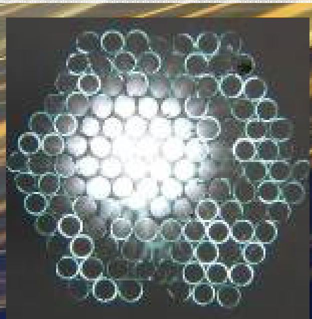
Academy of Sciences

Institute of Photonics and Electronics v.v.i.

Technology of Optical Fibers

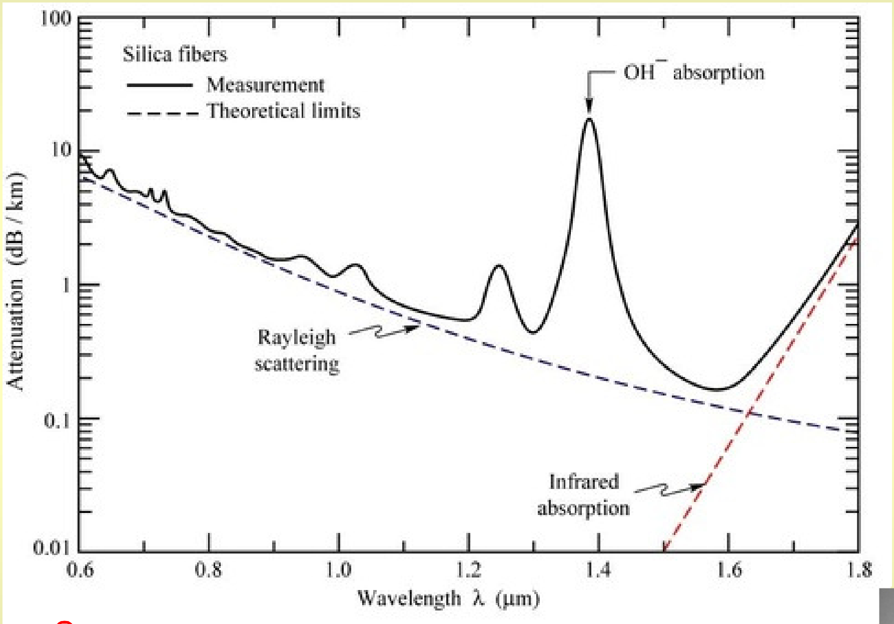
I.Kašík, www.ufe.cz

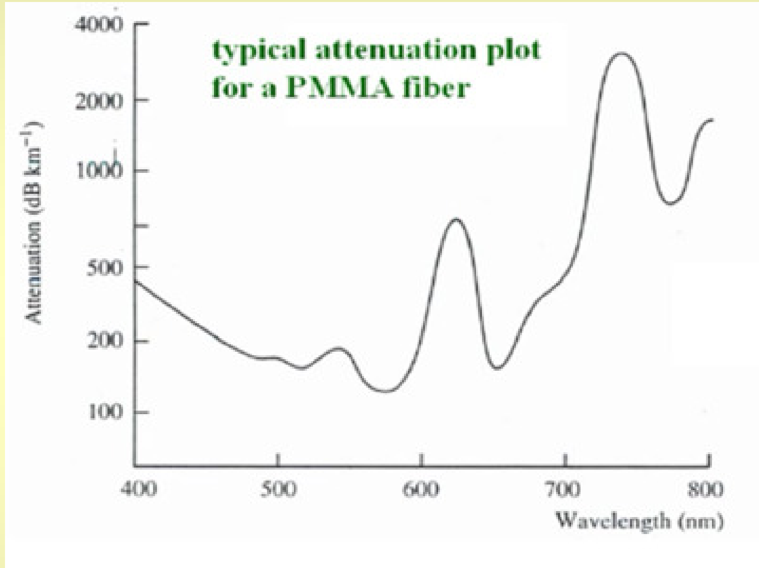
    

Optical fiber

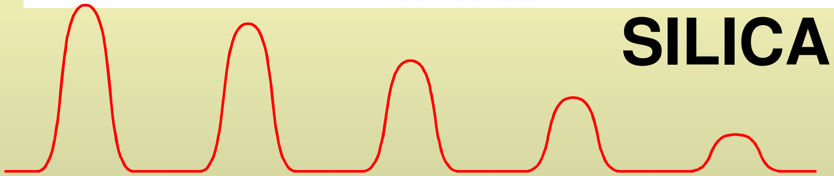
Optical fiber : dielectric structure, L<< r, $n_{core} > n_{clad}$

Optical losses in optical fibers (intrinsic, extrinsic)





SILICA



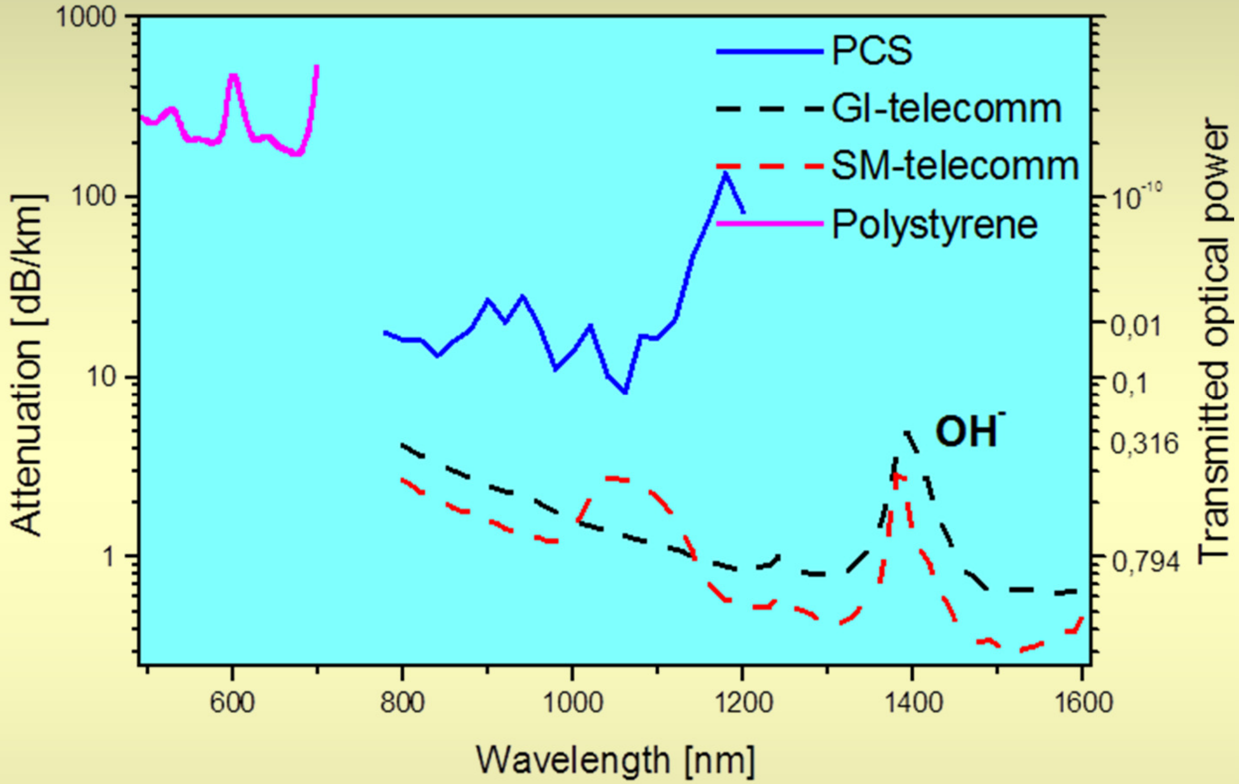
attenuation, dispersion

Nobel prize 2009 Ch.K.Kao

Optical fiber

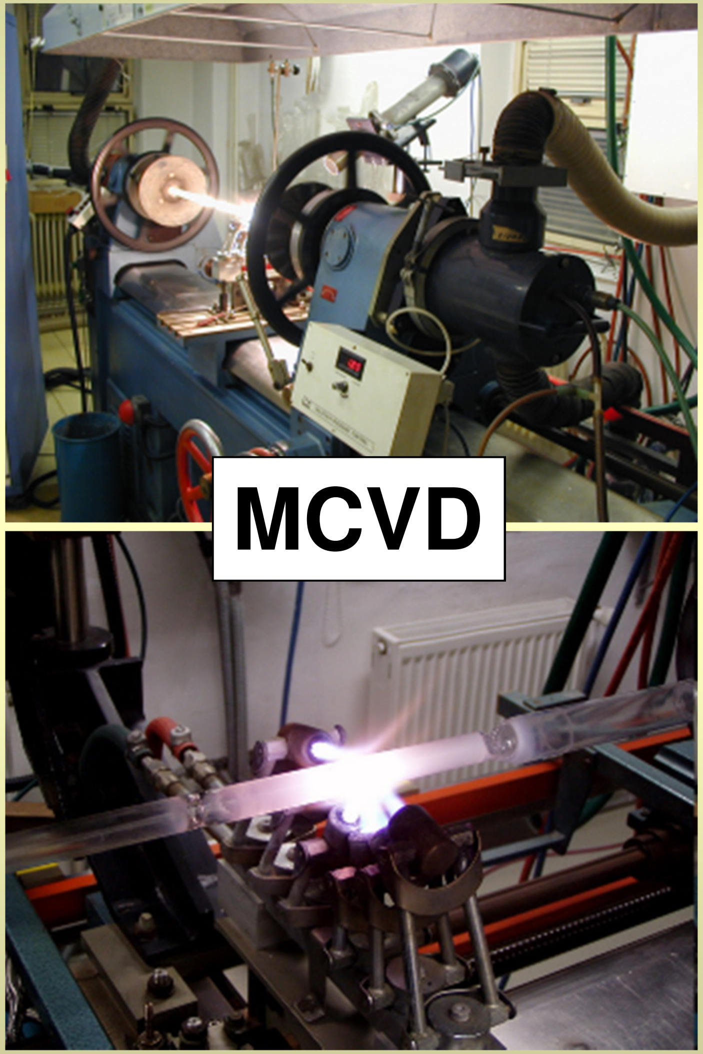
- **high-purity**
- **silica based materials,**

max. impurities acceptable in ppb (10^{-9})



Conventional glassmaking => ULTRA-PURE TECHNOLOGIES

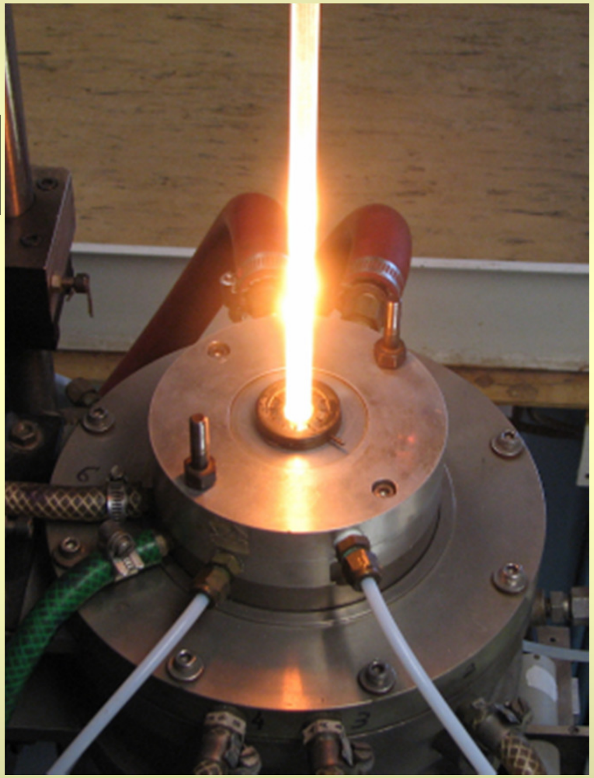
Optical fiber preparation



MCVD

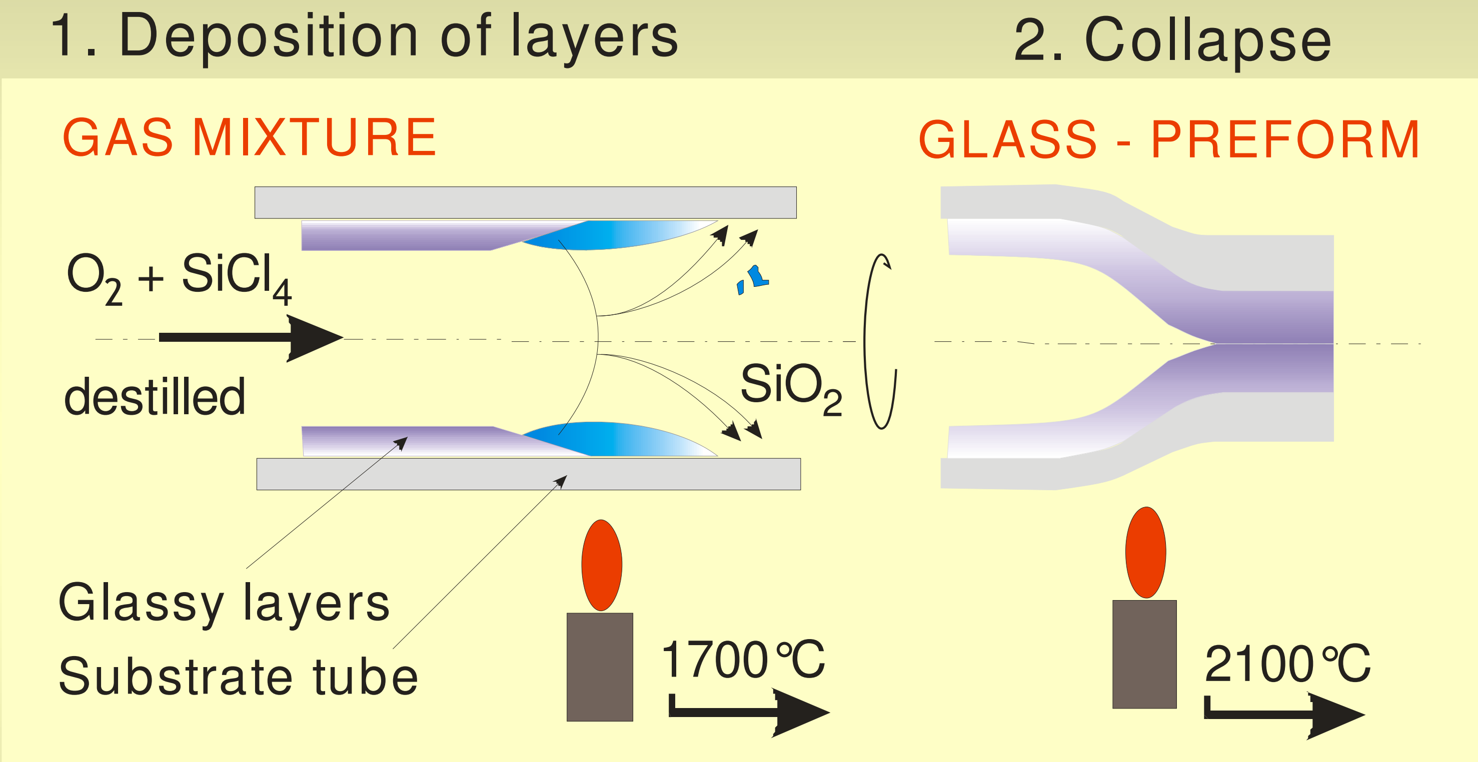
1. Preform

2. Fiber drawing



Preform preparation : CVD-based

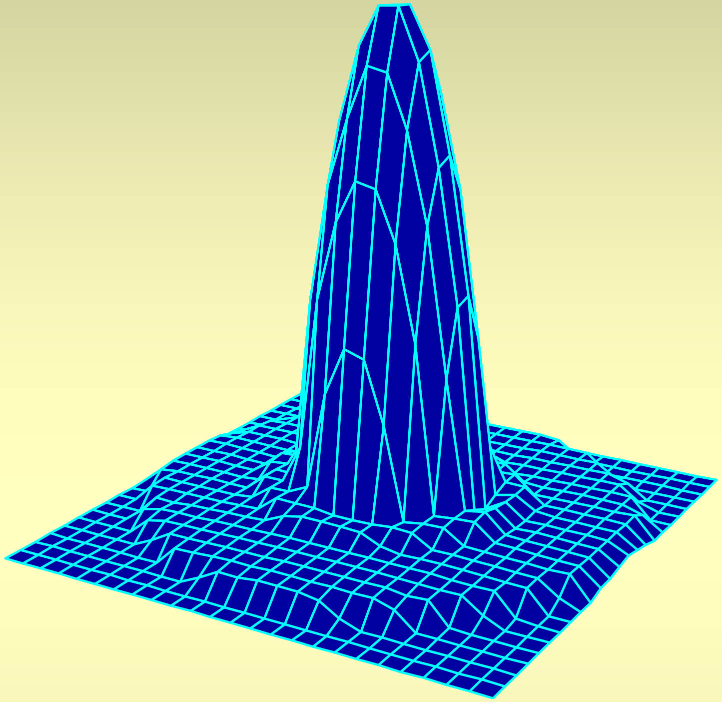
MCVD – (Modified) Chemical Vapor Deposition



- 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

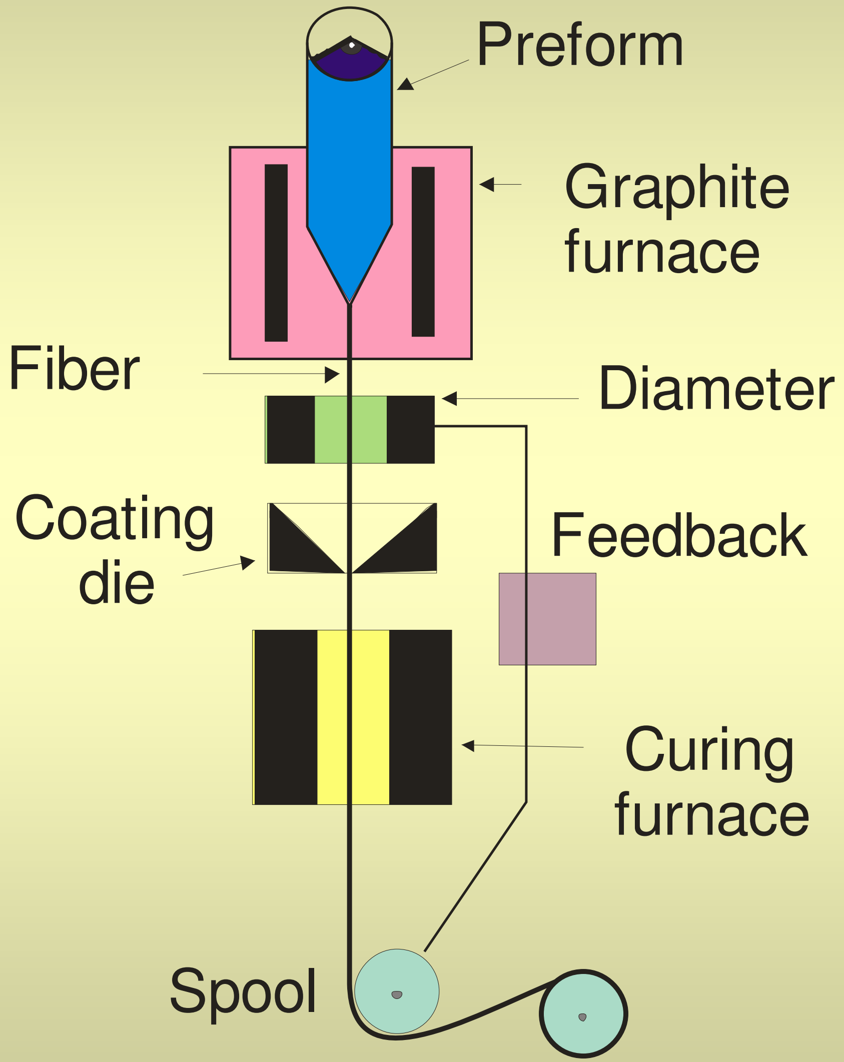
Microphoto of cross section of produced preform



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.

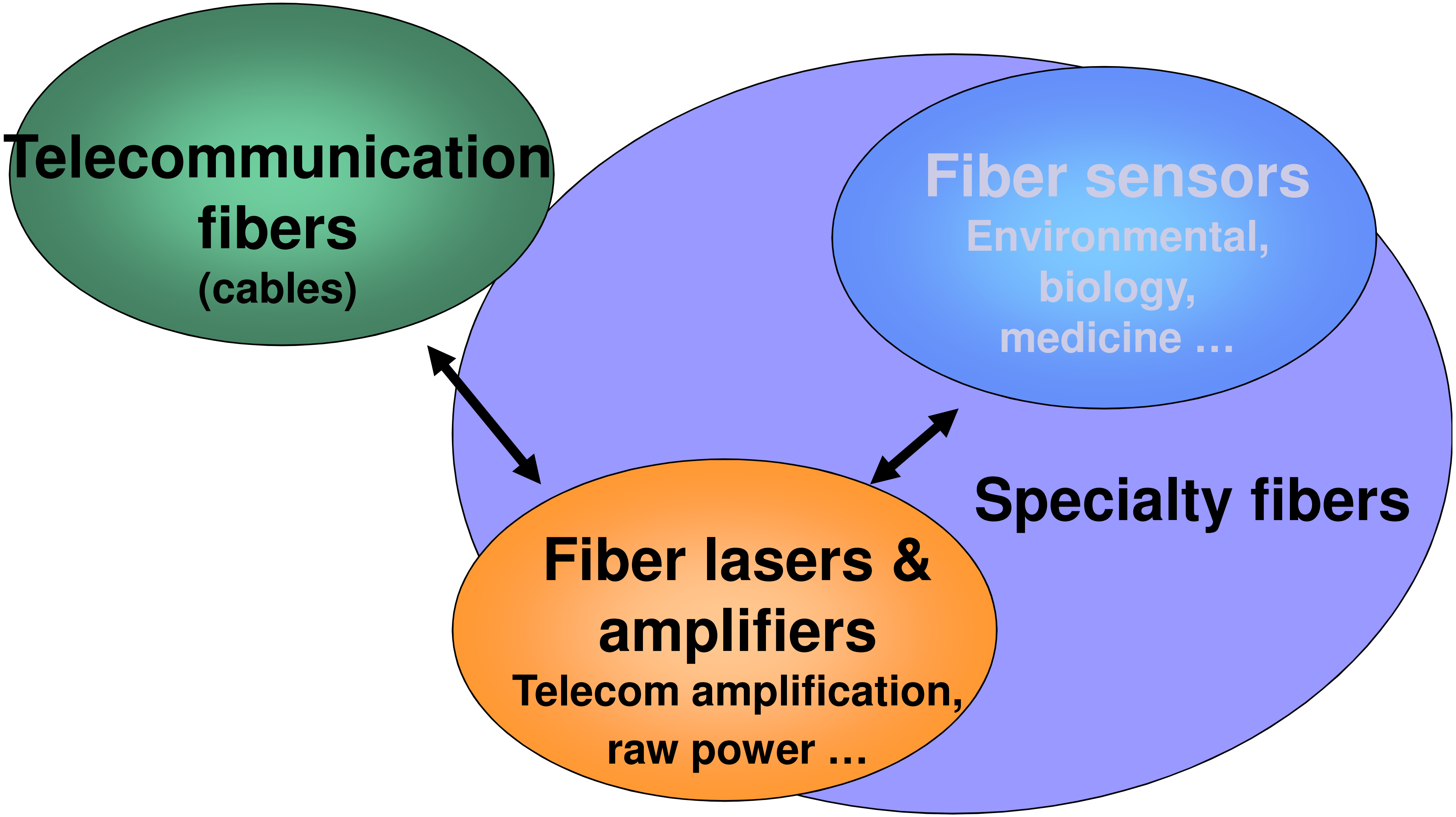
Drawing of optical fiber from preforms



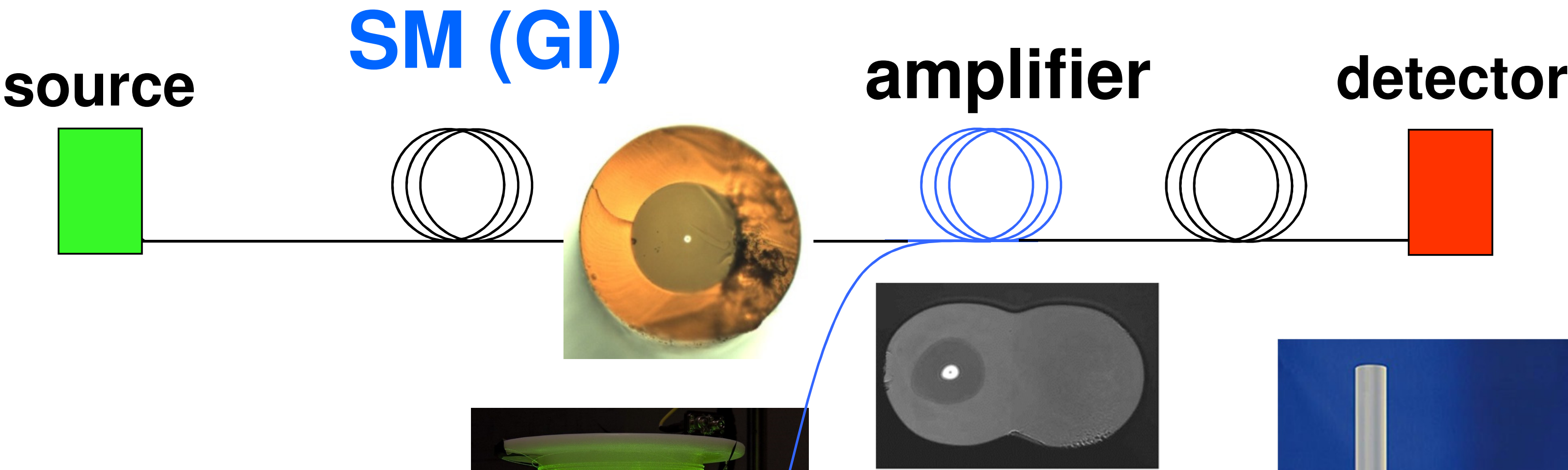
- Diameter
  80-1000 µm
- Temperature
  1800-2100℃

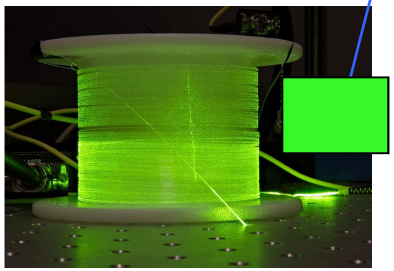
- No textile
- No thermo-insulation

Application



Optical fibers for communications
passive

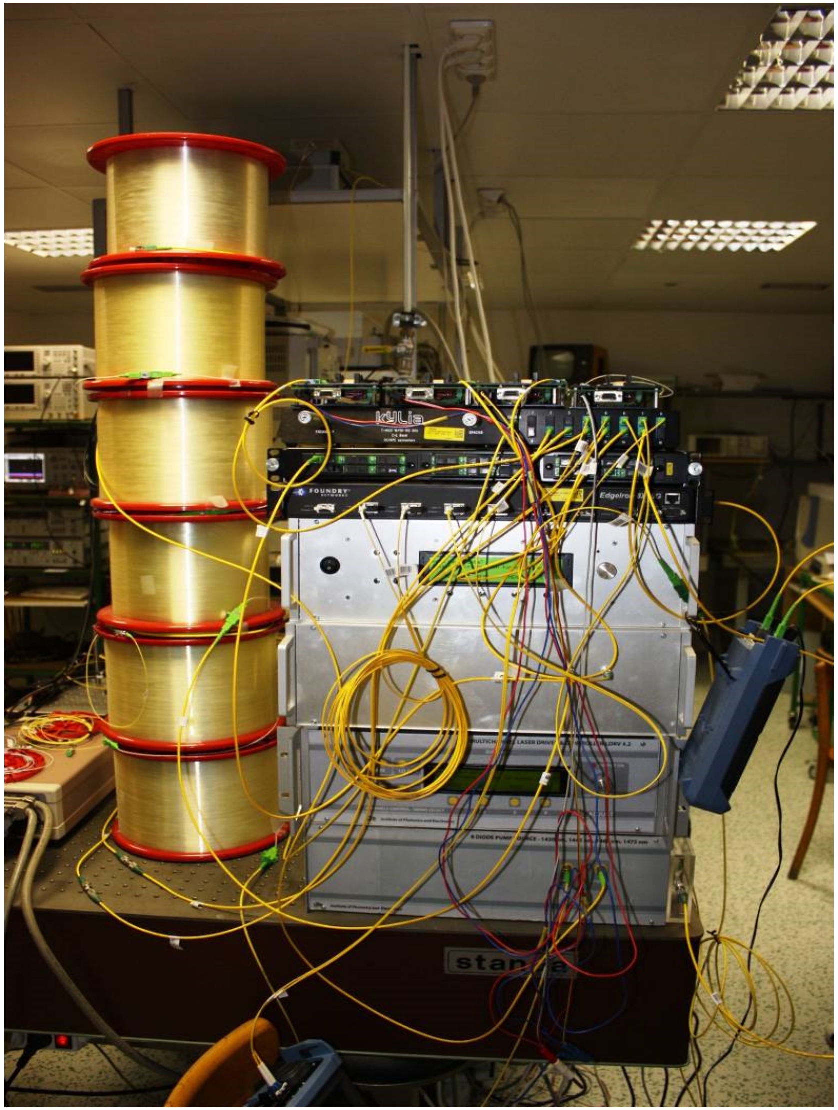


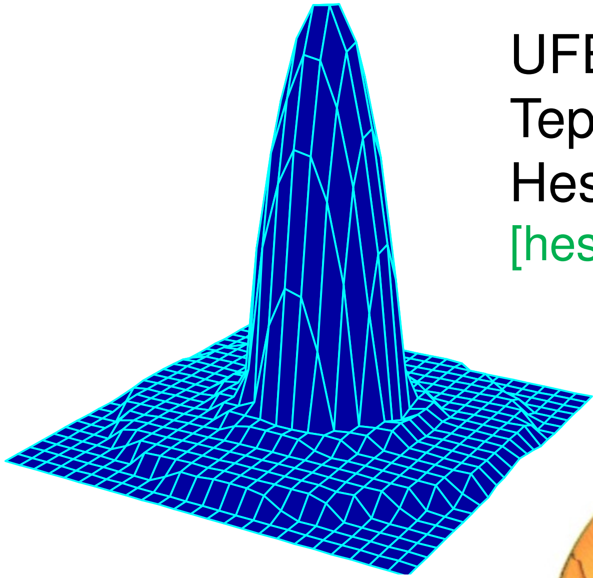


Requirements:

- Low attenuation, low dispersion
- Durability (temperature, pressure, EM field...)
- Low price (<< 1 USD/m)

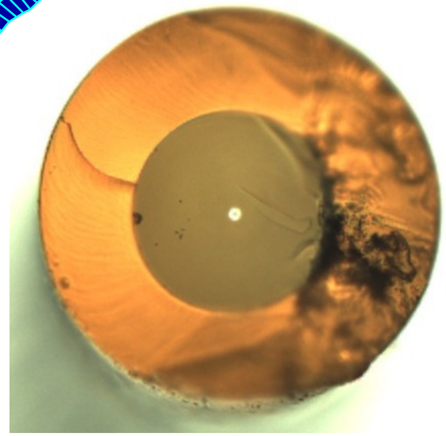
Telecommunications





GI - multimode

UFE Prague =>
Teplice, CR =>
Hesfibel, TR
[hesfibel.com.tr]



SM - singlemode

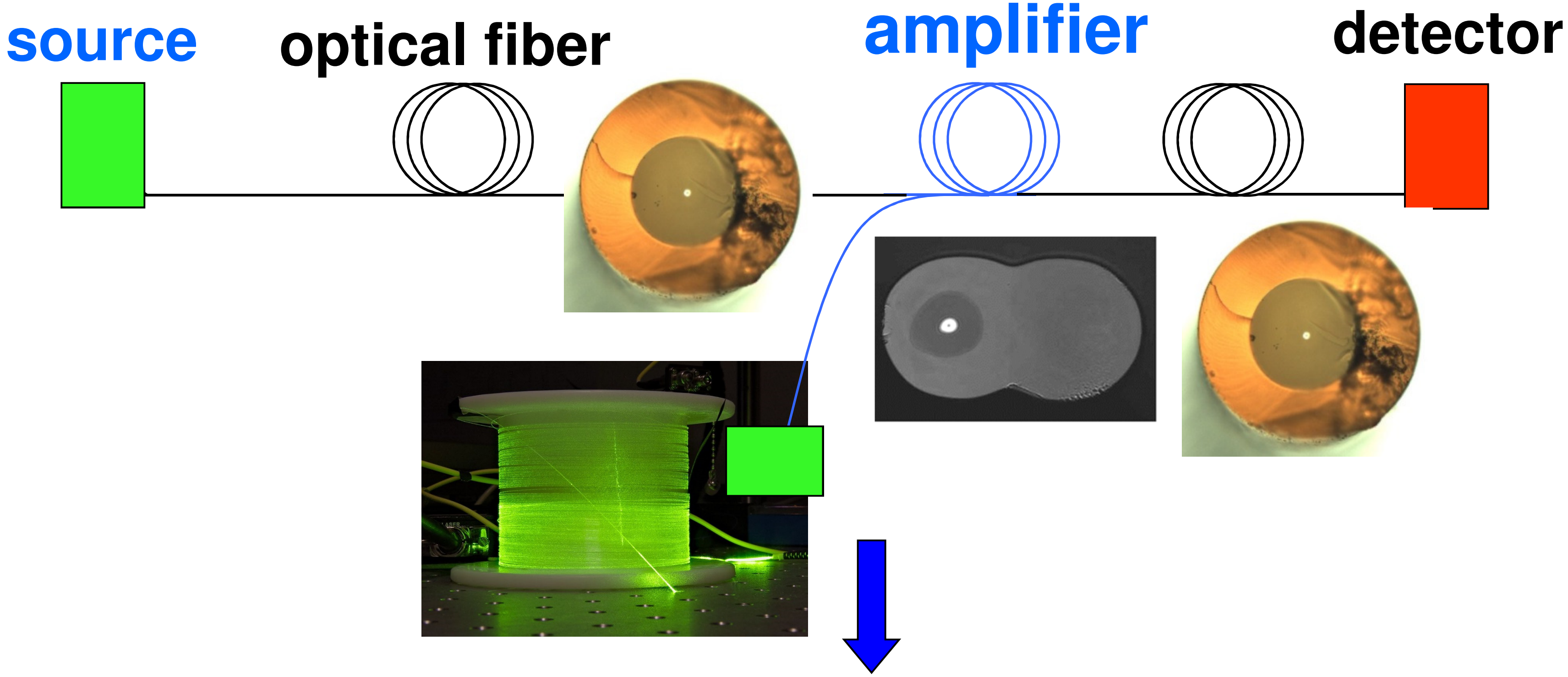
200 km telecom line - test

Telecommunications

Internet connection : 8.1 MB/s (7)
Fix line: EU 95% towns, 82 % countryside
CR 97% towns, 90 % countryside
FTTx 210 000 users in CR = 7%
Strategy: each municipality <200 inhabitants optical connection

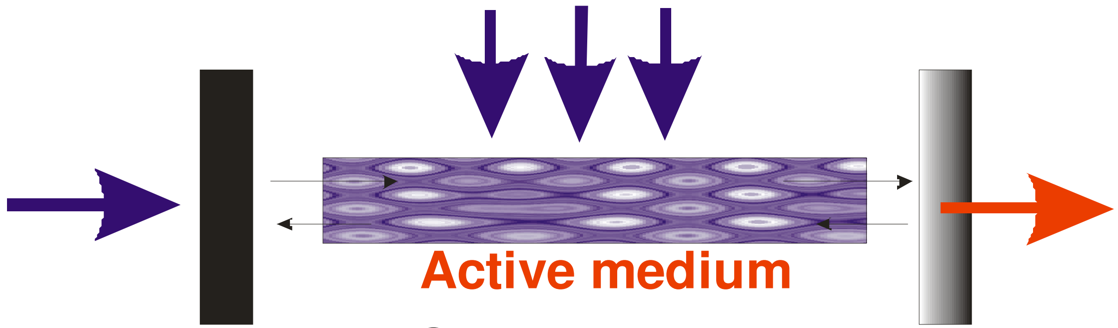
[Vodrazka, NoTeS, 2013]

Specialty optical fibers for communications
Fiber lasers and amplifiers



Fiber amplifier, fiber laser

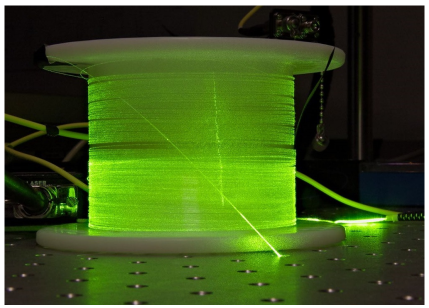
Silica specialty optical fibers for fiber lasers and amplifiers



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

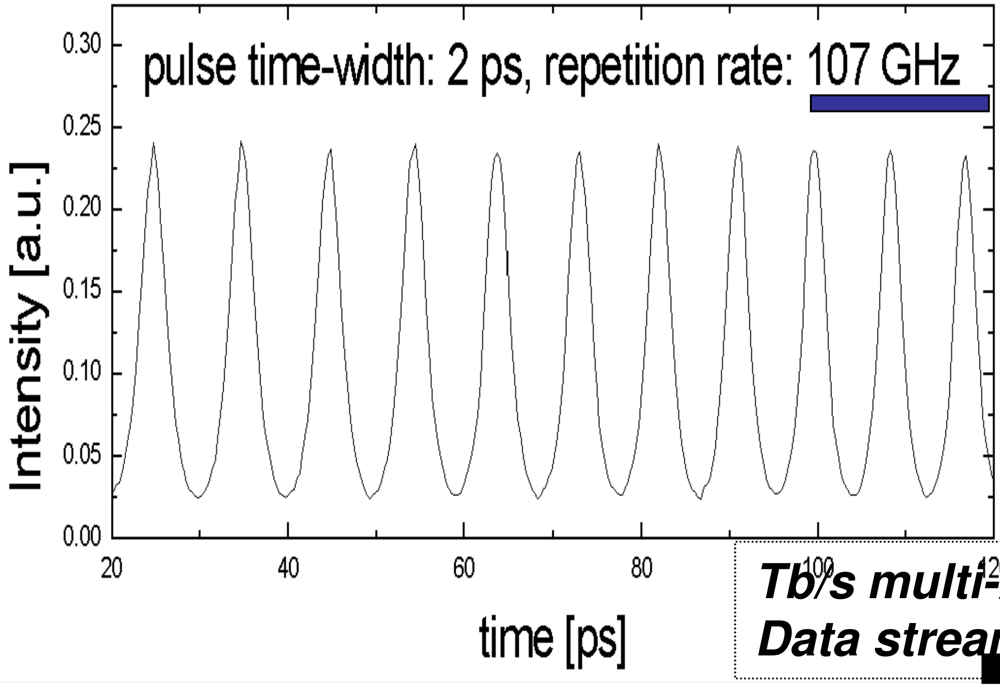
* high conversion efficiency (fiber lasers ~70-90%) - savings
* high quality beam (nearly Gaussian, low divergency)
* **high brightness** (high concentration of power)
* good thermal management (cooling)
* effective pumping
* tunability
* compactness
* size (long resonator in small space)

[IPG]

TDM mW WDM

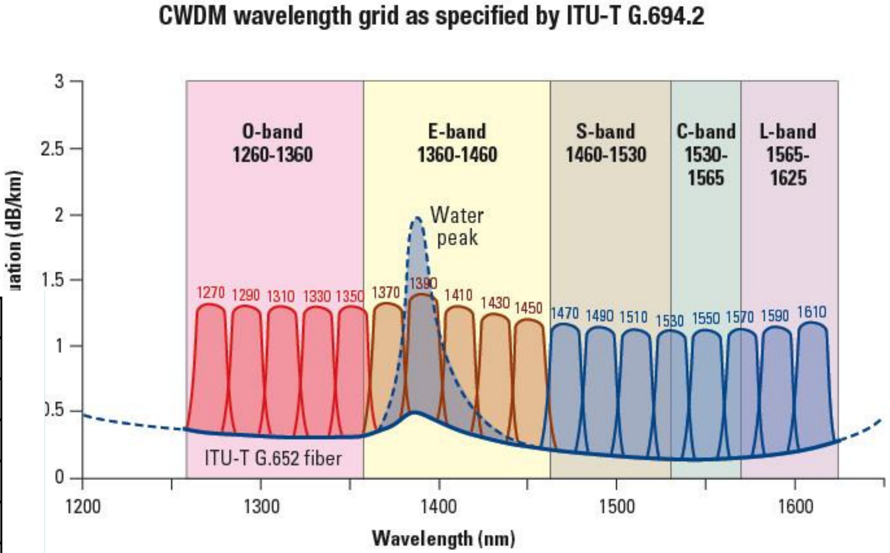
Time Division Multiplexing (TDM)

Q-switched FL

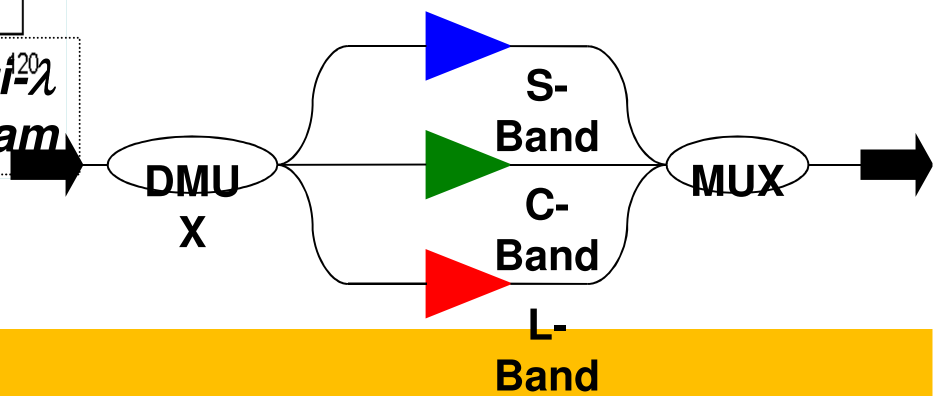


Tb/s multi-λ Data stream

[I.Kasik, J.Kanka, Pure&Appl.Opt.,1997]

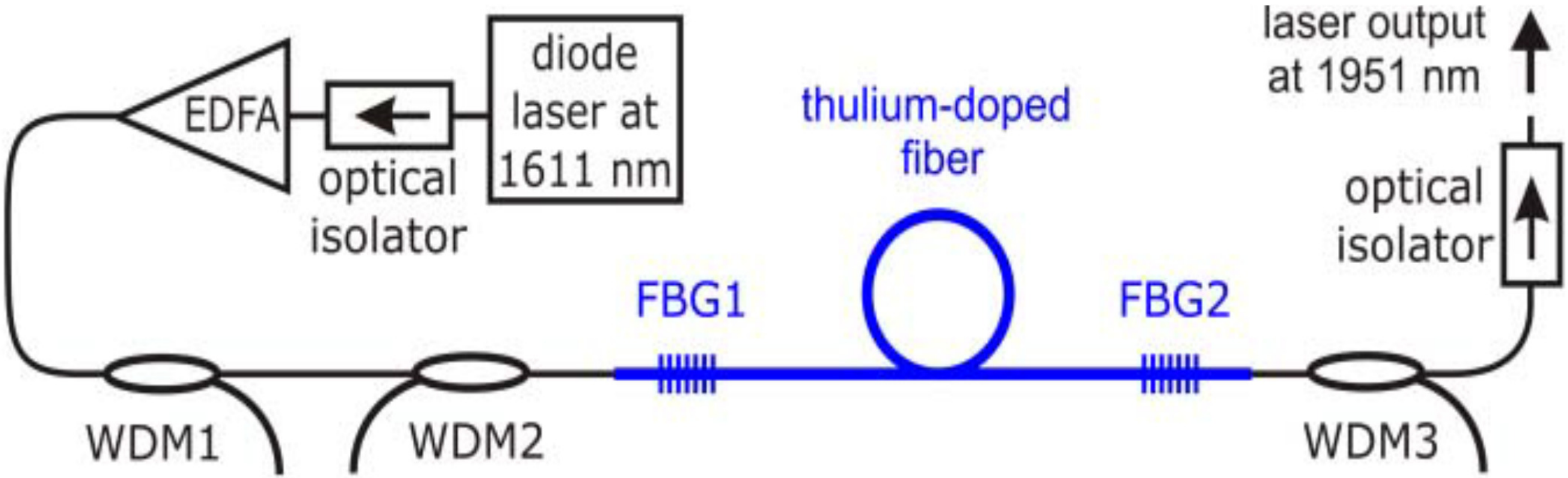


Wavelength Division Multiplexing (WDM)



Monolitic Tm fiber laser at 1951 nm

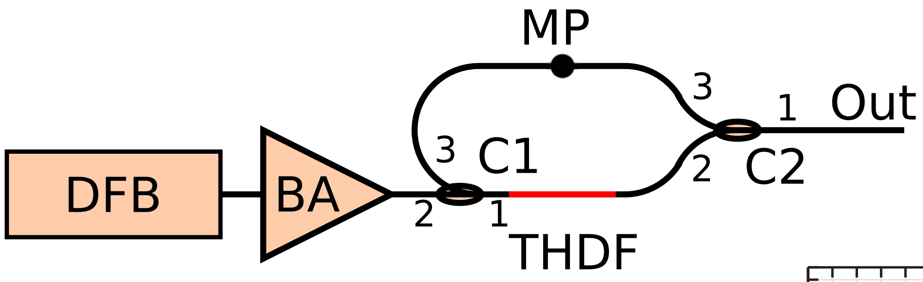
Eye-safe spectral region

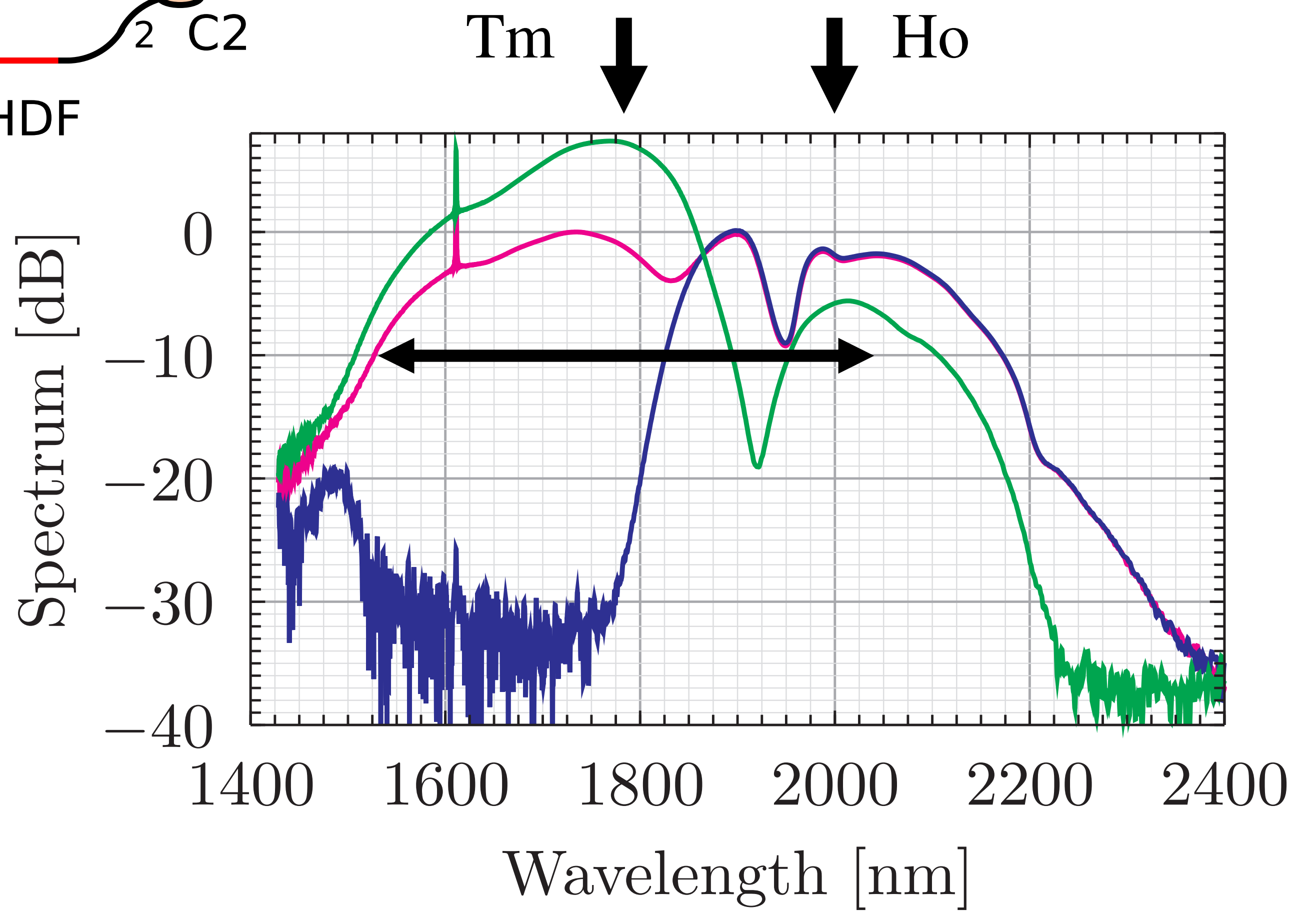


* 1000 ppm Tm^{3+}, 11mol% Al_2O_3, 0 mol% P_2O_5 or GeO_2,
* **deep-UV inscription of FBG**

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

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

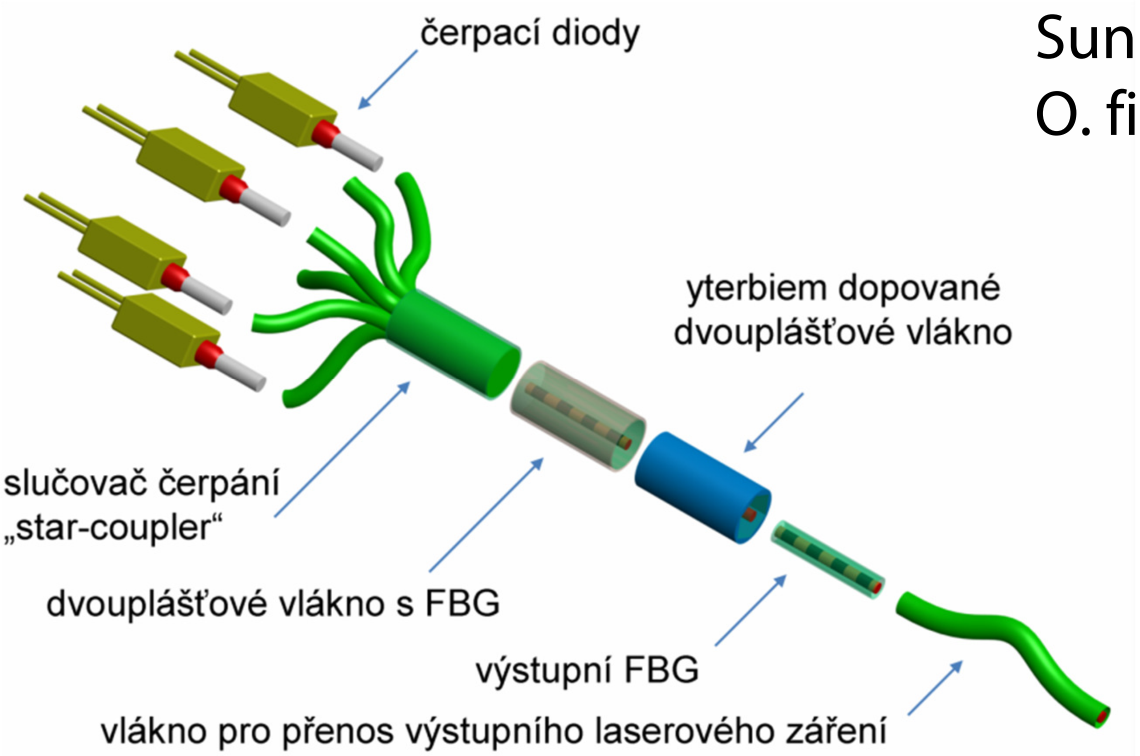




1800 ppm Tm^{3+} /
360 ppm Ho^{3+}

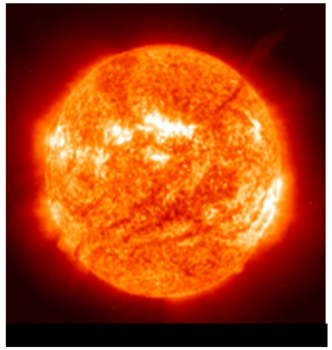
[P.Honzatko, Optics letters 39 (2014) 3650-3653]

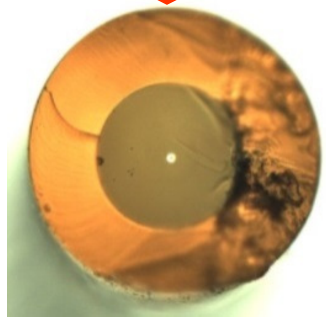
Fiber lasers mW → kW



Intenzity of light

Sun	63 MW/m2
O. fiber	12.7 GW/m2

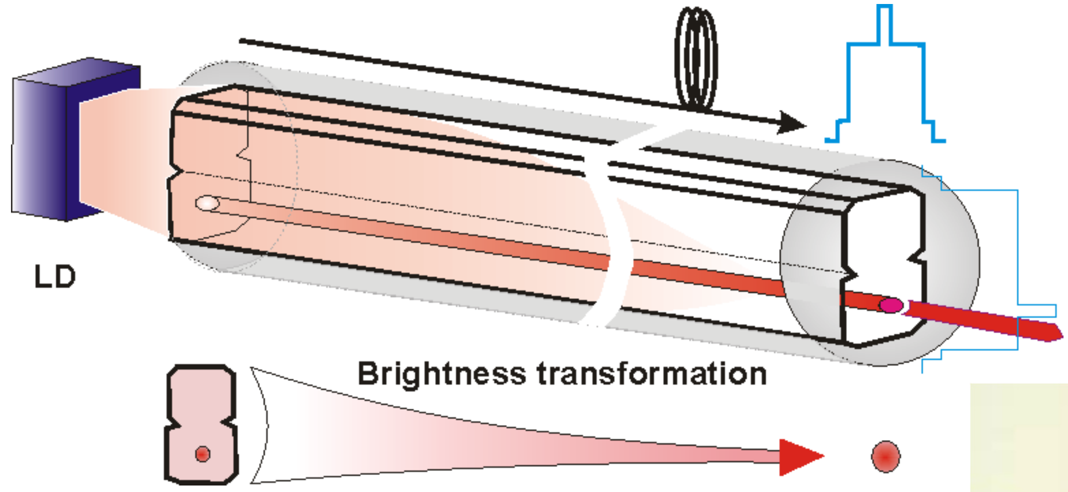




[P.Peterka, Eysafe, 2015]

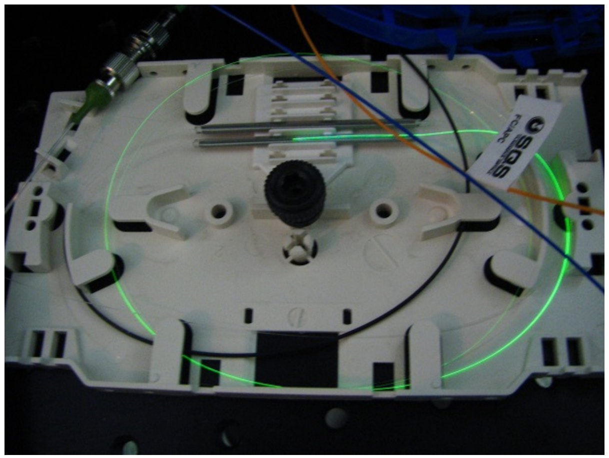
Beam combining, double-clad structures ....

Fiber lasers mW → kW

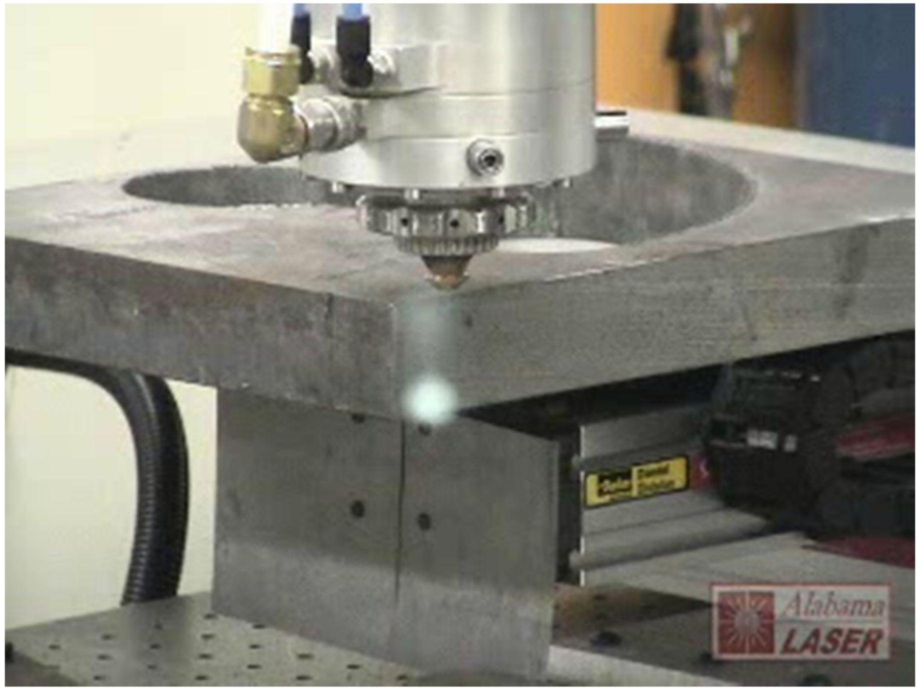


[Peterka, Kasik, CZ Pat.301215]

[IPG photonics.com]



Er/Yb - fiber laser



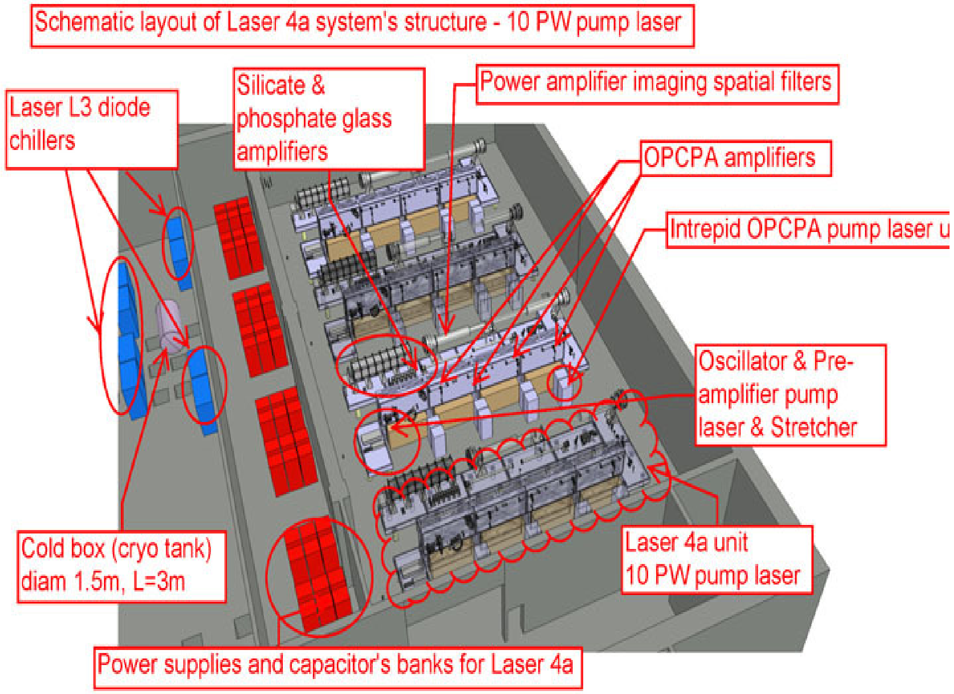
Splicing & cutting < 2kW

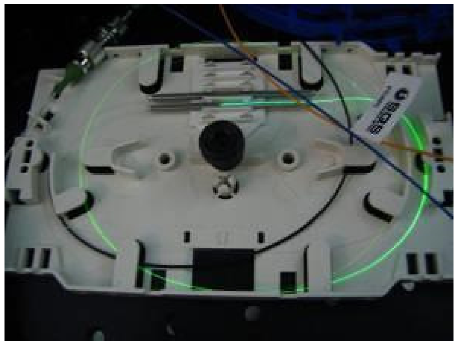
Fiber lasers vers. solid state lasers (SSL)

- **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]



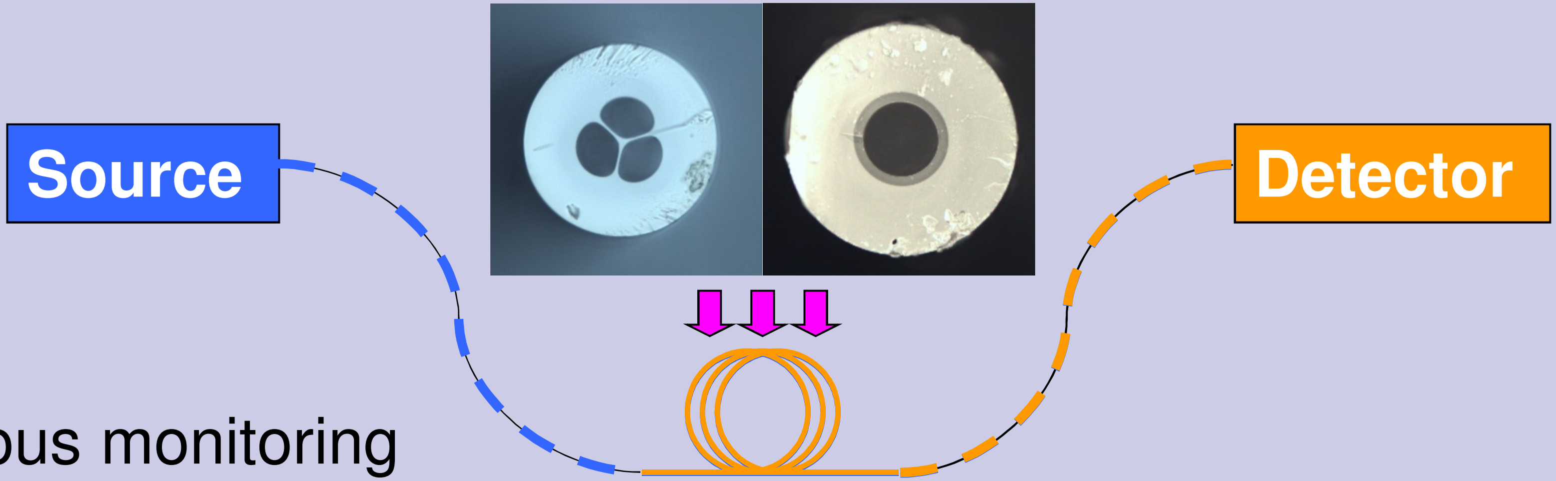


100 m

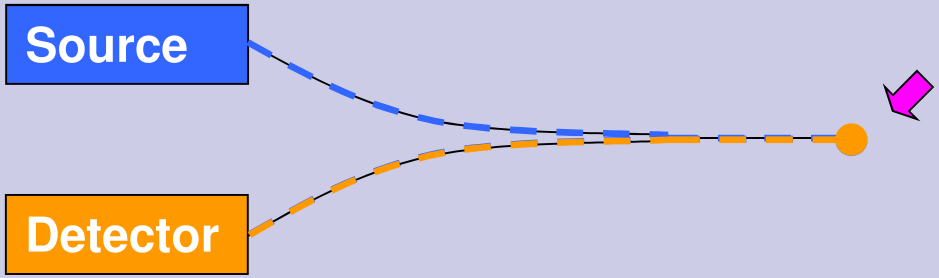
1 m

0.1 m

Optical fiber sensors



Continuous monitoring of (bio)chemicals and their concentration.



Suitable for :

remote sensing

distributed sensing

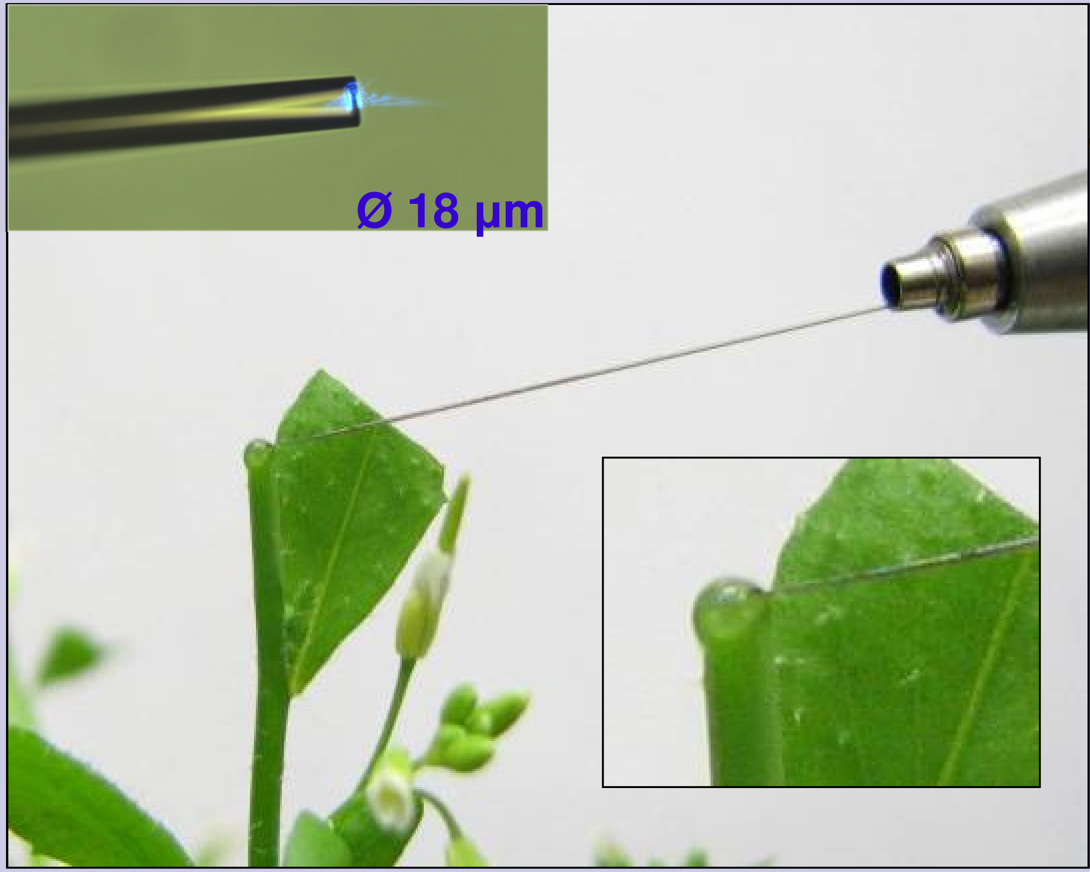
flammable or explosives

in high-voltage areas

human body

Optical fiber sensors

In vivo detection of pH in small samples ~ µL



[I.Kasik, ABC, 2010]

SUMMARY

1. Fiber technology : preparation of structures of high preciseness (<1%) 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 specialty (active). Fiber lasers competitive with Solid State Lasers (SSL).
4. Research of optical fibers & fiber lasers

ÚFE

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.
- **Saaleh,** Fotonika (1 - 4), Matfyzpres
- **J. Schrofel, K. Novotný** : Optické vlnovody, SNTL, 1986

- **S. R. Nagel, J. B. McChesney, K. L. Walker :** An overview of the MCVD process and performance, IEEE J. Quantum El. 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

Be UFE !

- **STUDY** (diploma, thesis)

  Czech Technical University

  Charles University

  Institute of Chemical Technology

- **PROJECTS** - partners CZ

- **INTERNATIONAL - collaboration**

Be carefull !

EXCURSION

1. Preform preparation (MCVD) + 2. Fiber drawing

3. Preform (fiber) characterization

Thank you for attention