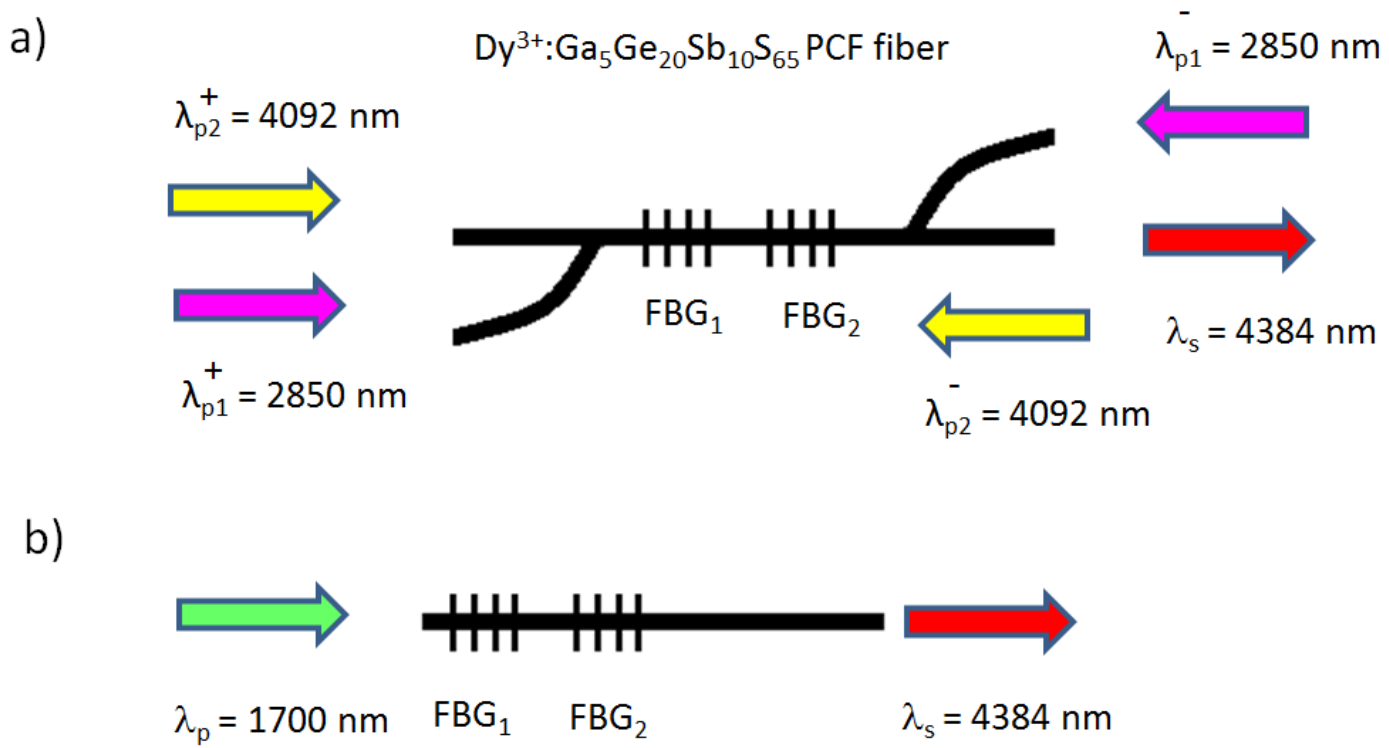
Tuning Methods





Pumping schemes

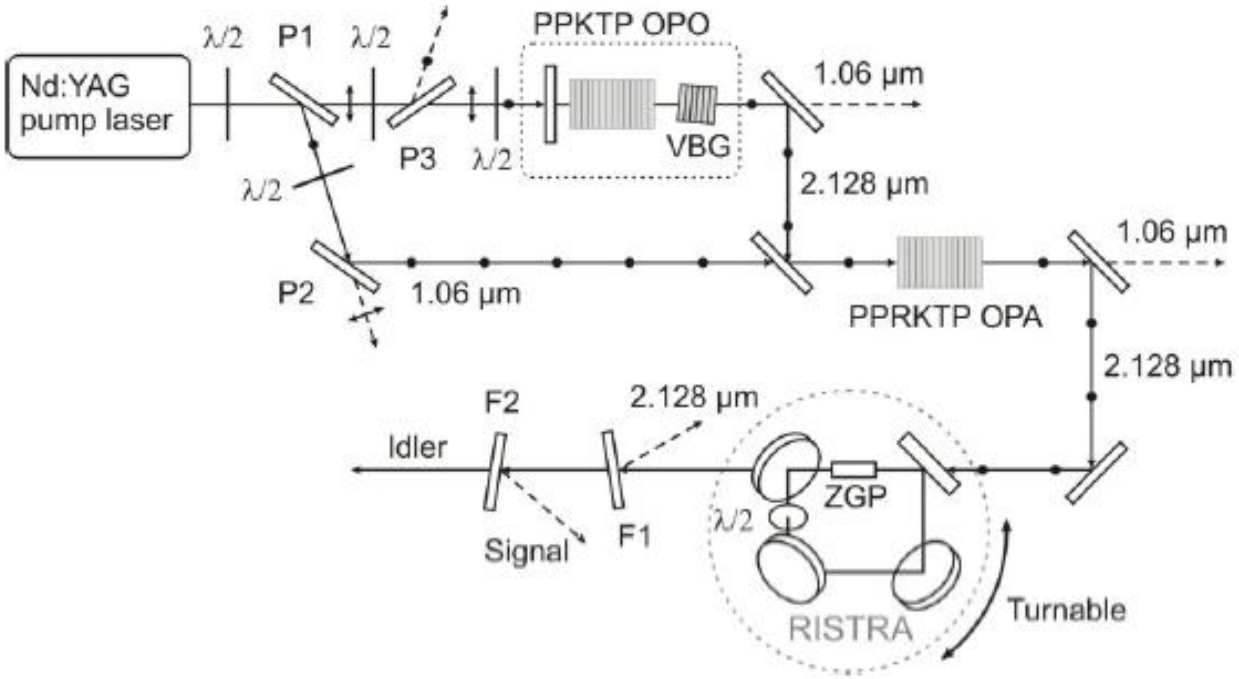
Pumping schemes of Mid-IR lasers based on a photonic crystal fiber (PCF) made of dysprosium doped chalcogenide glass Dy^{3+}:$Ga_5Ge_{20}Sb_{10}S_{65}$.



M. C. FALCONI et al. Design of an Efficient Pumping Scheme for Mid-IR Dy3+:Ga5Ge20Sb10S65 PCF Fiber Laser" accepted on IEEE Photonic Technology Letter DOI 10.1109/LPT.2016.2581022

We are not alone...

(and new frequency generation)



CONCLUSION

Each one plays a key role in achieving new wavelength operation

Efforts should be coordinated

(open call for STSM soon)

Thank you for your attention