INTERNATIONAL YEAR OF LIGHT 2015

ÚFE

Academy of Sciences

Institute of Photonics and Electronics v.v.i.

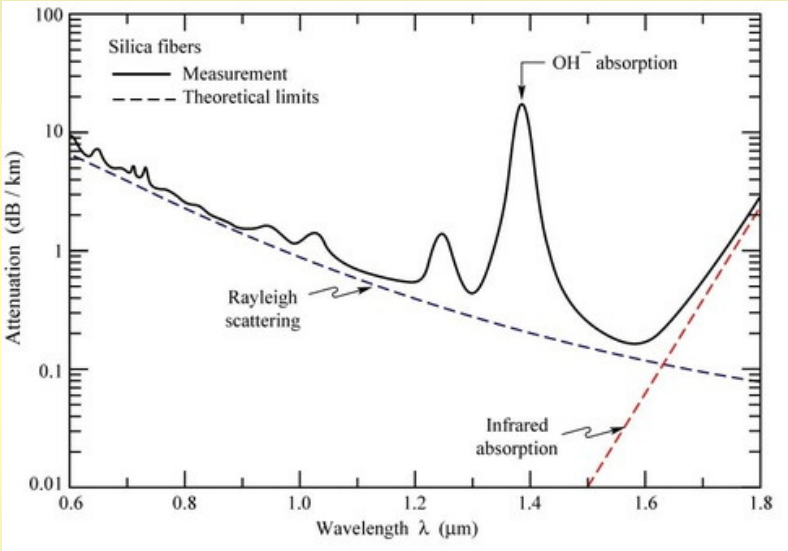
Technology of Optical Fibers

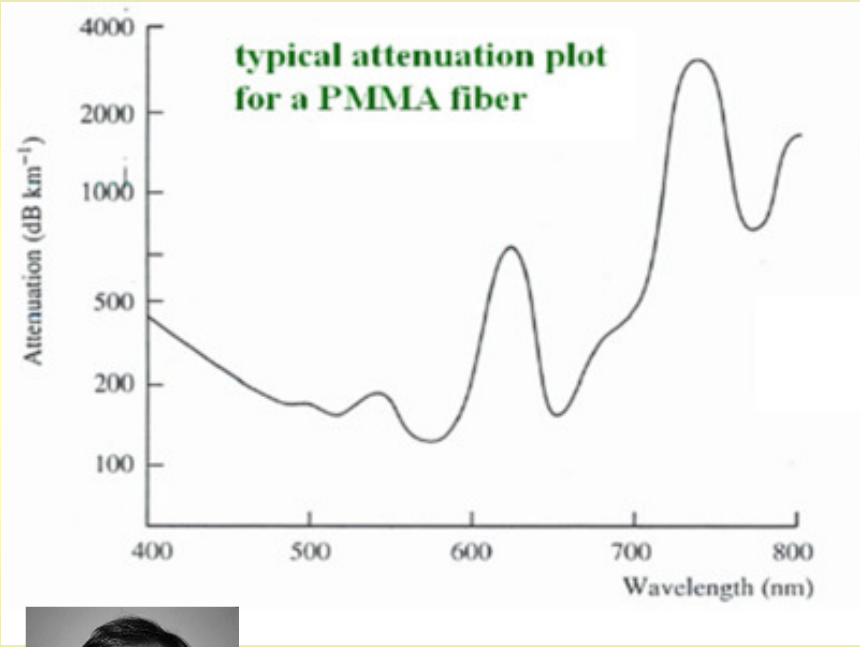
I.Kašík, www.ufe.cz

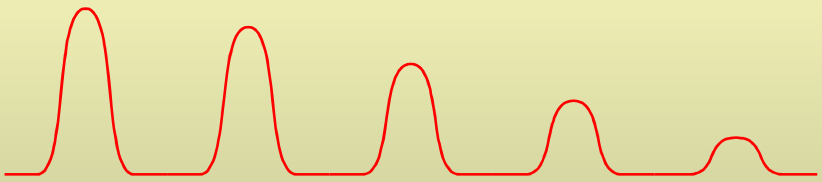
Optical fiber

Optical fiber : dielectric structure, L<< r, $n_{core} > n_{clad}$

Optical losses in optical fibers (intrinsic, extrinsic)





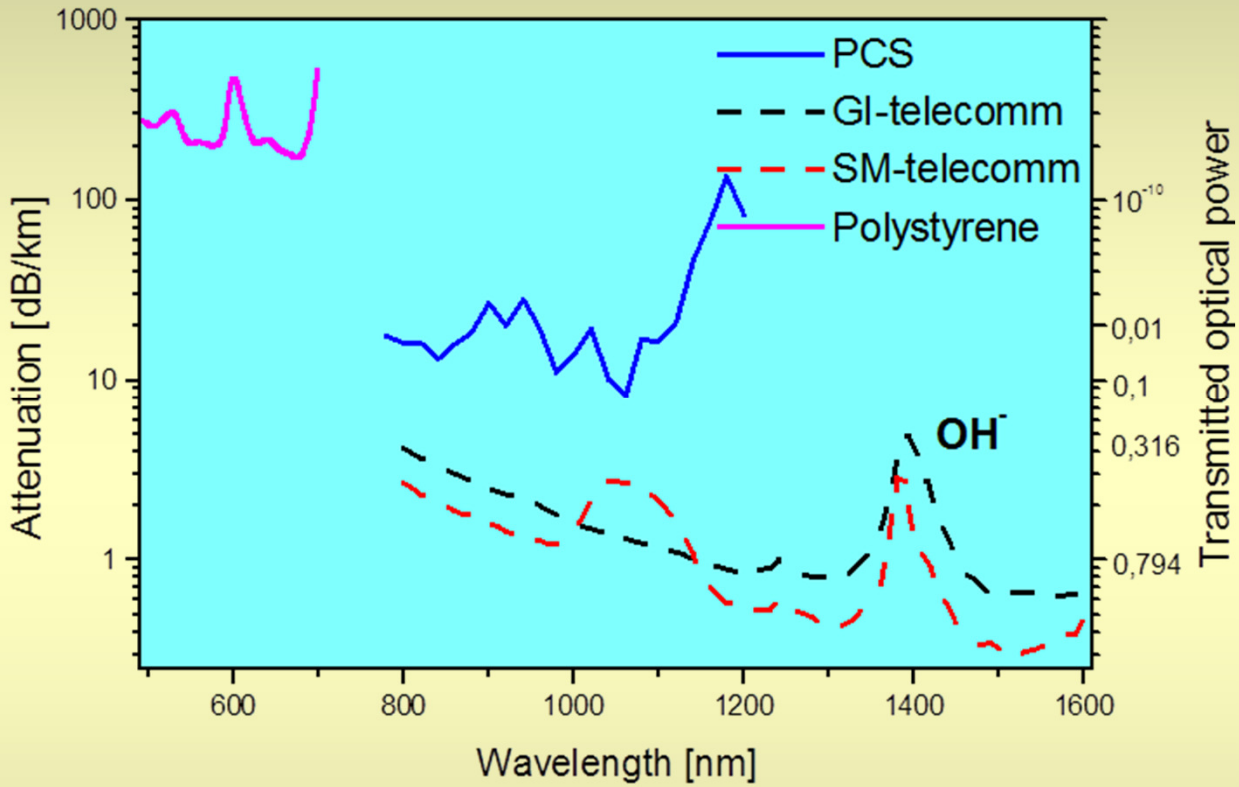


attenuation, dispersion

Nobel prize 2009 Ch.K.Kao

Optical fiber

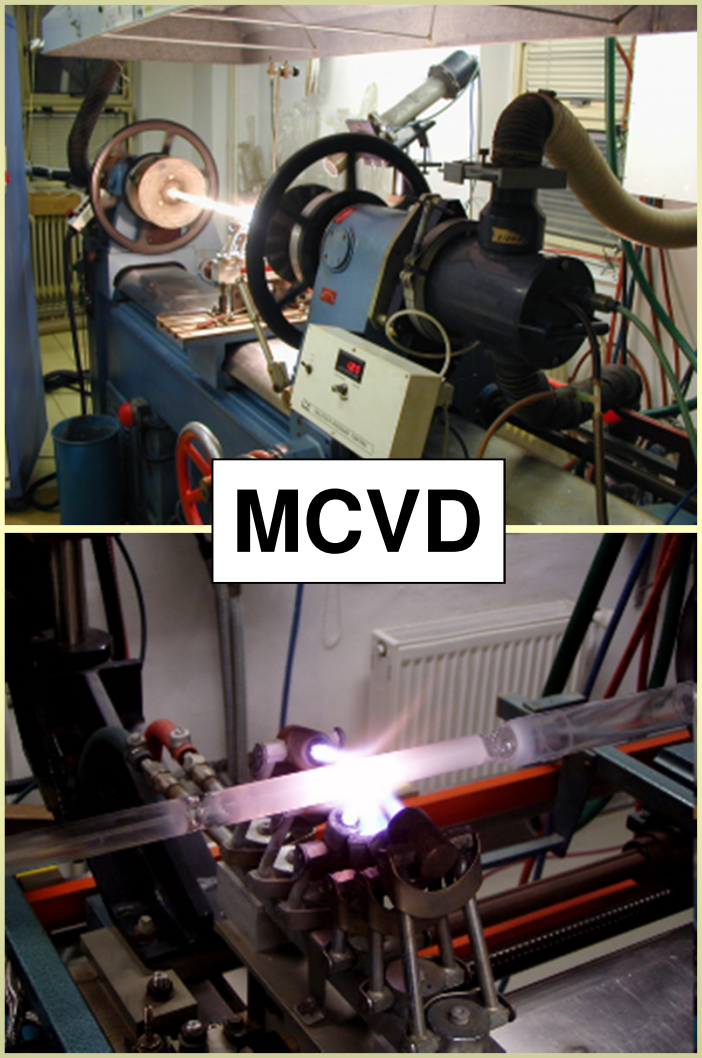
- high-purity
- silica based materials,
max. impurities acceptable in ppb (10^{-9})



Conventional glassmaking =>

ULTRA-PURE TECHNOLOGIES

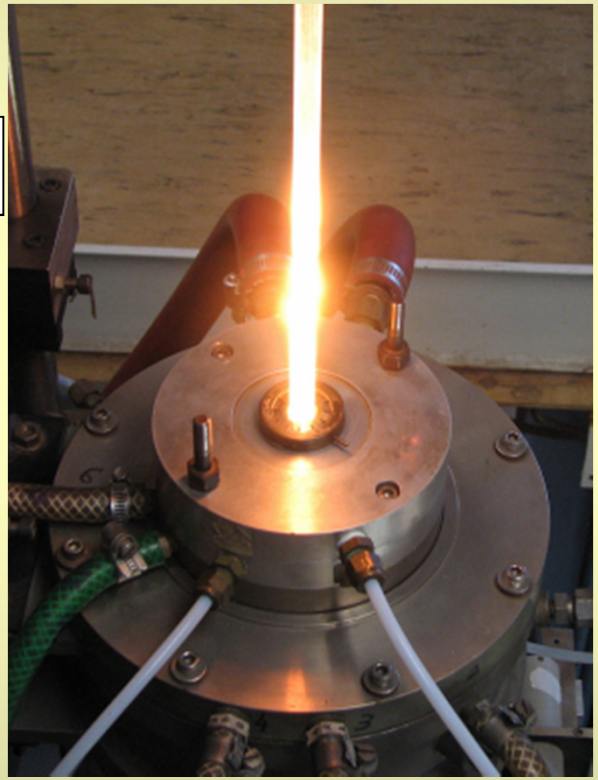
Optical fiber preparation



MCVD

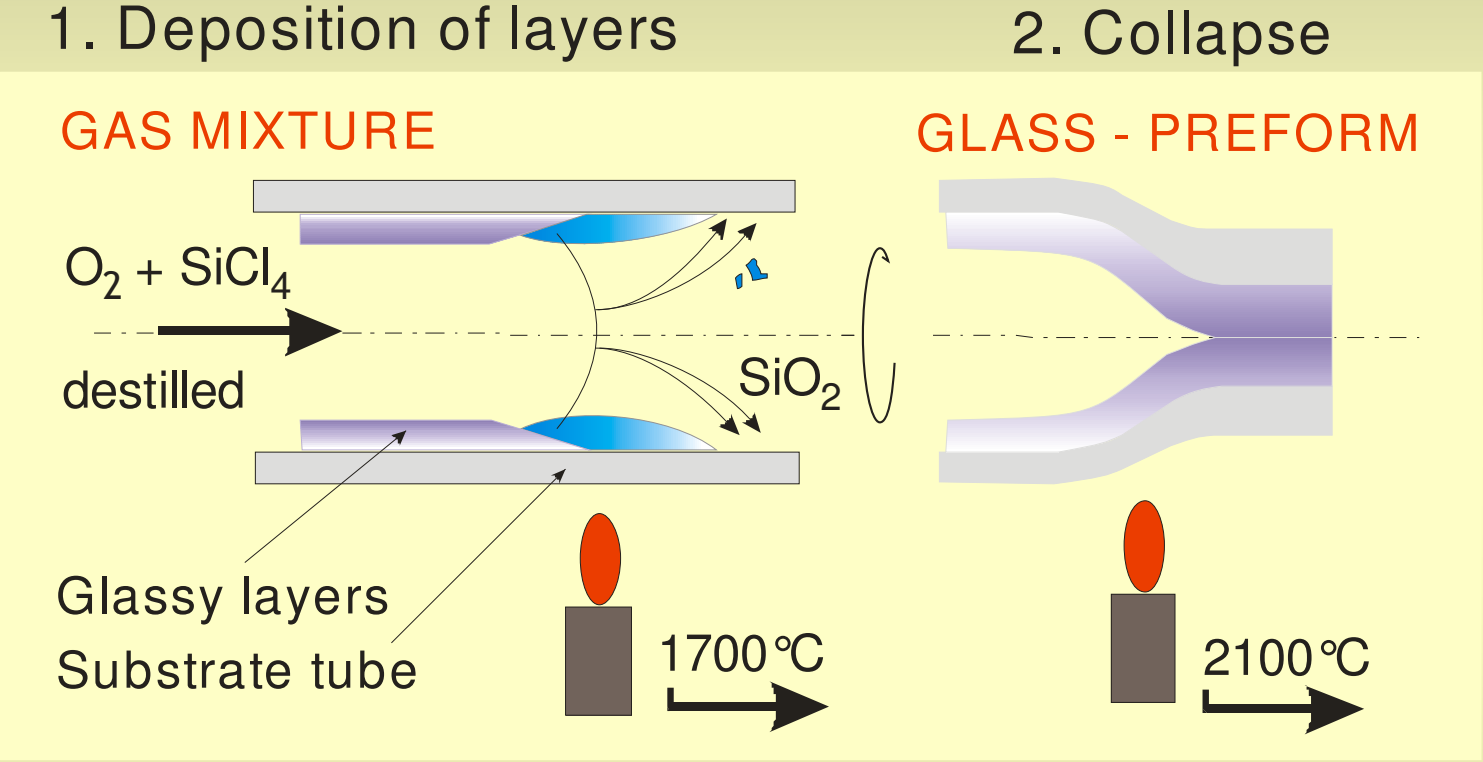
1. Preform

2. Fiber drawing



Preform preparation : CVD-based

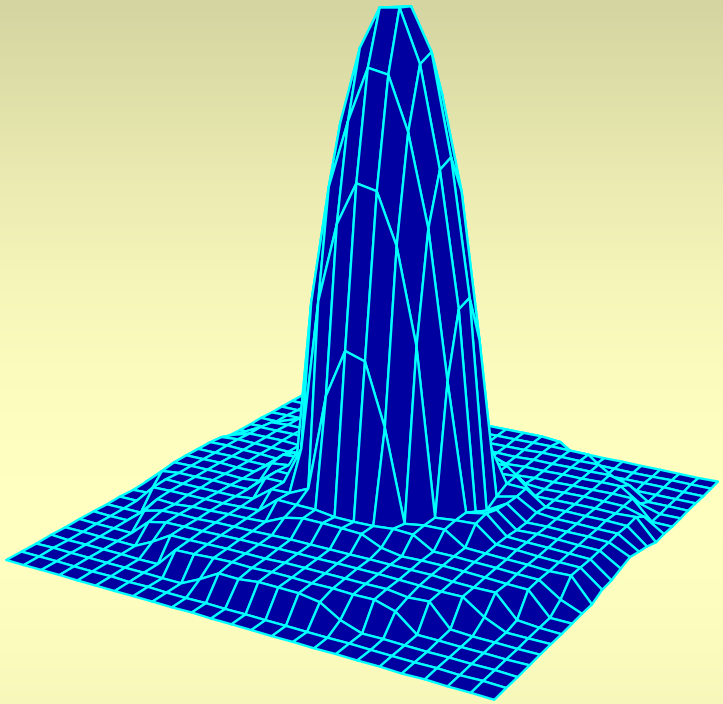
MCVD – (Modified) Chemical Vapor Deposition



- Sequential sintering of **thin glassy layers** (of thickness 1-20 μm) onto inner wall of silica substrate **resulting in bulk material – preform**
- **high purity** (~ 10^1 ppb) **high preciseness** (better than 1 %)

Preform

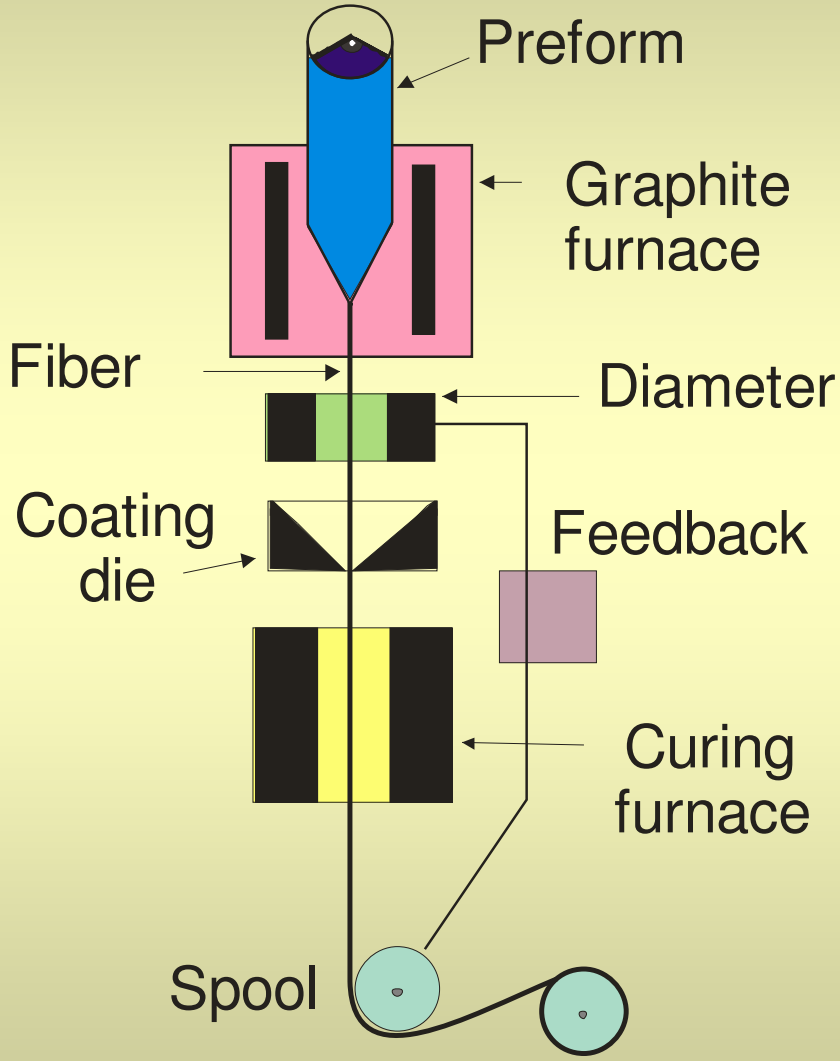
Microphoto of cross section of produced preform



Tomography of the refractive-index profile of preform

- High purity material due to FO-Optipur purity starting materials.
- High quenching rate ranging from 10^2 to 10^3 °C/s.

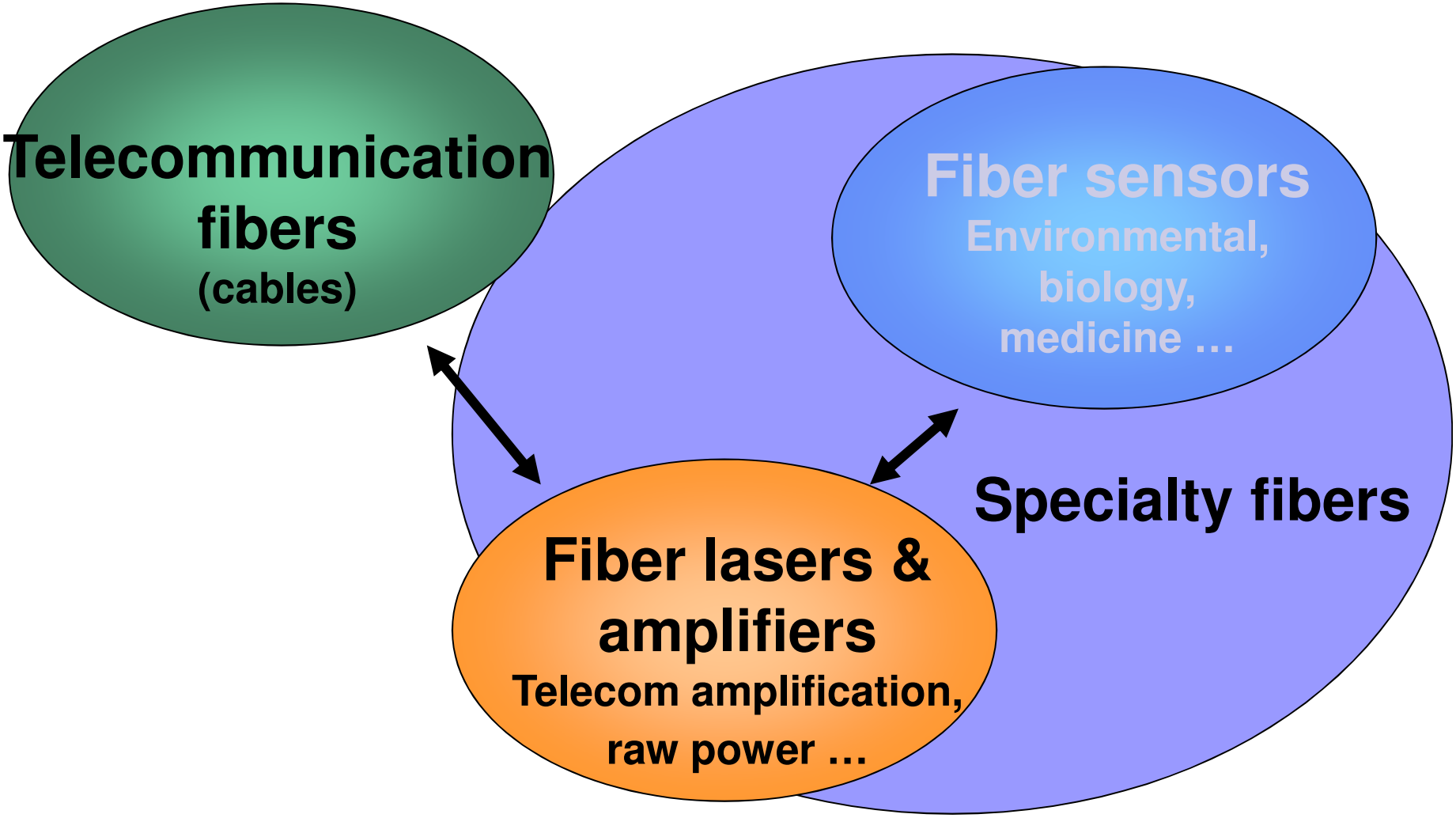
Drawing of optical fiber from preforms



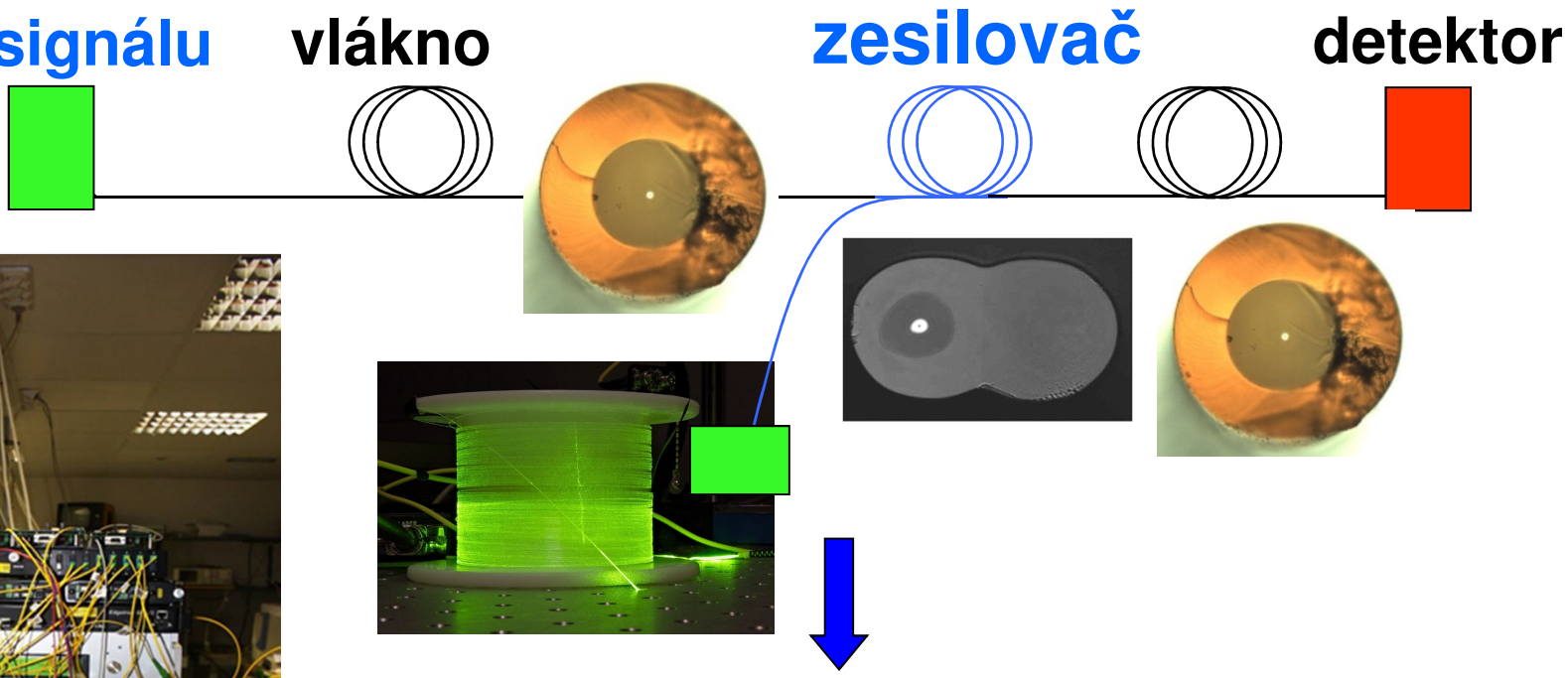
- Diameter
  80-1000 µm
- Temperature
  1800-2100 ℃

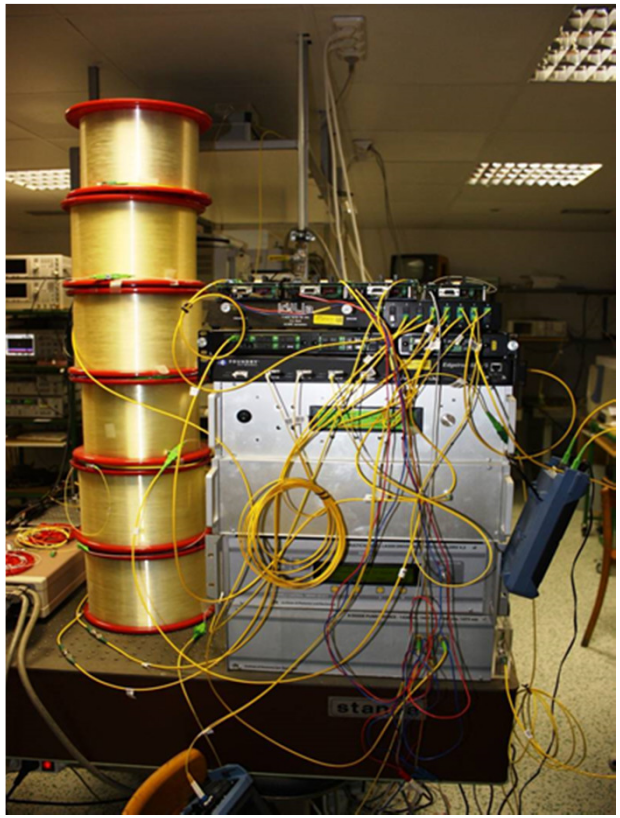
- No textile
- No thermo-insulation

Application



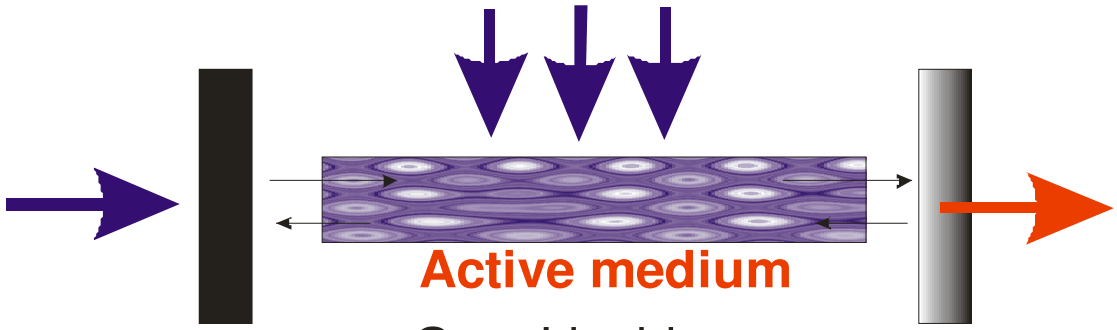
Telecommunications





Vláknový zesilovač, laser

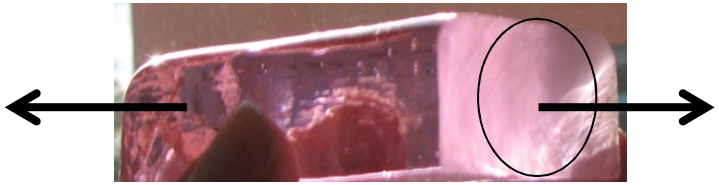
Silica specialty optical fibers for fiber lasers and amplifiers

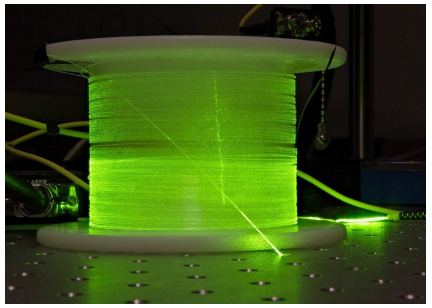


Mirror
100%

Gas, Liquid
Solid state :
* semidonductor
* glass
* OPTICAL FIBER

Mirror
8-99%





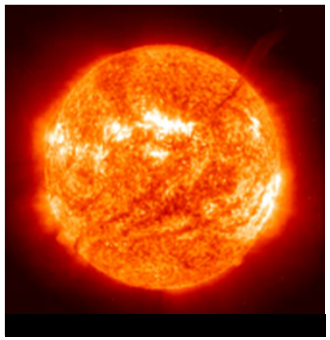
Er^{3+}

[C.J. Koester, E. Snitzer, Appl.Opt. (3) 1964, 1182] , [S.B. Poole, J.Lightwave Tech. LT-4 (**1986**), 870], [E.Desurvire, J.Lightwave Tech. LT-7 (1987), 835]

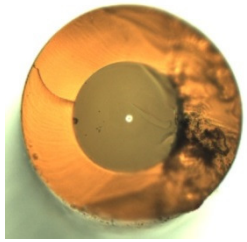
Fiber lasers mW → kW

* high conversion efficiency (fiber lasers ~70-90%) - savings
* high quality beam (nearly Gaussian, low divergency)
* **high brightness** (high concentration of power)
* good thermal management (cooling)
* effective pumping
* tunability
* compactness
* size (long resonator in small space)

[IPG]



sun	63 MW/m^2
fiber laser	12.7 GW/m^2

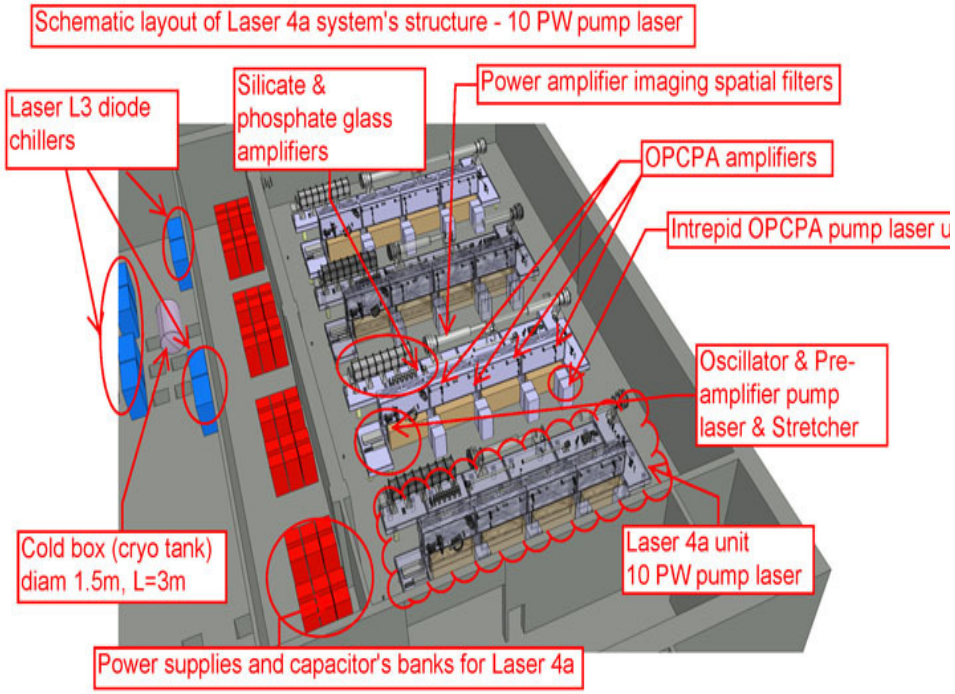


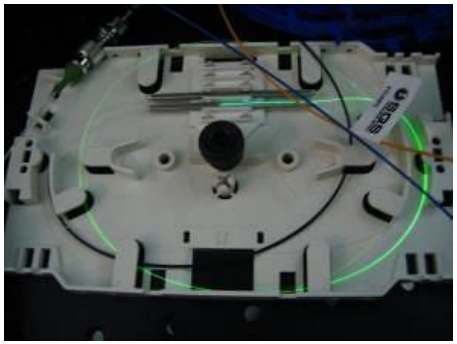
Fiber lasers vers. solid state lasers (SSL)

- **High brightness + flexibility**

fs pulses **5 PW** / 25x25 cm
ELI Beamlines [10^{15} W/um^2]

CW 40- **100 kW** / 10 um^2
IPG Photonics [10^{15} W/ um^2]





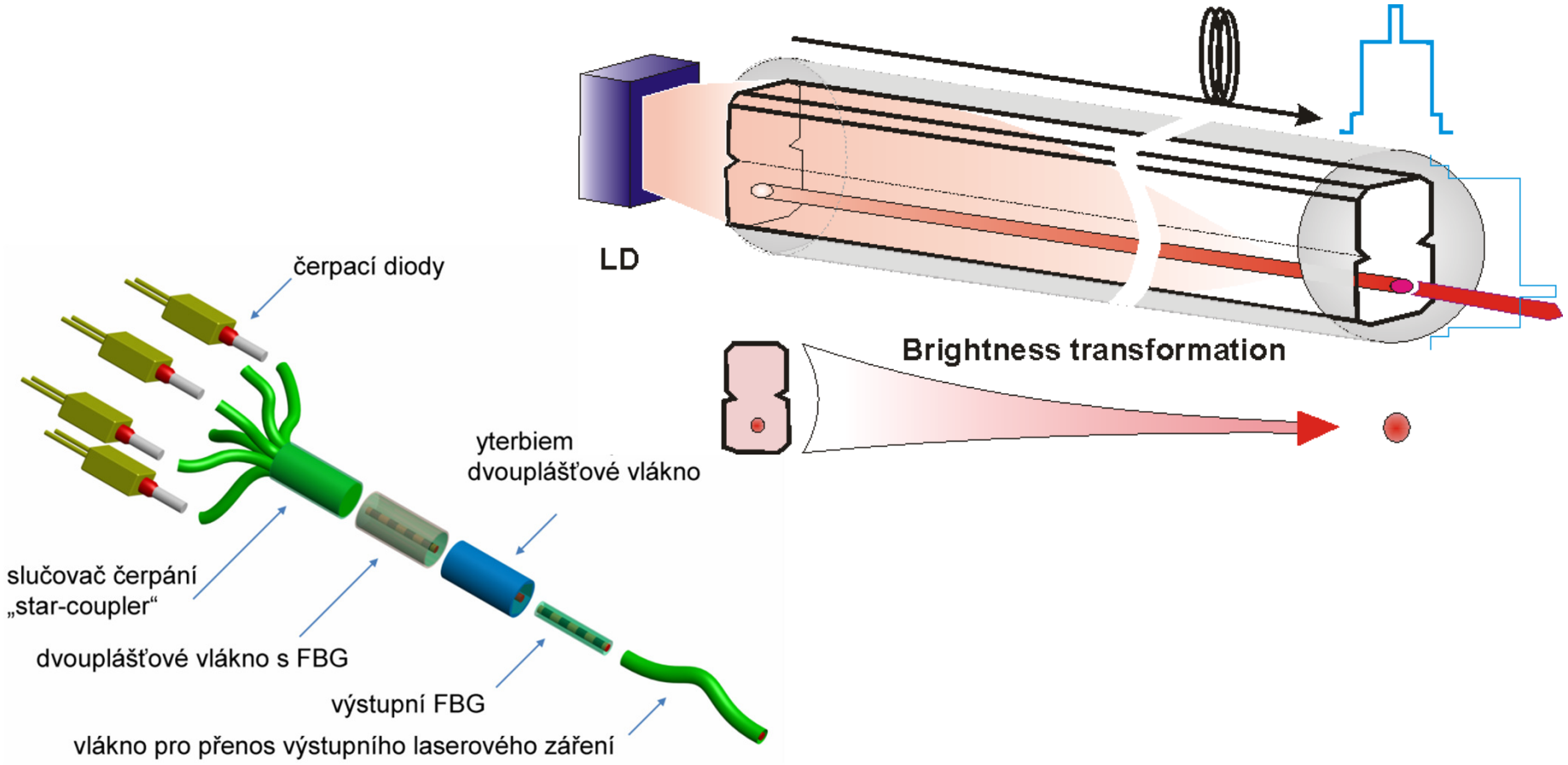
100 m

1 m

0.1 m

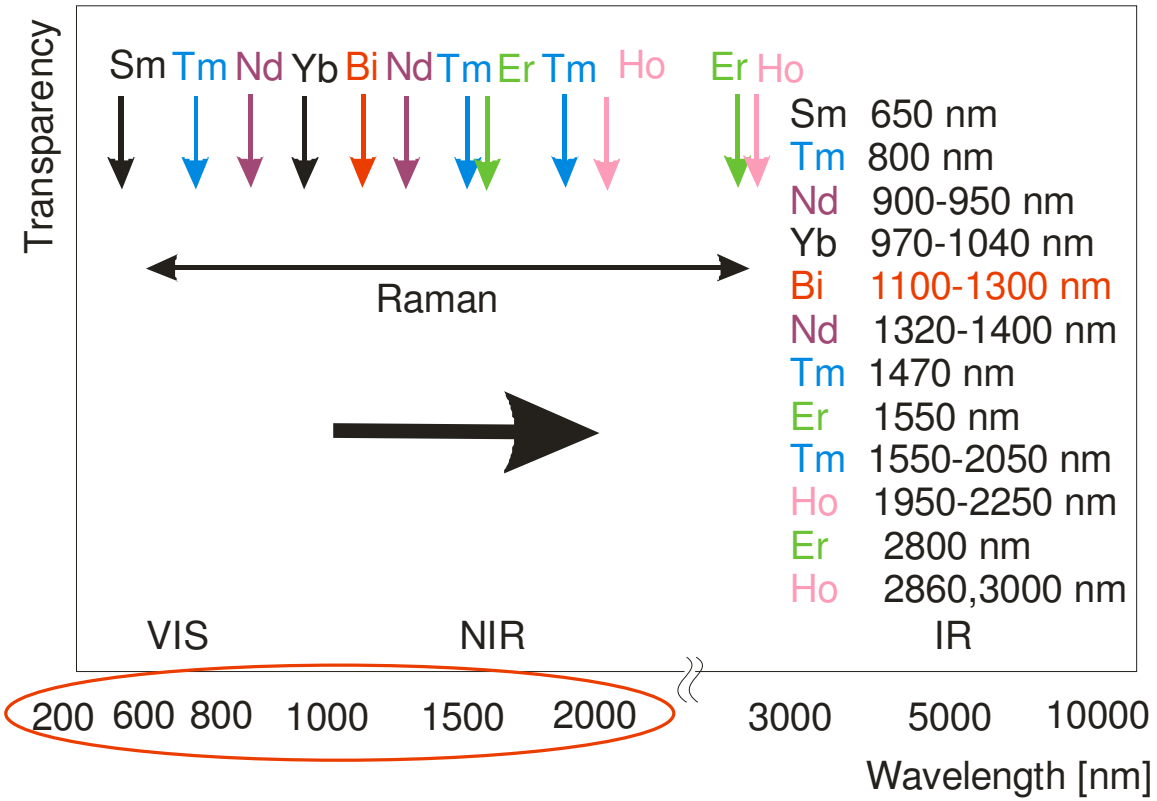
Silica (VIS-NIR) specialty optical fibers for fiber lasers and amplifiers

DC structures, beam combining ..



Silica (VIS-NIR) specialty optical fibers for fiber lasers and amplifiers

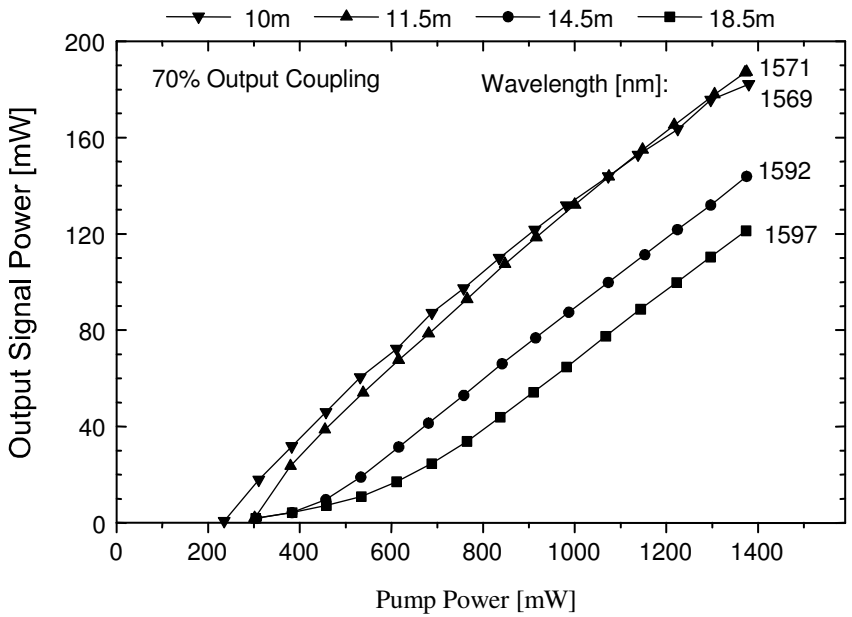
Dopants

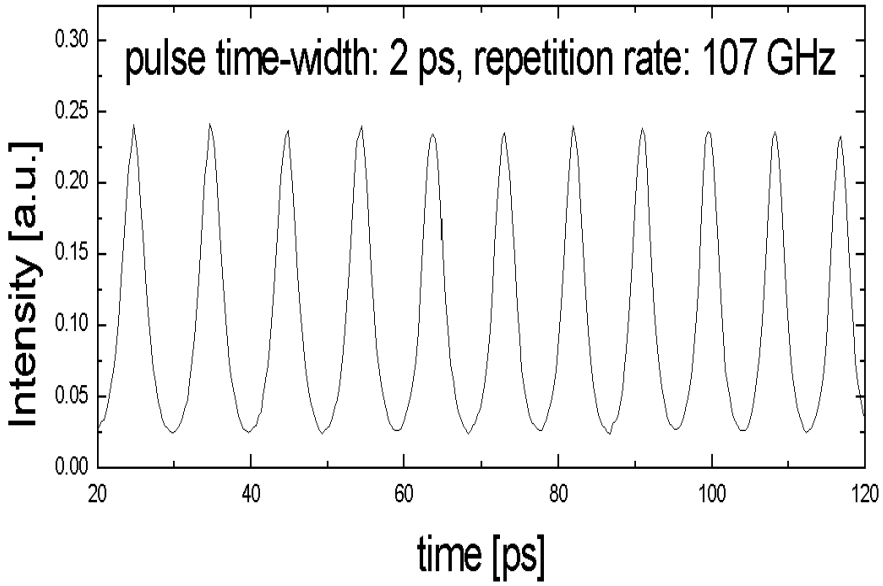


Dopant combination : effective pumping due to energy transfer

High-power lasers : **Er (1.5 um), Yb (1.1 um), Tm (1,9 um)**

Er/Yb fiber for soliton laser at 1 550 nm





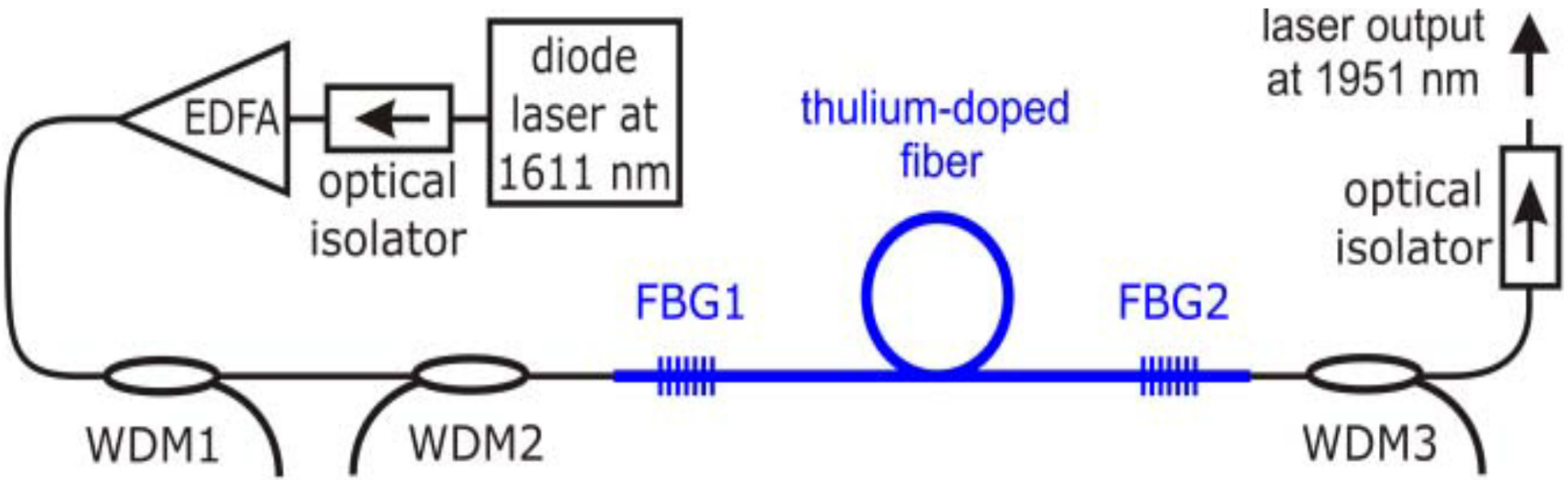
Er^{3+}/Yb^{3+} : 1000/10 000 ppm, Al_2O_3-SiO_2

[Kasik, V. Matejec, J. Kanka, P. Honzatko : Pure and Appl. Opt. **7** (1998) 457-465]

[I. Kasik, V. Matejec, M. Pospisilova, J. Kanka, J. Hora : Proc. **SPIE 2777** (1995) 71-79]

Monolitic Tm fiber laser at 1951 nm

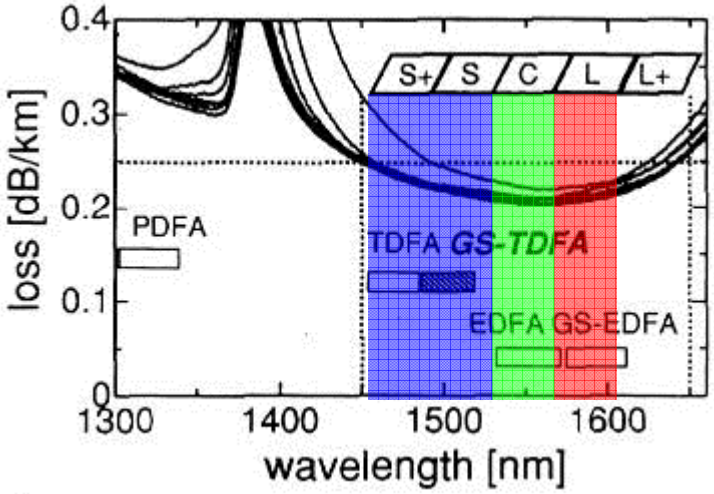
Eye-safe spectral region

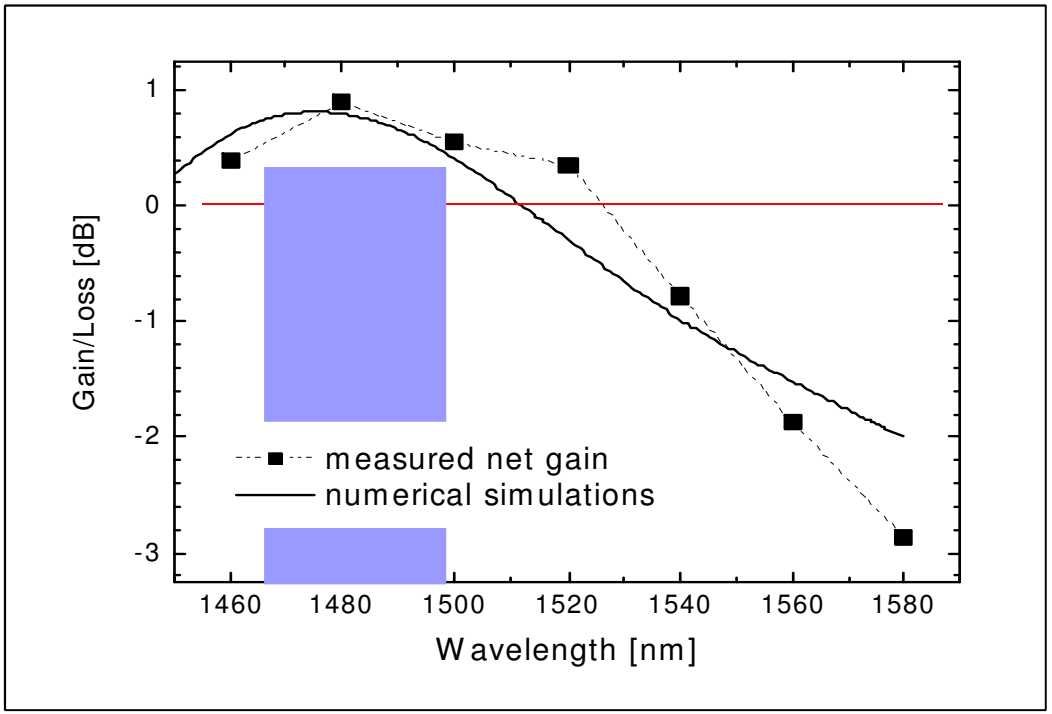


* 1000 ppm Tm^{3+}, 11mol% Al_2O_3, 0 mol% P_2O_5 or GeO_2,
* **deep-UV inscription of FBG**

[P.Peterka, Photonic Technol Lett, 25, 2013, 1623]

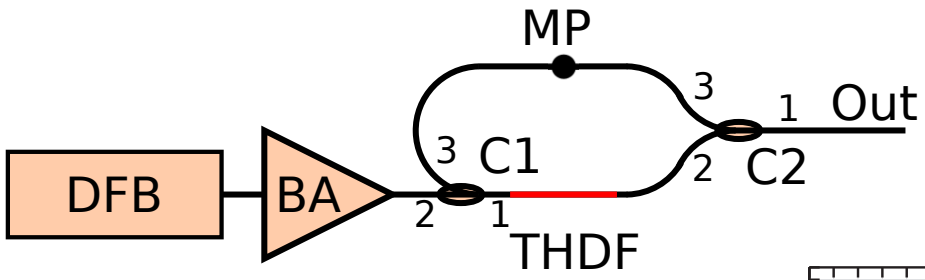
Tm fiber for amplifier at 1470 nm

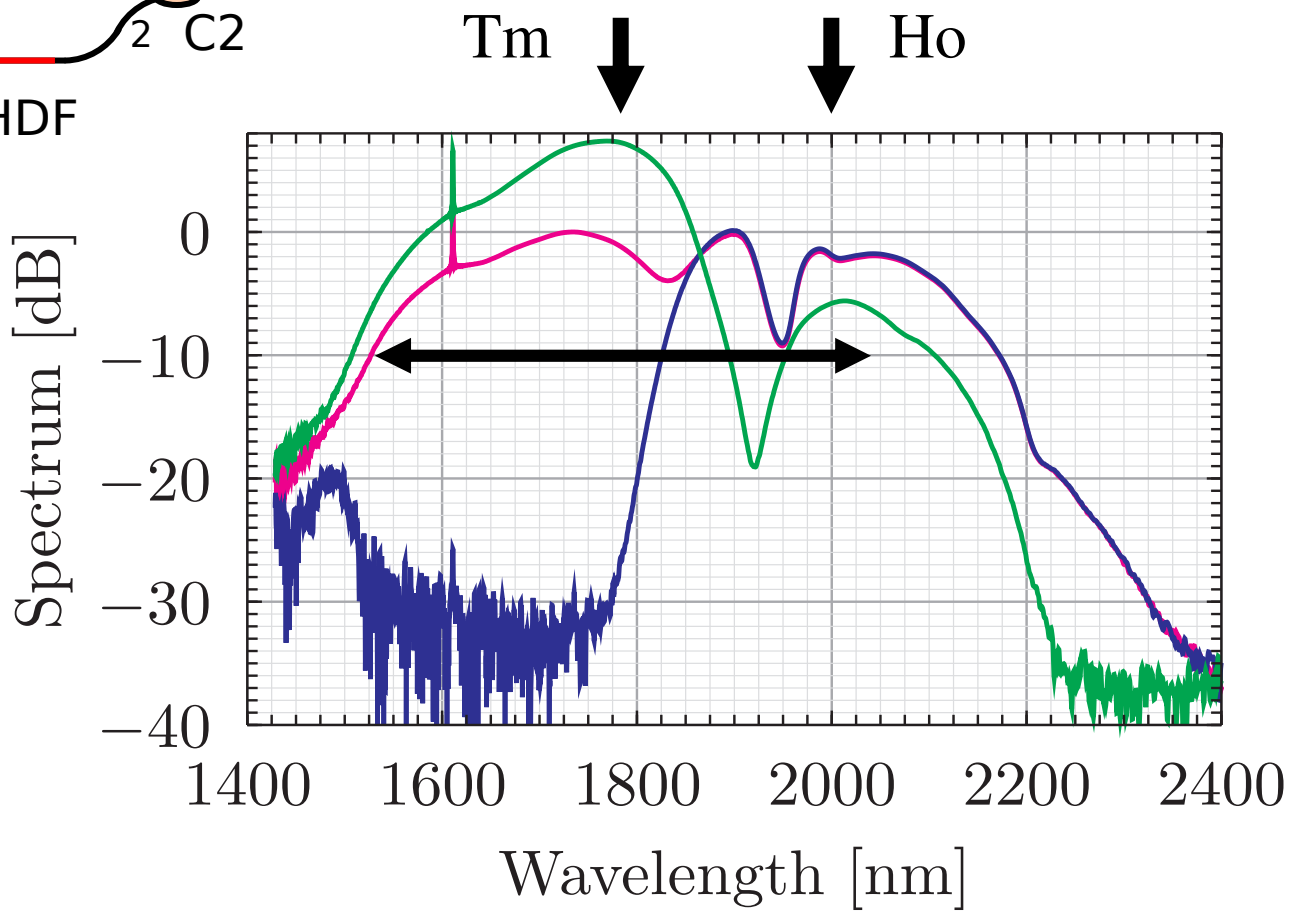




[P.Peterka, Opt. & Quantum El., 36 2004, 201], [W.Blanc, Proc. SPIE 6180, 2006, 61800V.1], [P.Peterka, Optical Materials 30 (2007) 174]

Tm/Ho fiber for ASE (1550-2050 nm) source

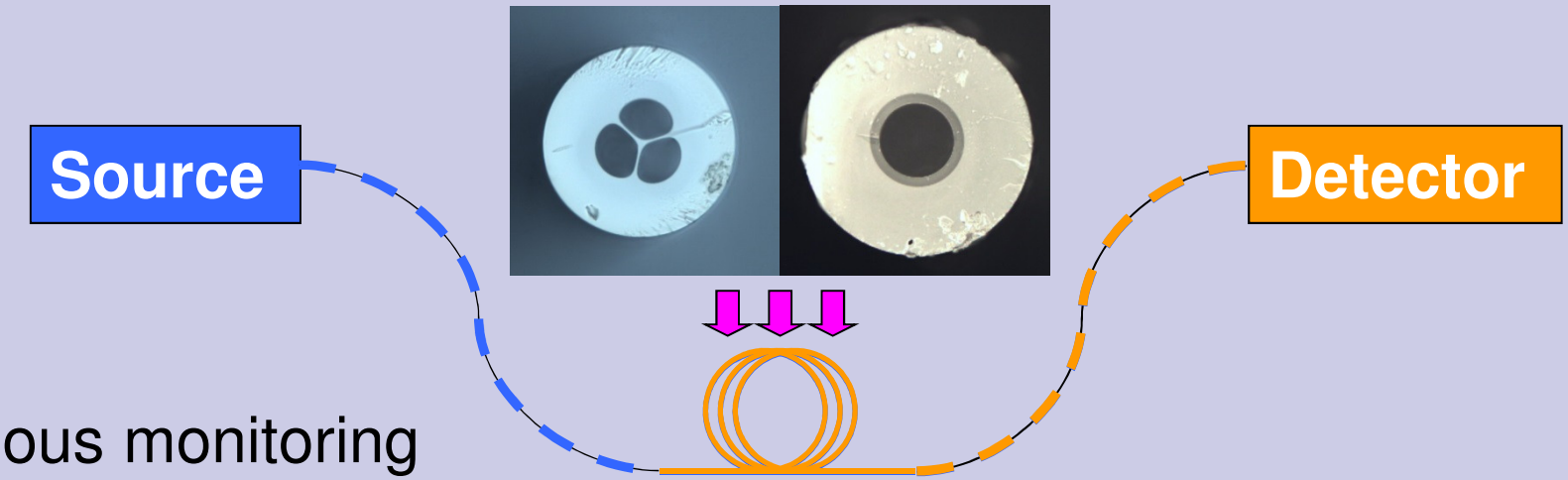




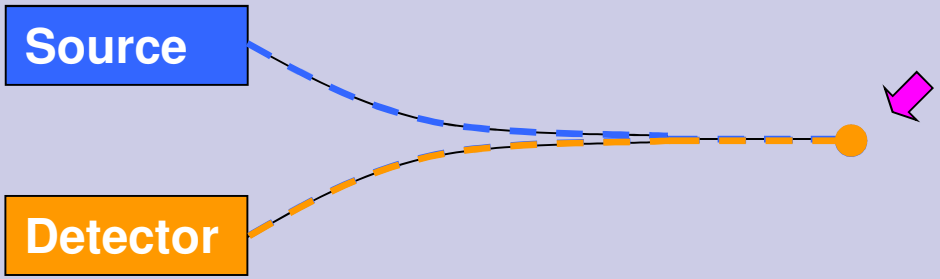
1800 ppm Tm^{3+} /
360 ppm Ho^{3+}

[P.Honzatko, Optics letters 39 (2014) 3650-3653]

Optical fiber sensors



Continuous monitoring of (bio)chemicals and their concentration.

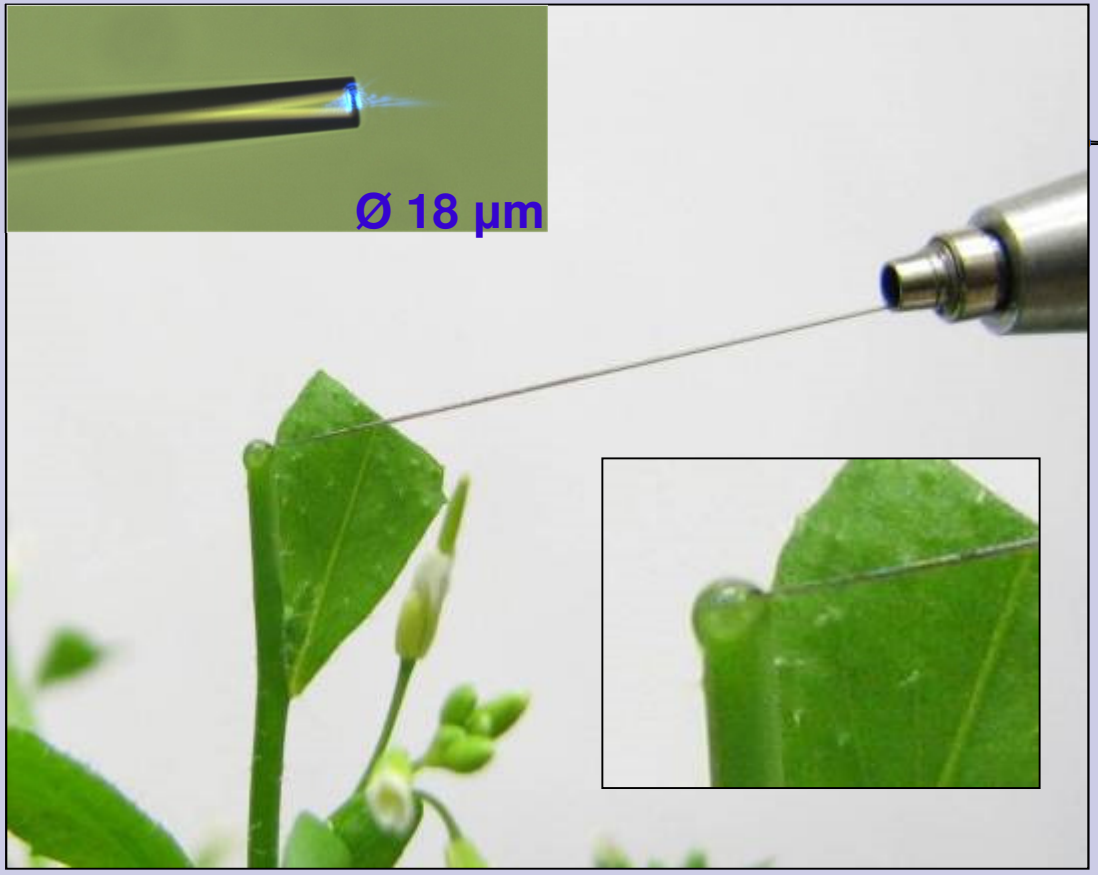


Suitable for :

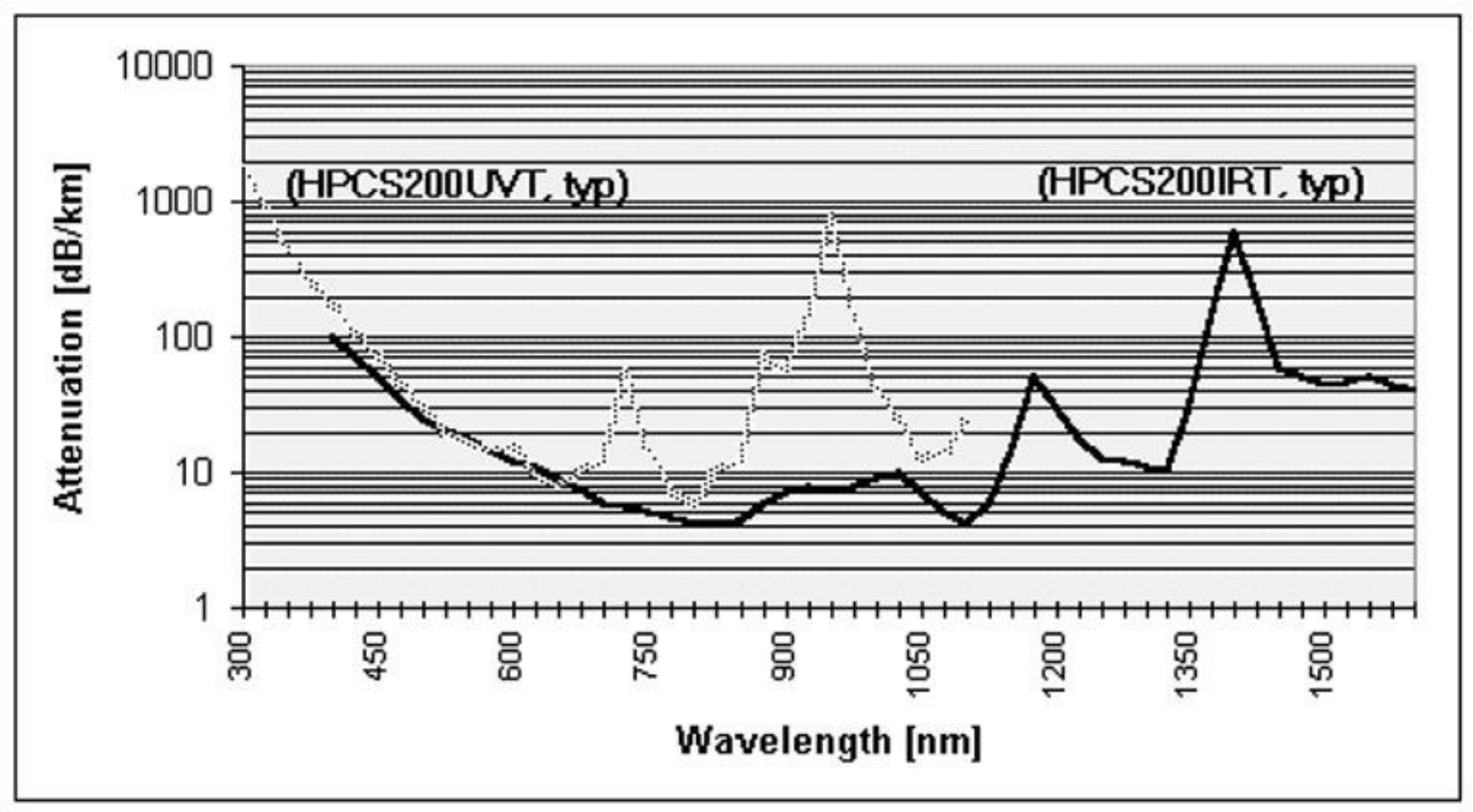
- remote sensing
- distributed sensing flammable or explosives
- in high-voltage areas
- human body

Optical fiber sensors

In vivo detection of pH in small samples ~ µL



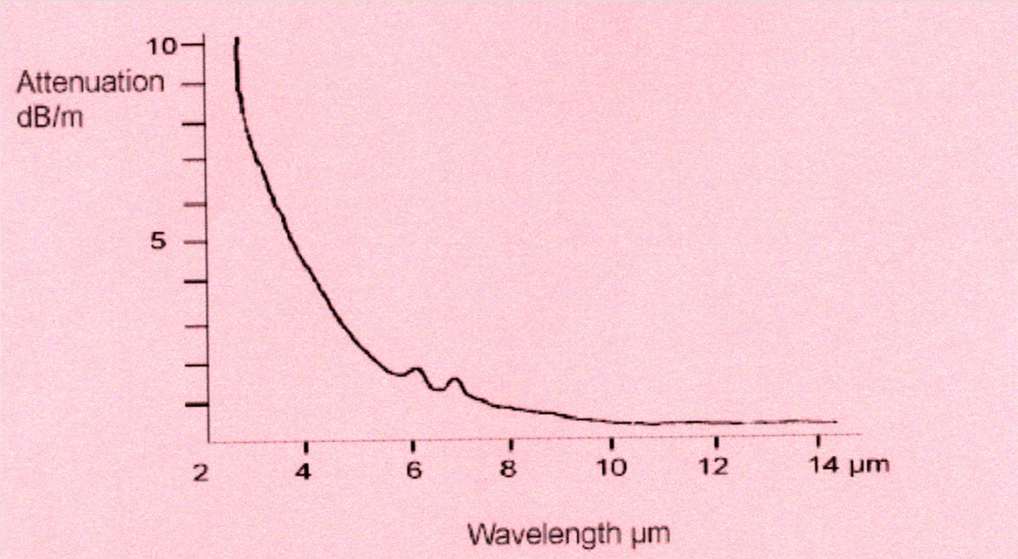
OPTICAL FIBERS – Materials - UV



- silica fibers - SUPRASIL $n_{200\,nm} = 1.55$ [ceramoptec.de, OceanO, IPE …]
- planar silica, crystalline CaF_2 (MgF_2) – [edmundoptics, technicalglass …]

OPTICAL FIBERS – VIS/NIR, IR

Silica n_{633} =1.457 & doped silica n_{633} = 1.45-1.50 [corning, lucent, ocean_o, IPE]
Glass (silicate - Simax, Vycor, Pyrex) n_{588} =1.5-1.95 [schott, LiFaTec.de, IPE…]
Plastic n_{588} =1.5-1.6 [mitsubishi.com, luceat.it, unlimited-inc.com…]



- fluoride glasses [univ-rennes1.fr …] (up to ~4 µm)
- **sapphire [CRYTUR] (up to ~4 µm)**
- silver-halides $AgCl_xBr_{1-x}$ (up to 15 µm)
- chalco glasses (Se, As_2S_3, As_2Se_3…) [oxford-electronics, orc.soton.ac.uk] (< 20 µm)
- refractive indexes $_{2\text{-}20um}$ ~ 2 – 2.5 >> silicate glasses [LiFaTec]

SUMMARY

1. Fiber technology : preparation of structures of high preciseness from materials of ultra-high purity (impurities in ppbs only).
2. Fiber preparation in two steps : preform preparation and fiber drawing. (M)CVD technique (preform) makes possible to prepare multilayered tailored structures of suitable level of purity.
3. Fibers lasers : opportunity !!
4. Research of optical fibers (CR) :

ŪFE

References

- **J. M. Senior** : Optical fiber communications - Principle and practise, Pearson Education Limited, Harlow, England, 2009.
- **A. Mendez, F.T. Morse** : Specialty optical fibers handbook, Elsevier Science & Technol, USA, 2006.
- **J. Schrofel, K. Novotný** : Optické vlnovody, SNTL, 1986
- **Saaleh,** Fotonika (1 - 4), Matfyzpres

- **S. R. Nagel, J. B. McChesney, K. L. Walker :** An overview of the MCVD process and performance, IEEE J. Quantum Electron. QE-18 (1982) 459-477

- **Peterka - Vláknové lasery**
- Československý časopis pro fyziku 1/2010, 4-5/2010, 1/2011
- Jemná mechanika a optika (2015)
- Sdělovací technika 3/2011