INTERNATIONAL YEAR OF LIGHT 2015

ÚFE

Ústav fotoniky a elektroniky AV ČR, v.v.i.

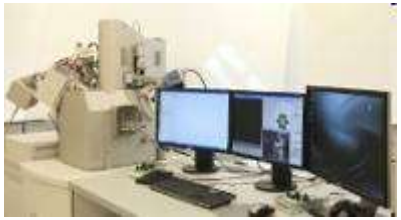
Technologie optických vláken

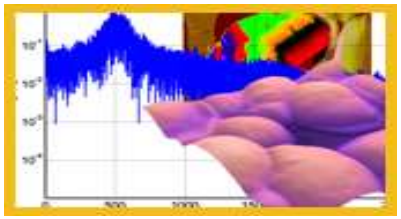
http://www.ufe.cz/cs/ondrej-podrazky-students

Ústav fotoniky a elektroniky

ÚFE

Prof. Jiří Homola
Head of UFE





Optické biosenzory (Homola)

Vláknové lasery a nelineární optika (Honzátko)

Nano-optika (Piliarik)

Příprava a charakterizace nanomateriálů (Grym)

Bioelektrodynamka (Cifra)

Laboratoř Státního etalonu času a frekvence (Kuna)

Přehled

- Úvod

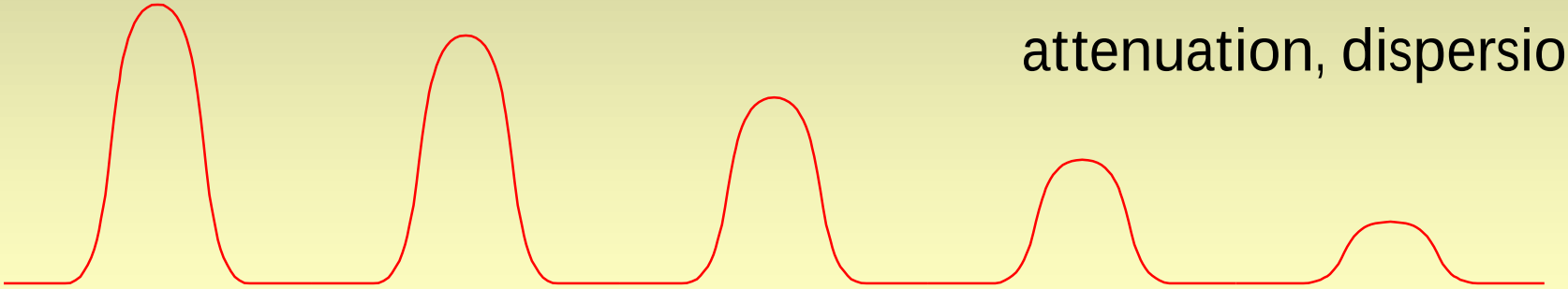
- **Optická vlákna:** **– čisté materiály a technologie**
- Využití opt .vláken:
  - telekomunikace
  - vláknové lasery a zesilovače
  - vláknové senzory

- Shrnutí

Optical fiber

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

attenuation, dispersion



Optical losses in optical fibers

- trasparency of 3 mm of window-glass ≈ 2 km of optical fiber

Charles K. Kao

Nobel prize 2009

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

ULTRA-PURE TECHNOLOGIES

Purity of material

1. Per Analysis – PA (99 - 99,5 %)
2. Semiconductor – PP (99,9995 %)
3. Ultra-pure - FO Optipur / for trace analysis [ppb]

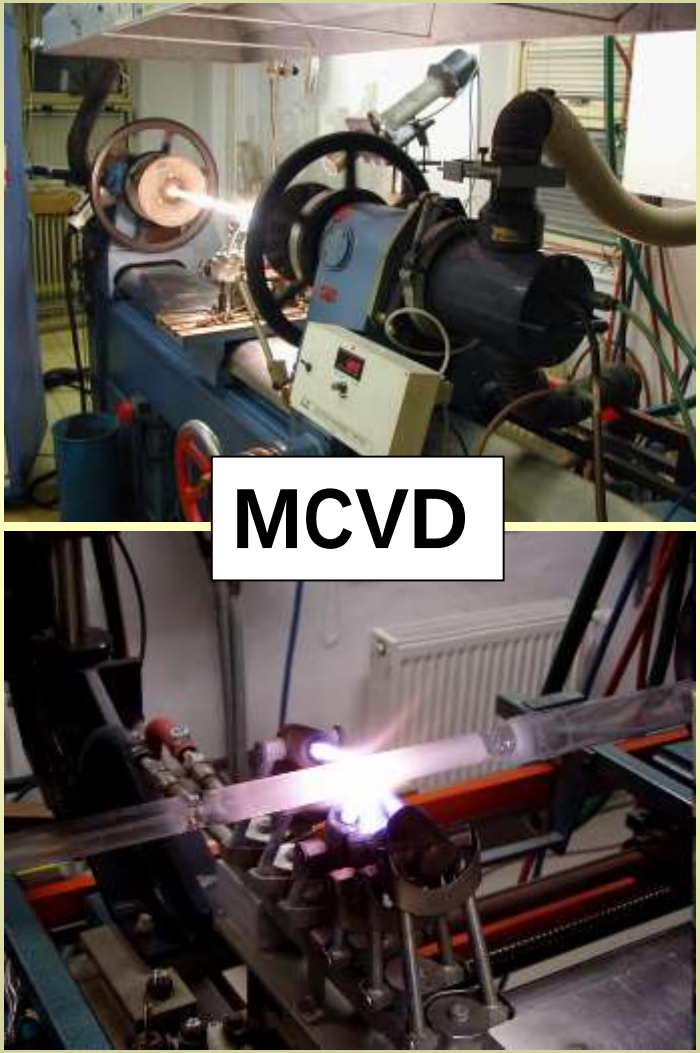
% – 10^{-2}

ppm – 10^{-6} (parts per million)

ppb – 10^{-9} (parts per billion) : content of impurities acceptable in FO Optipur materials

Ultra-pure technologies - CVD !

Optical fiber preparation



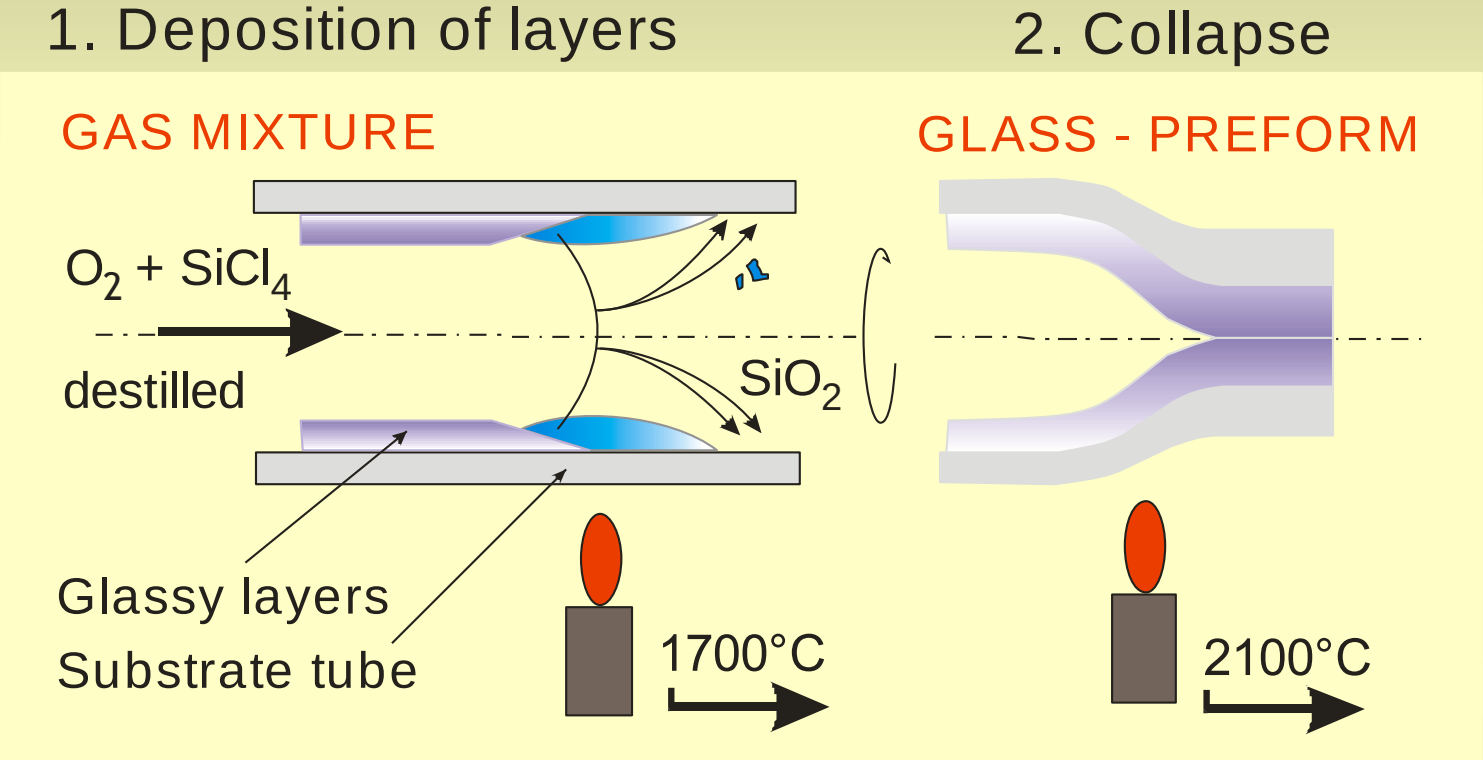
MCVD

1. Preform

2. Fiber drawing

Preform preparation

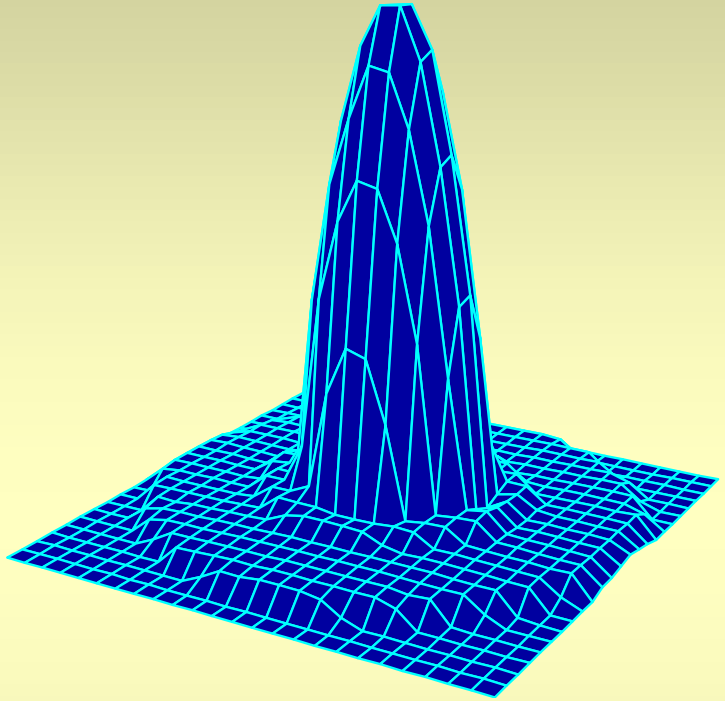
MCVD – (Modified) Chemical Vapor Deposition



- 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 preparation

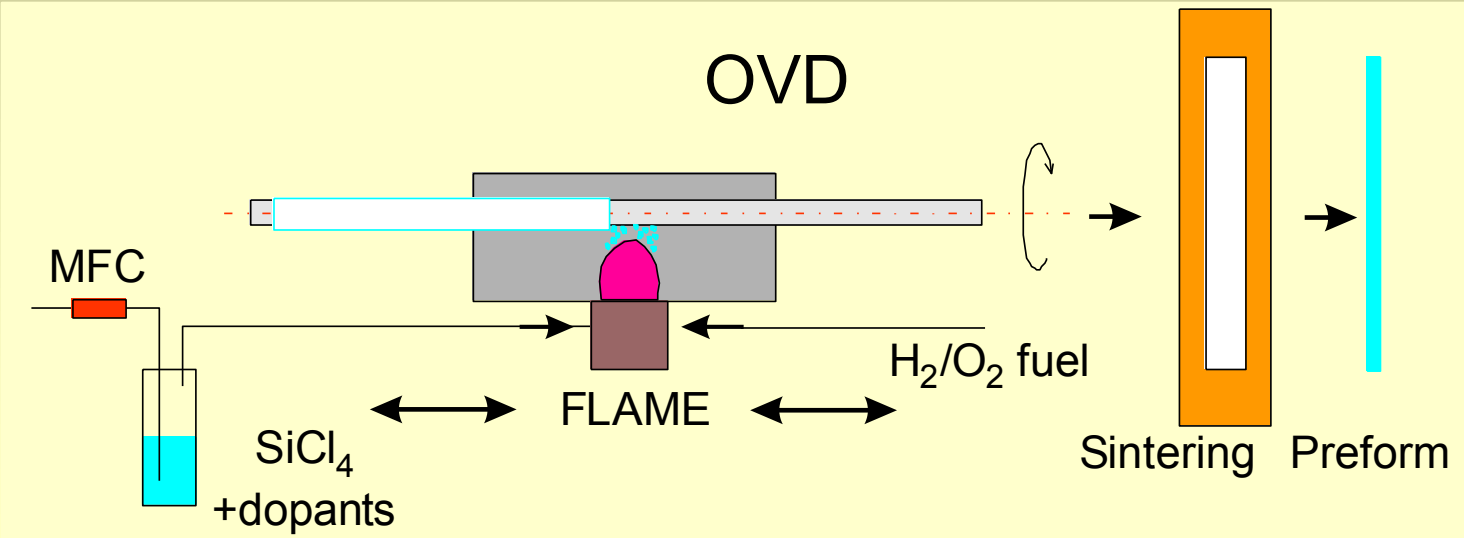
Microphoto of cross section of produced preform

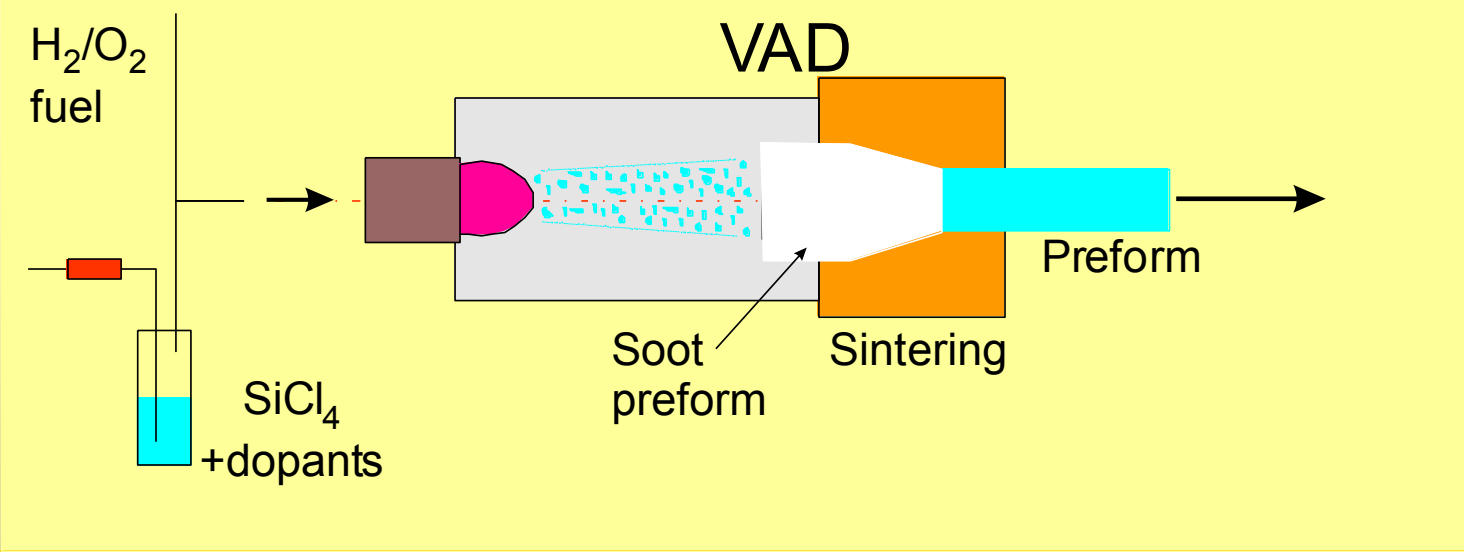


Tomography of the refractive-index profile of preform

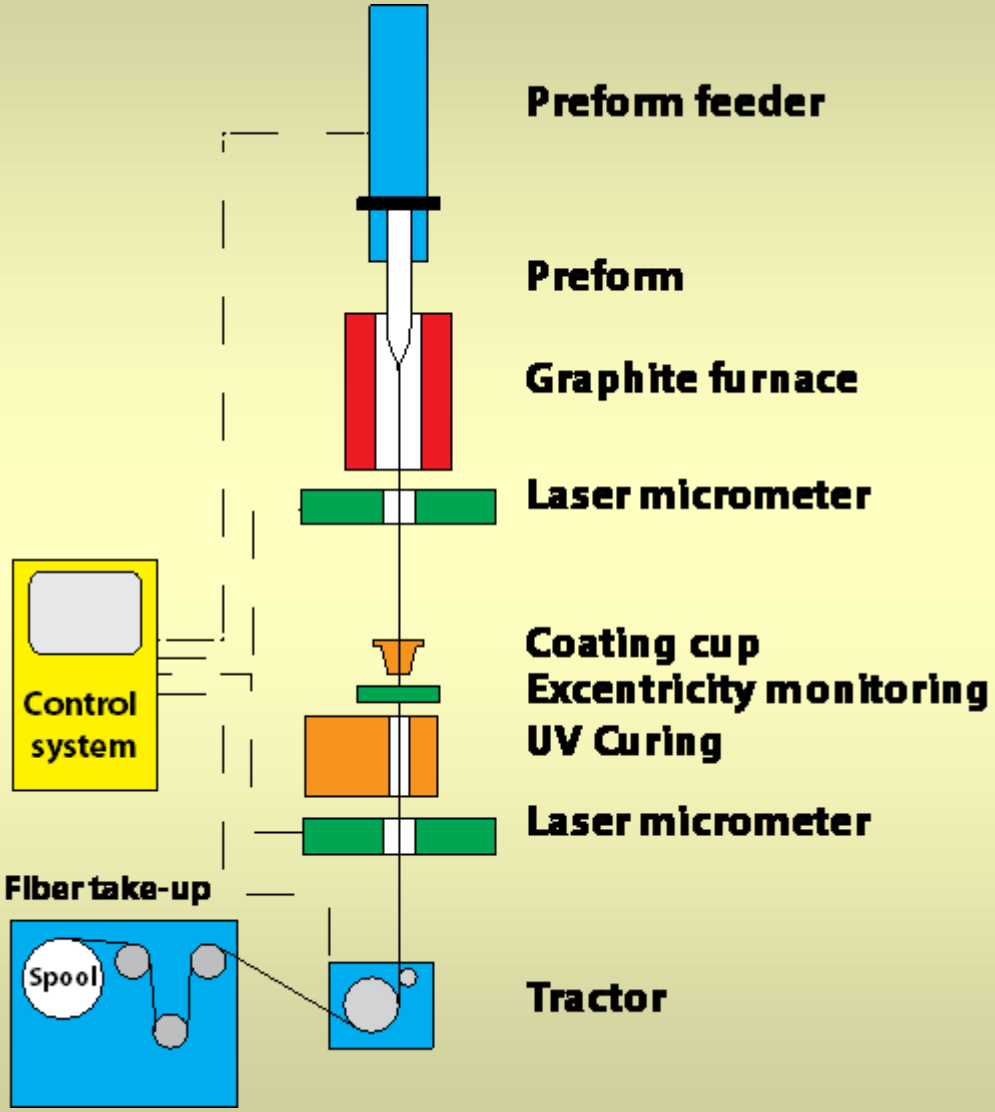
- High purity material due to FO-Optipur purity starting materials.
- High quenching rate ranging from 10^2 to 10^3 °C/s.

Other CVD Technologies





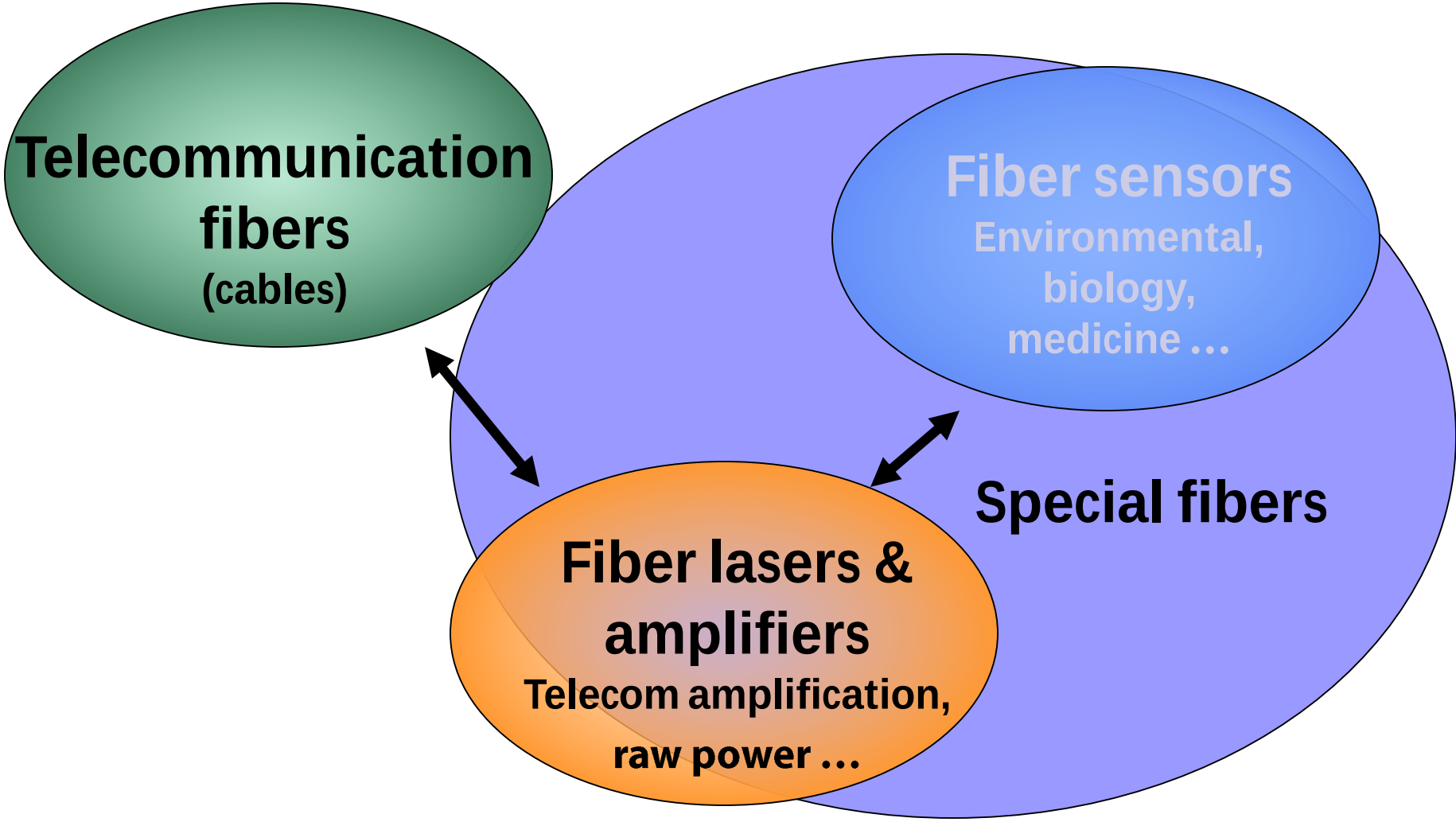
Drawing of optical fiber from preforms



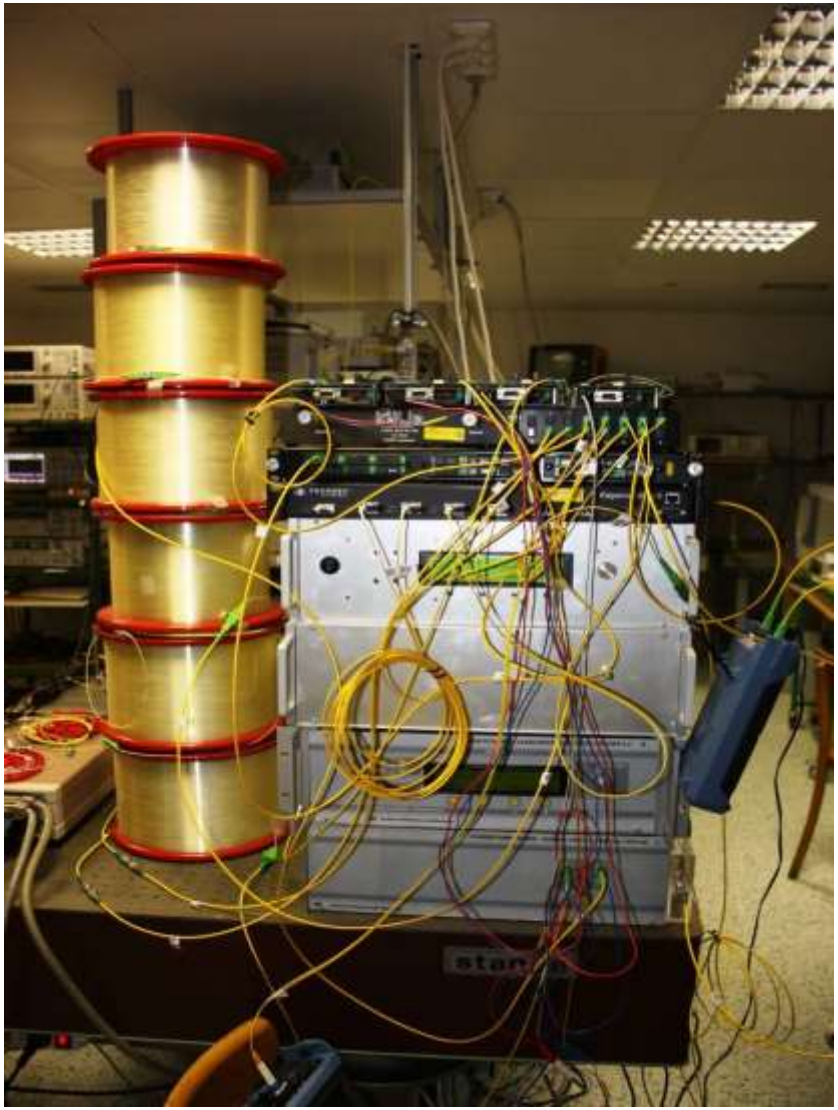
- Diameter
  80-1000 µm
- Temperature
  1800-2100°C

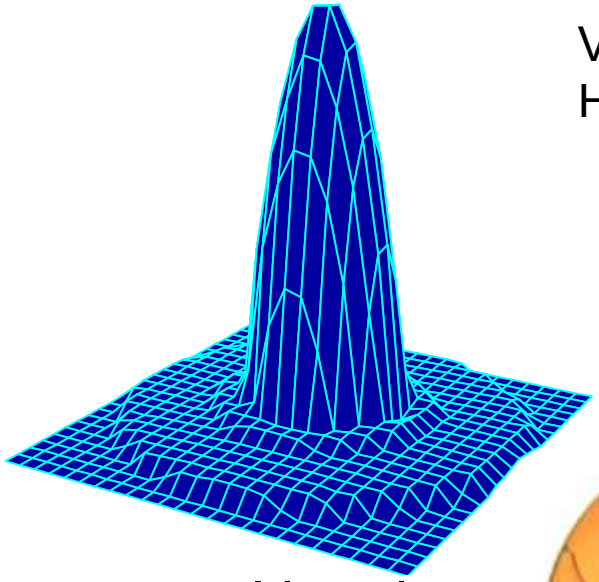
- No textile
- No thermo-insulation

Application



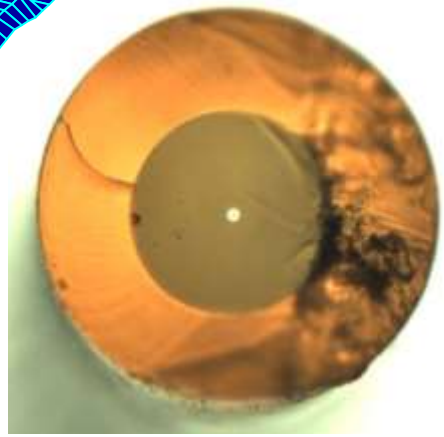
Telecommunications [mW]





VÚSU Teplice,
Hesfibel - TR

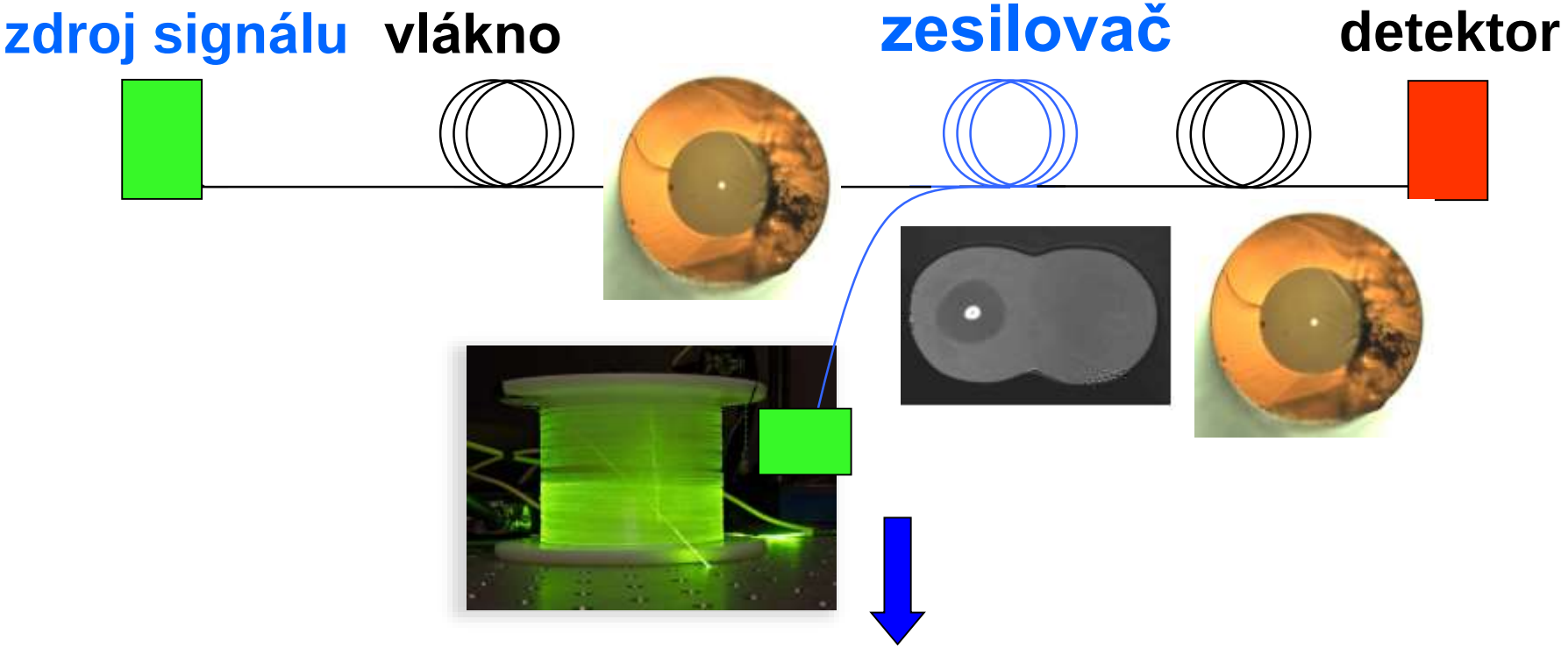
GI - multimode



SM - singlemode

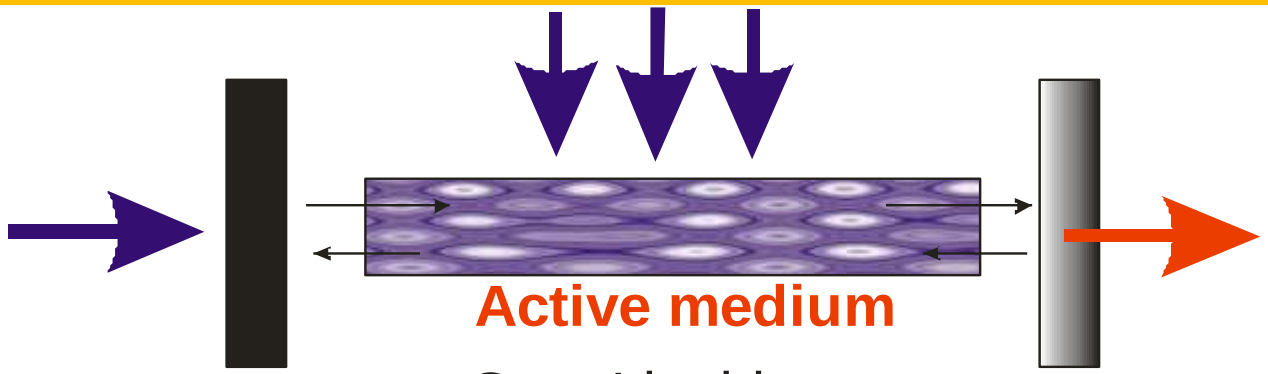
200 km telecom line - test

Speciální vlákna pro telekomunikace :
Vláknové lasery a zesilovače



Vláknový zesilovač, laser

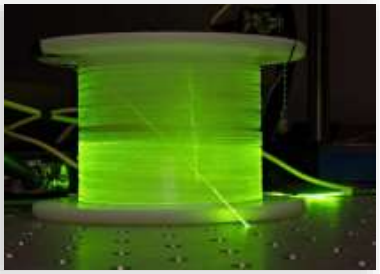
Silica specialty optical fibers for fiber lasers and amplifiers



Mirror
100%

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

Mirror
8-99%



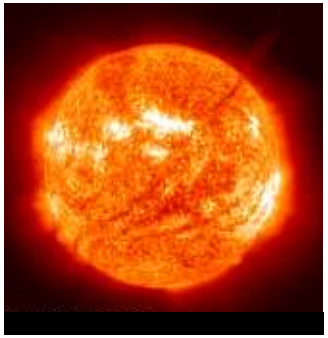
Er^{3+}

[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]

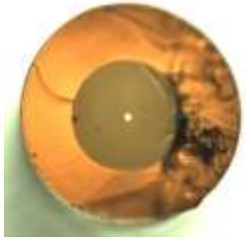
Fiber lasers mW → kW

* **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]

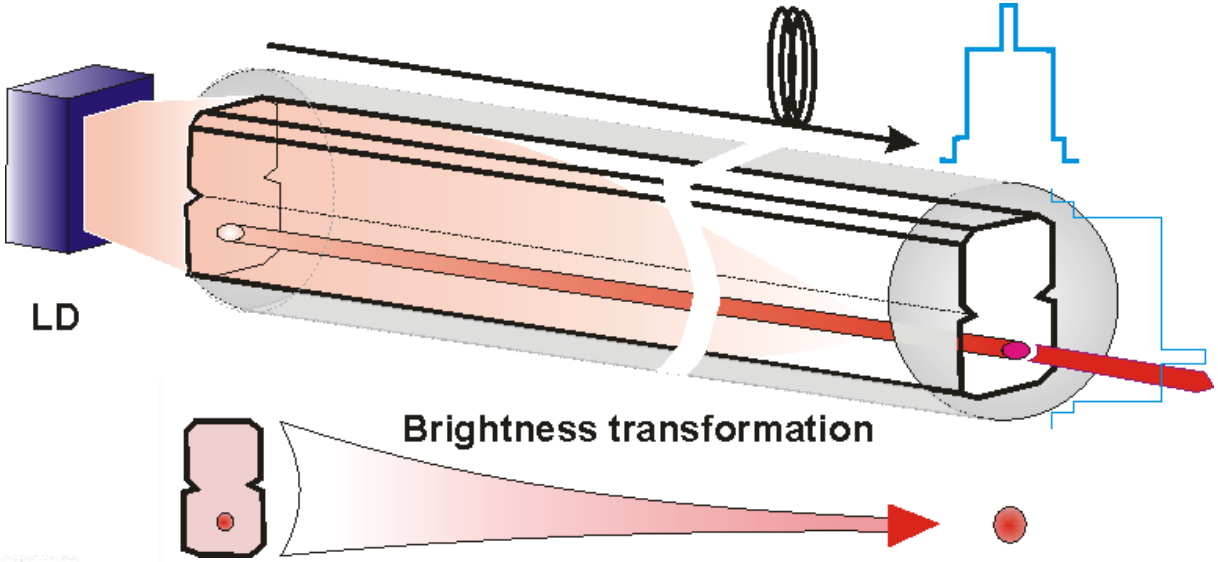


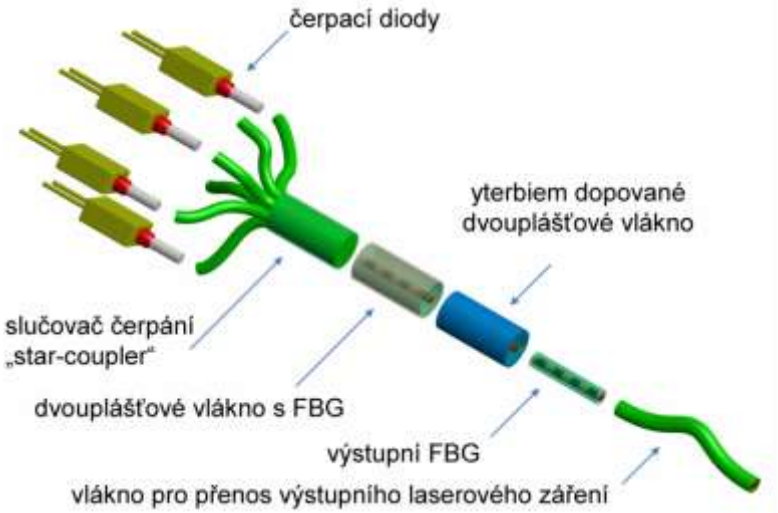
sun	63 MW/m^2
fiber laser	12.7 GW/m^2



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

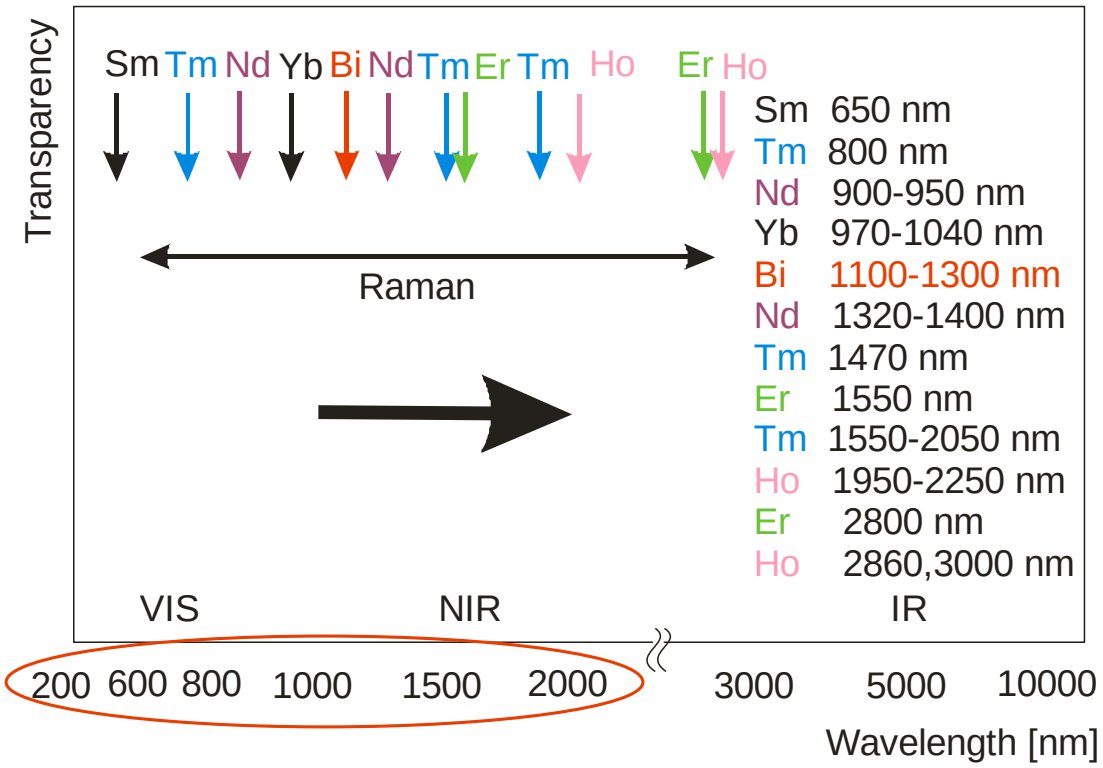
DC structures, beam combining ..





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

Dopants



Dopant combination : effective pumping due to energy transfer

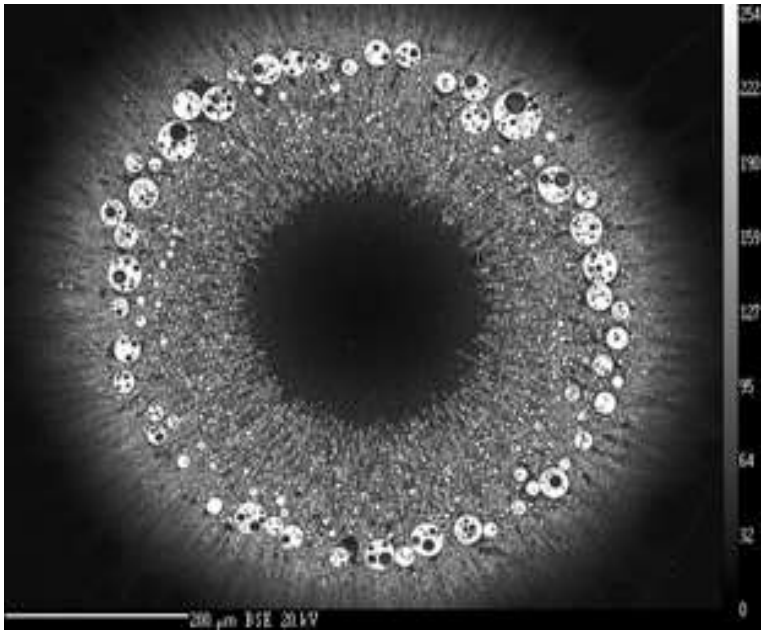
High-power lasers : Er (1.5 um), Yb (1.1 um), Tm (1,9 um)

RE-doped SILICA

+ low optical losses in wide transmission window

+ good thermal durability and stability

- low miscibility of RE with silica



Increase of RE doping + Mixing of RE

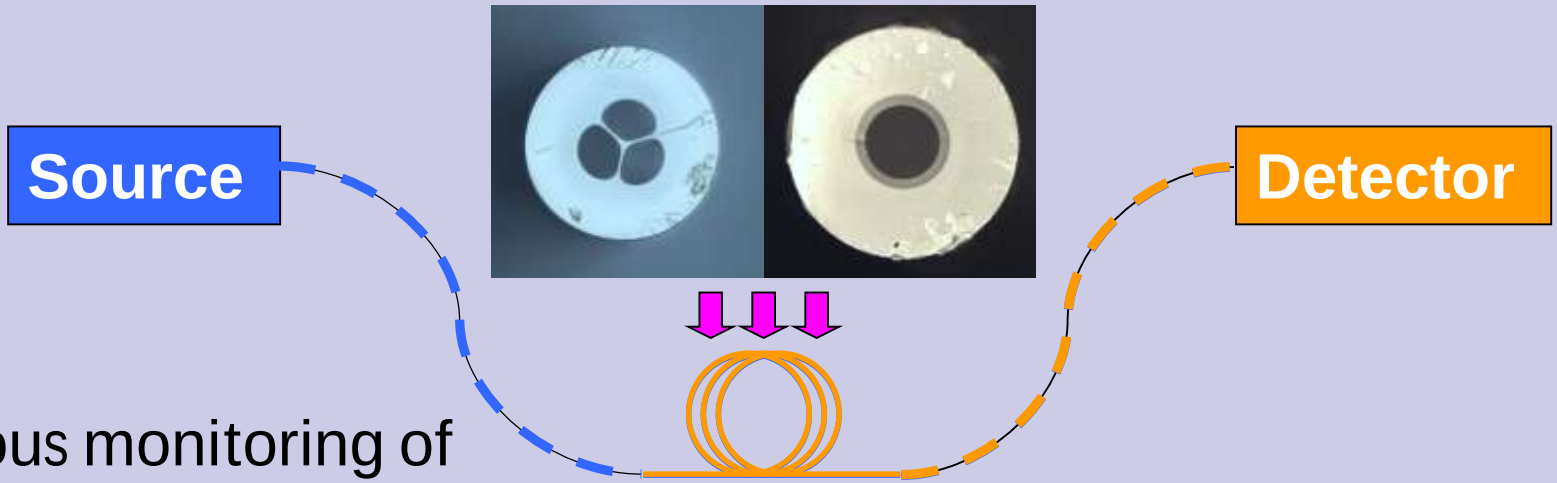
→ phase separation

→ unacceptable attenuation

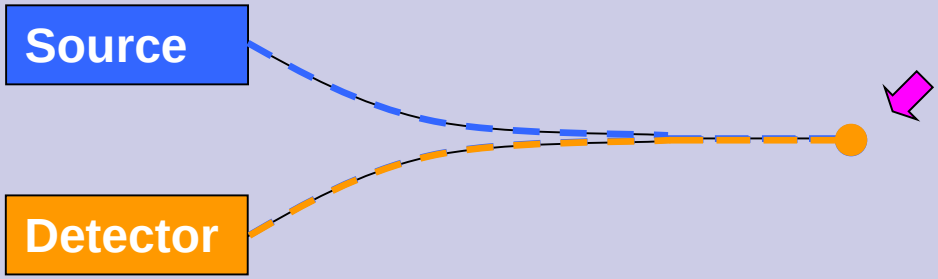
=> modification of matrix with (GeO_2), Al_2O_3, P_2O_5 … Sb_2O_3

= **dissolving of RE in glass matrix** + increase of RI

Optical fiber sensors



Continuous monitoring of (bio)chemicals and their concentration.

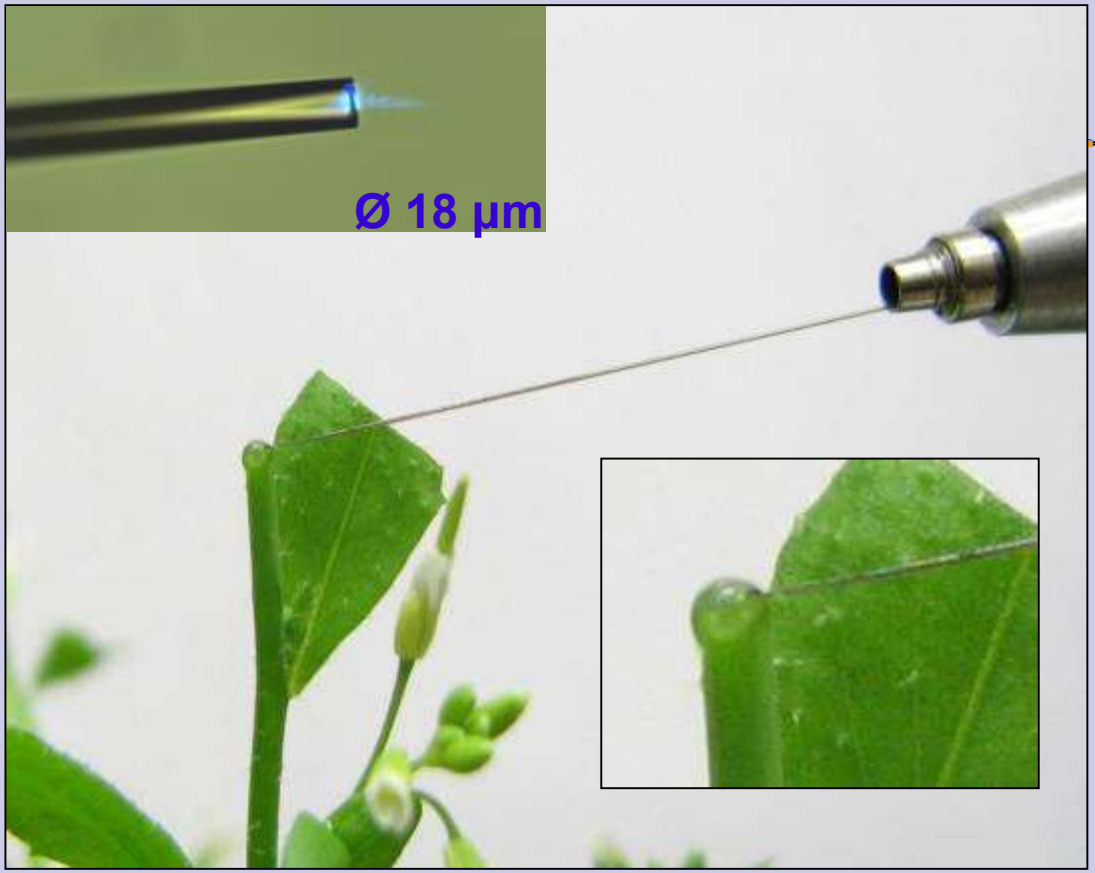


Suitable for :

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

Optical fiber sensors

In vivo detection of pH in small samples (droplets, cells)



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 conventional (passive) and special (active).
4. Research of optical fibers (CR) :

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 55 (2010)
- Sdělovací technika 3/2011