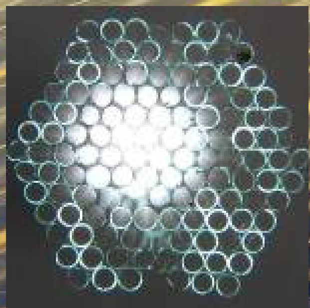
Optická vlákna

Laboratoř optických vláken

Ústav fotoniky a elektroniky, AVČR, v.v.i.

www.ufe.cz/dpt240; www.ufe.cz/~kasik

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

Prof. Jiří Homola
Česká hlava 2009

ZÁKLADNÍ VÝZKUM:

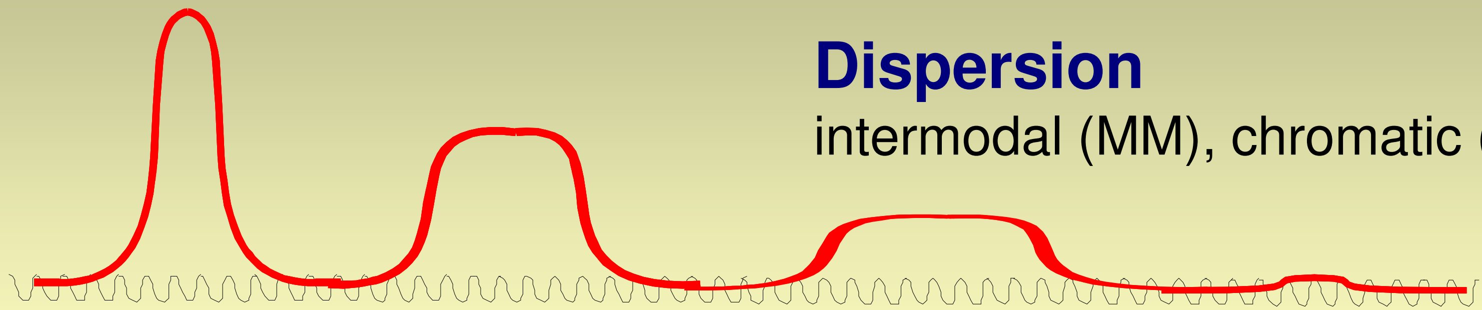
fotonika - optická vlákna
- vláknové lasery a zesilovače
- optické biosenzory

státní etalon času, detekce pole živých buněk

Outline

1. Intro
2. Technology
3. Application
   - Telecommunications
   - Fiber lasers, amplifiers
   - Fiber sensors
4. Optical fibres – materials and structures
5. Summary

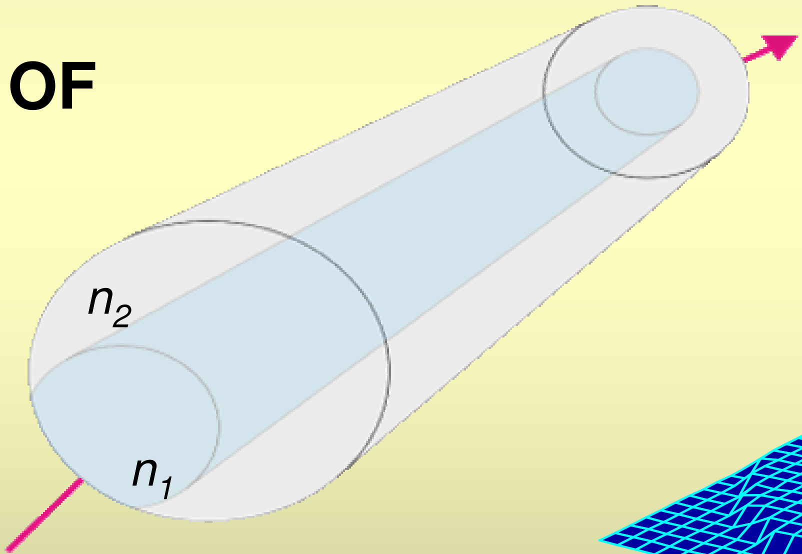
Fibers, properties – dispersion, structure



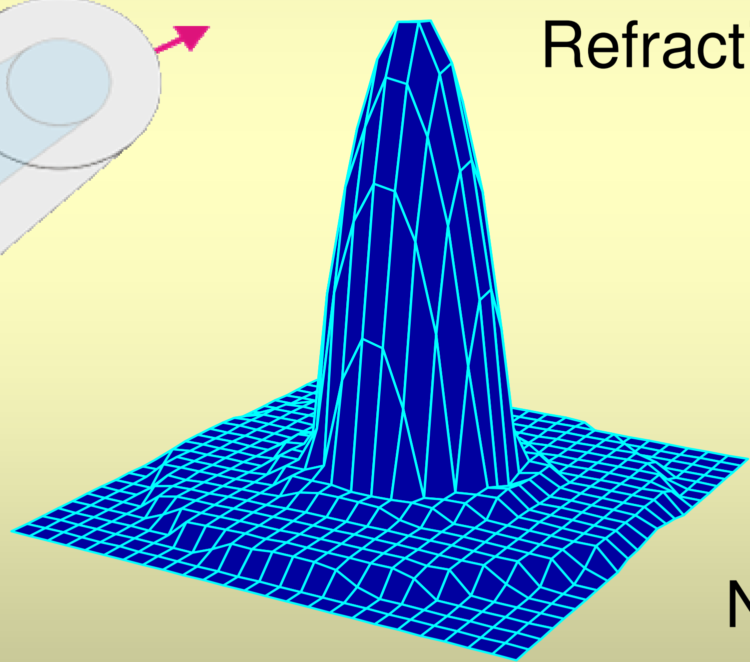
Dispersion

intermodal (MM), chromatic (SM)

OF



$n_1 > n_2$

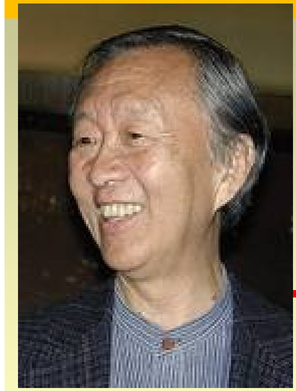


Refractive-index profile

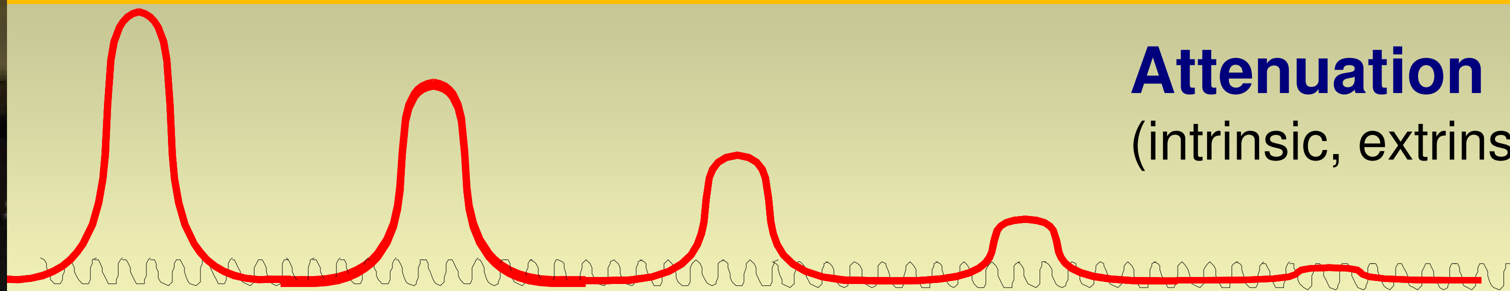
NA_{SM} (0.1-0.25)

NA_{MM} (0.2-0.5)

Optical properties and material purity

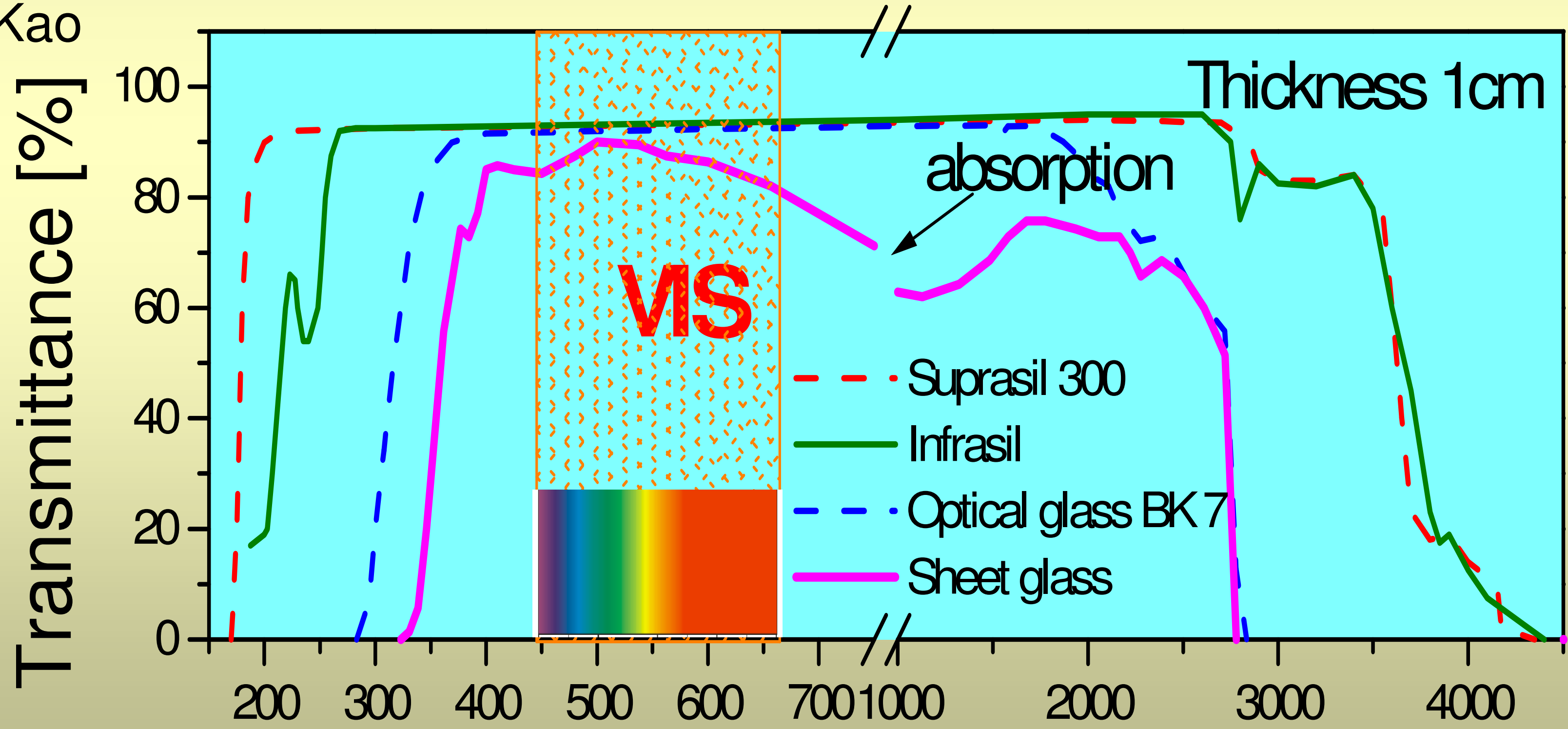


Ch. Kao



Attenuation

(intrinsic, extrinsic)



Material purity

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)

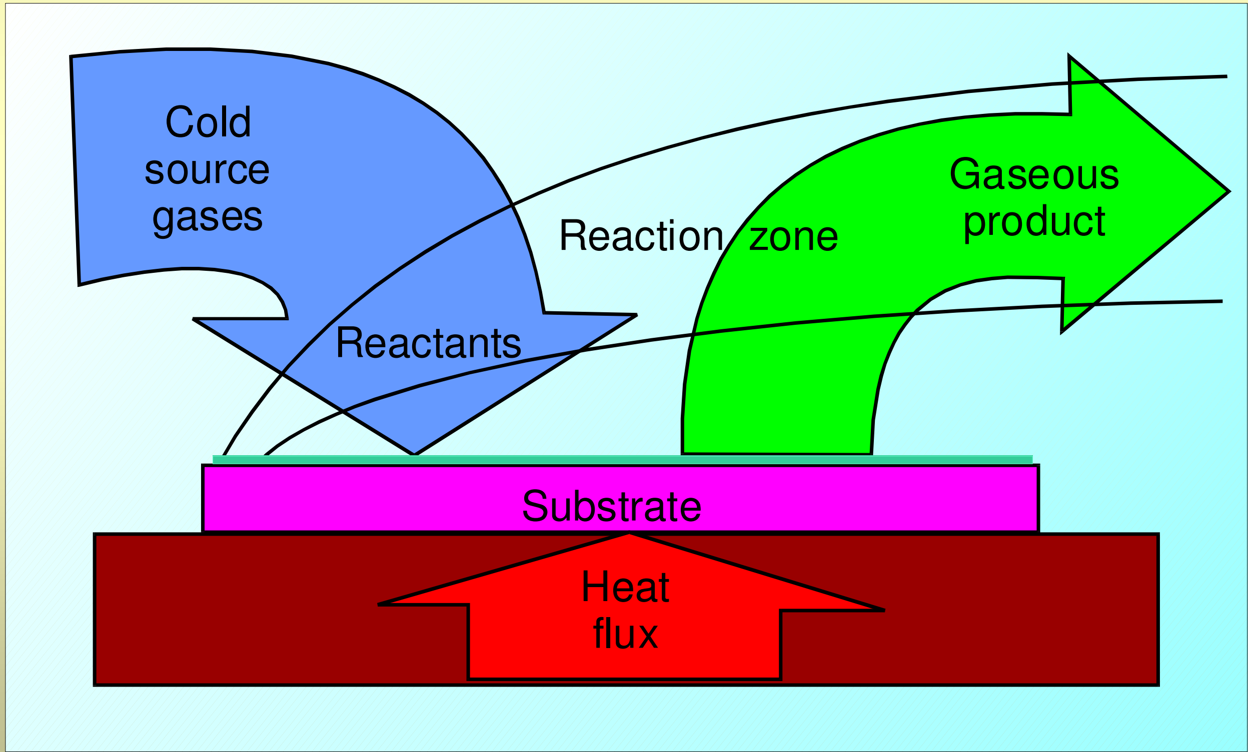
ppb – 10^{-9} (parts per billion) : content of impurities acceptable in FO Optipur materials

Ultra-pure technologies - CVD !

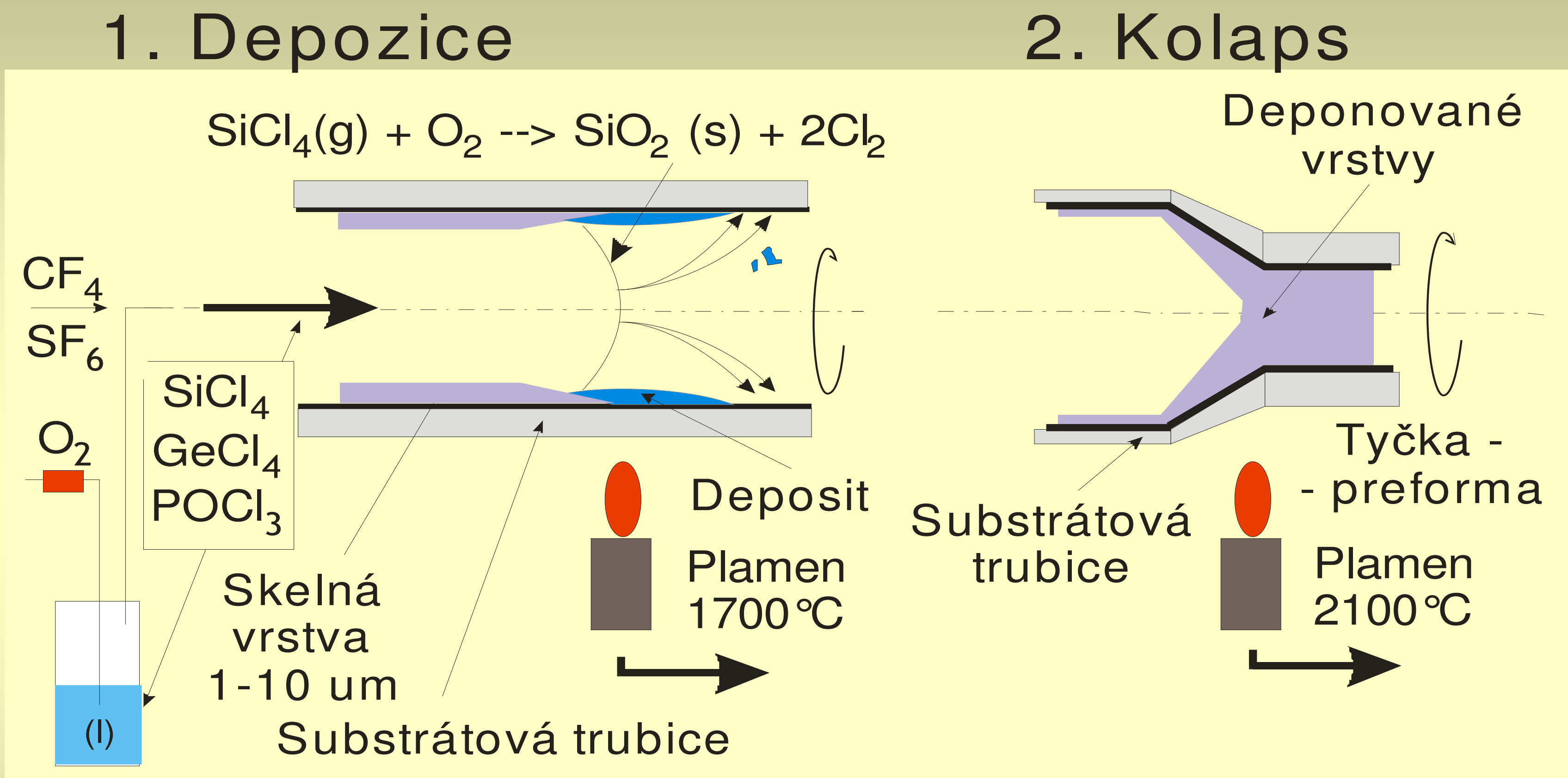
TECHNOLOGY
CVD - Chemical Vapor Deposition

= production and deposition of material in solid state from starting materials in gaseous state through a chemical reaction :

A (g) + B(g) = AB (s) [after M. L. Hitchman, 1980, E. Erdos, 1983]



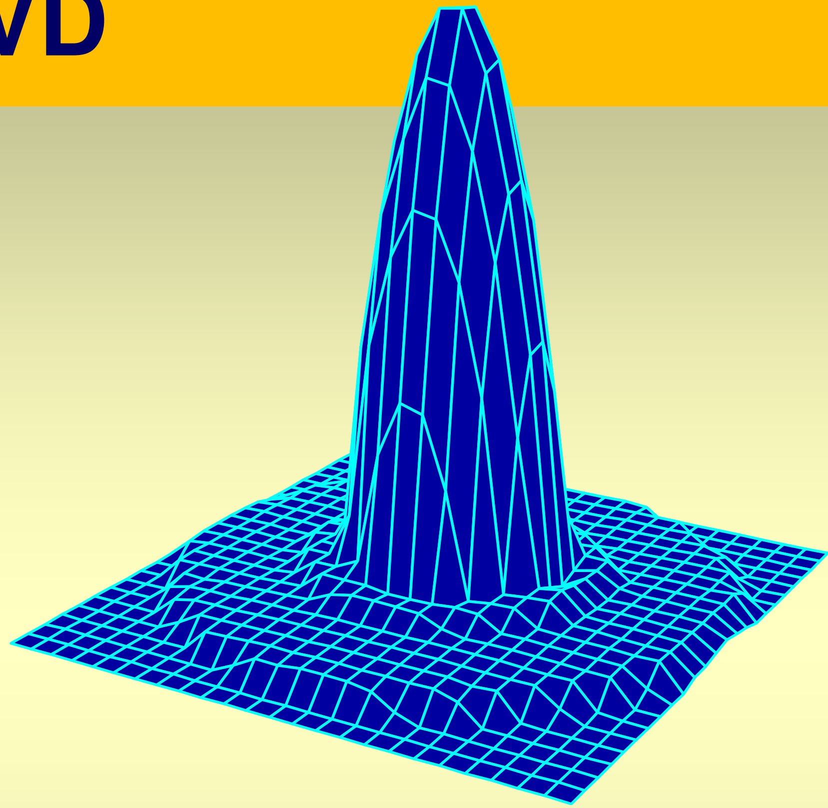
MCVD – Chemical Vapor Deposition



- 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 %)

MCVD

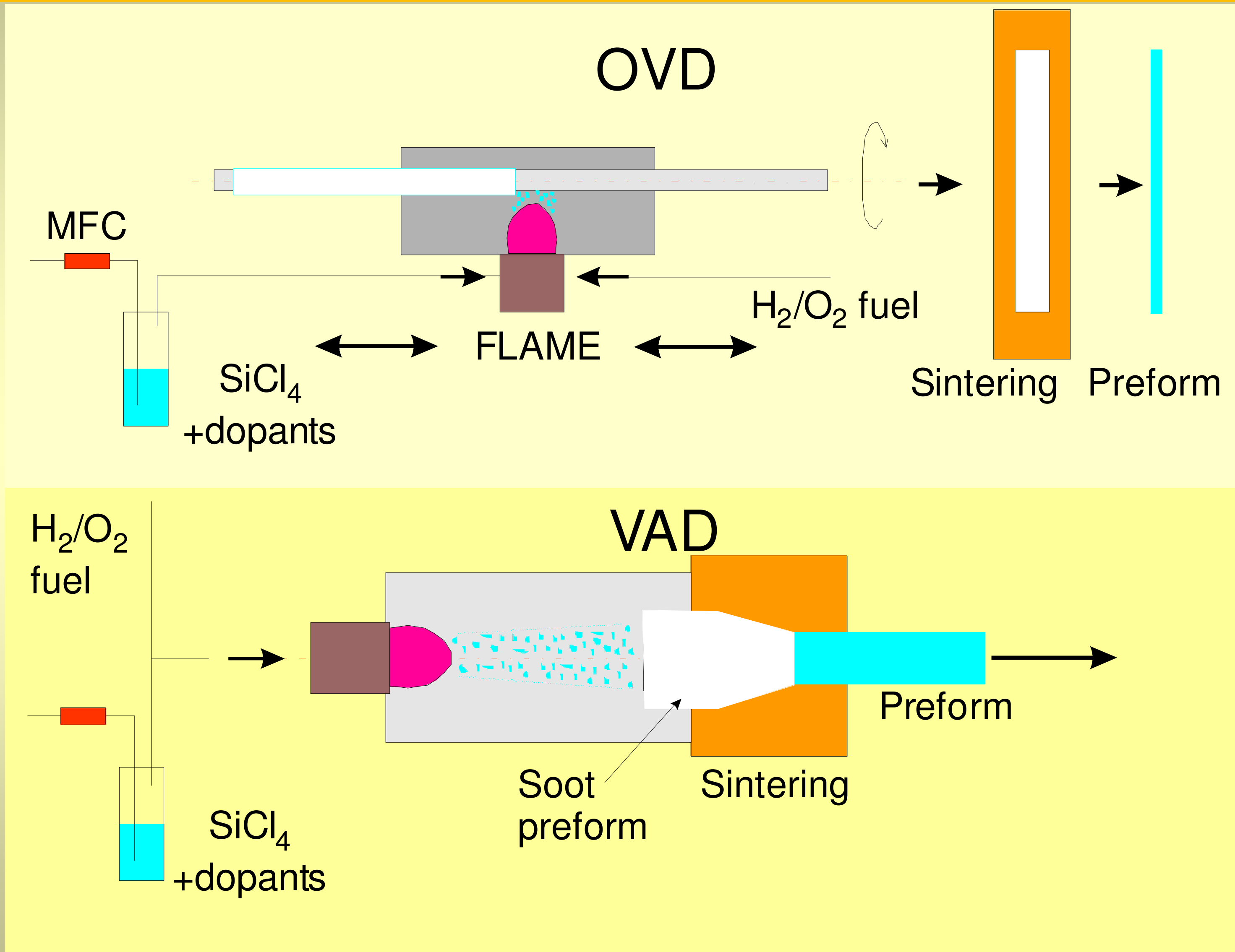
Microphoto of cross section of produced preform



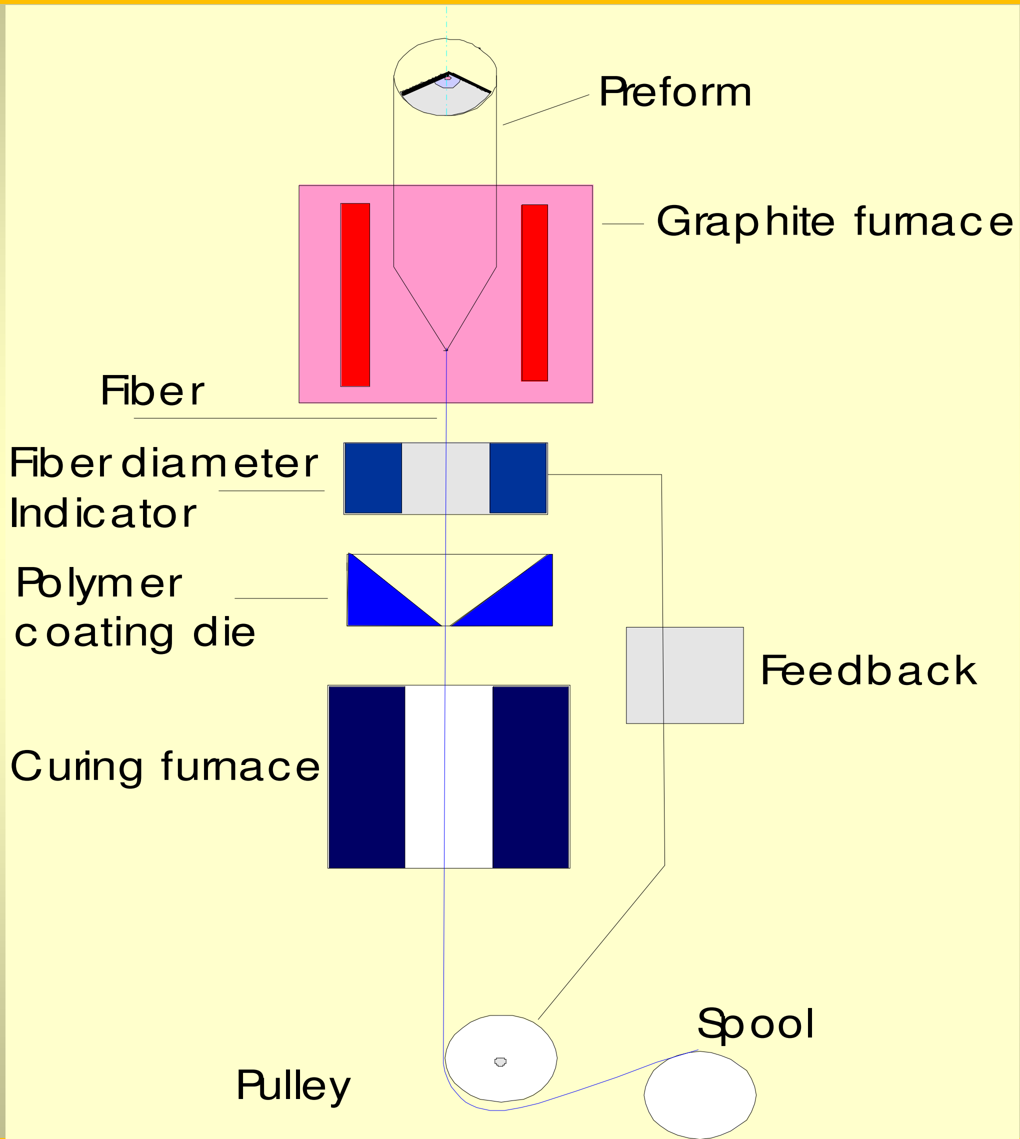
Tomography of the refractive-index profile of preform

- 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

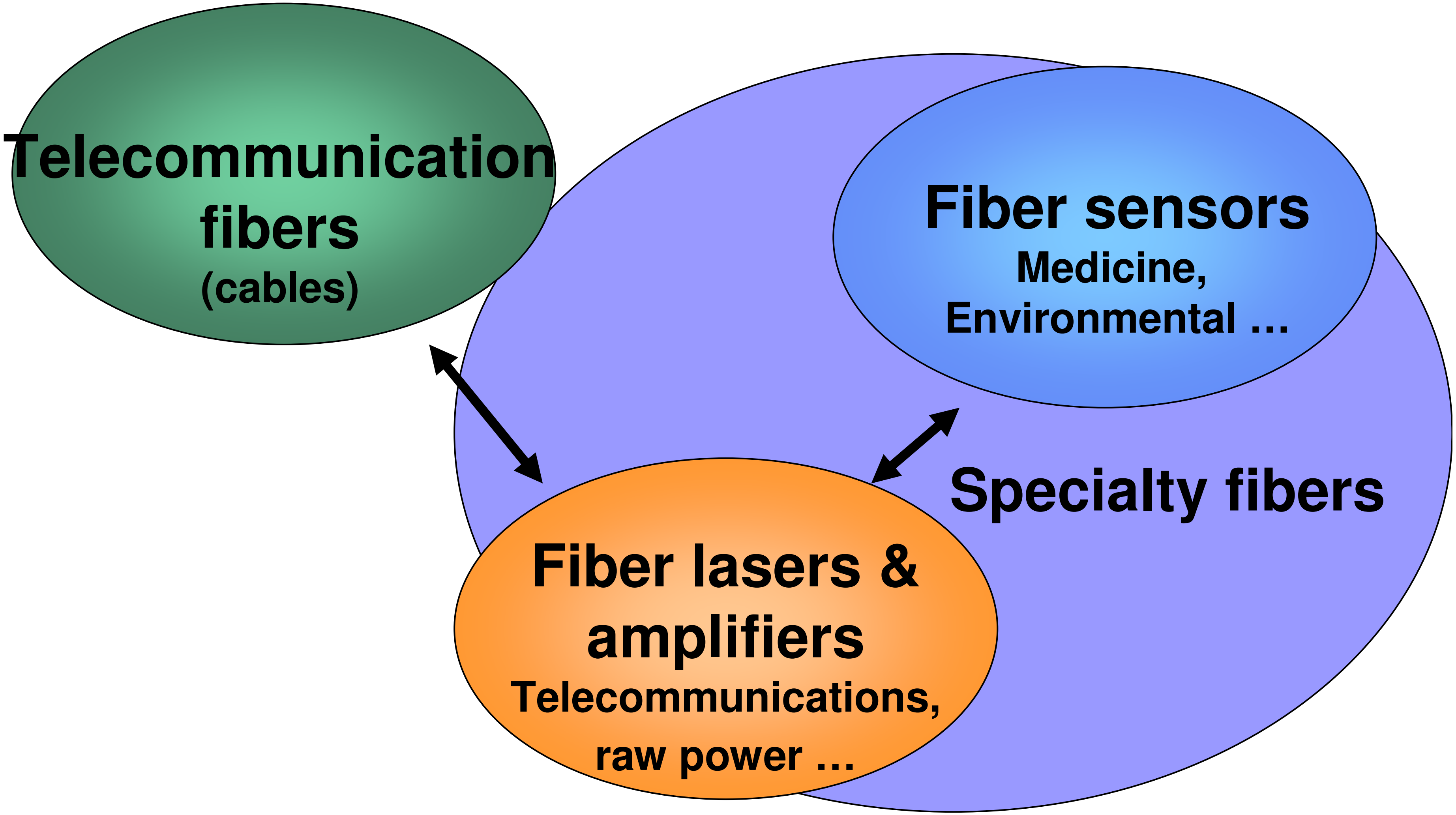


Drawing of Optical Fibers



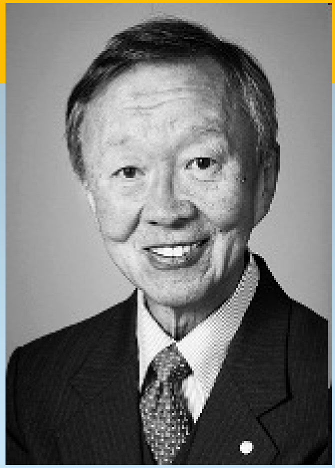
- diameter
  80-1000 µm
- temperature
  1800-2000 °C

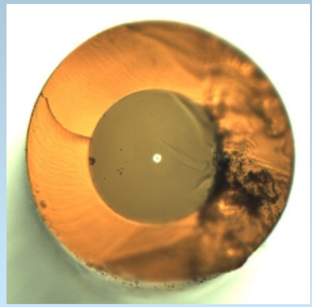
Application

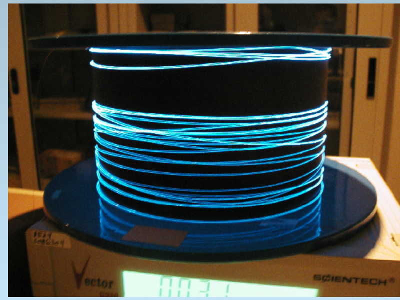


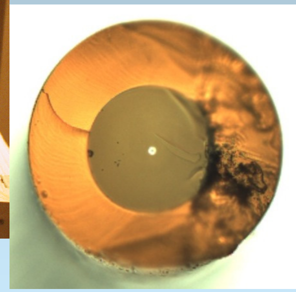
Telecommunications

Kao
1966



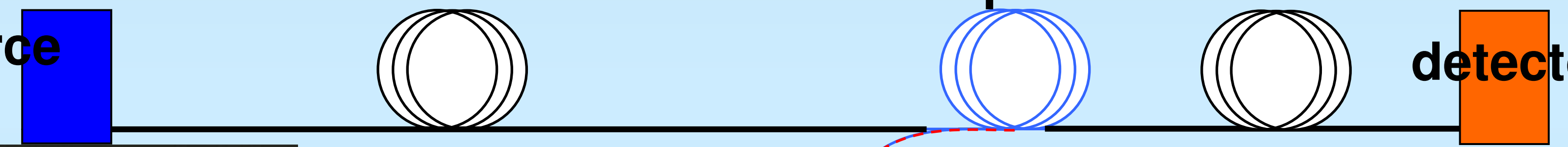


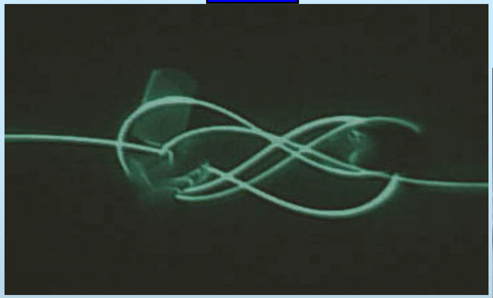


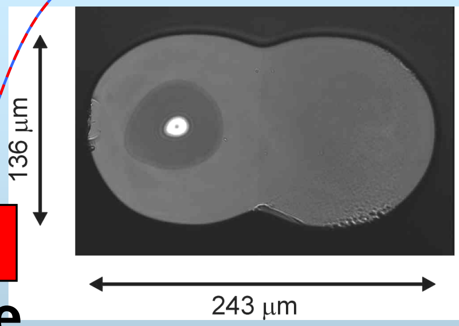


100 km fiber

Fiber
amplifier

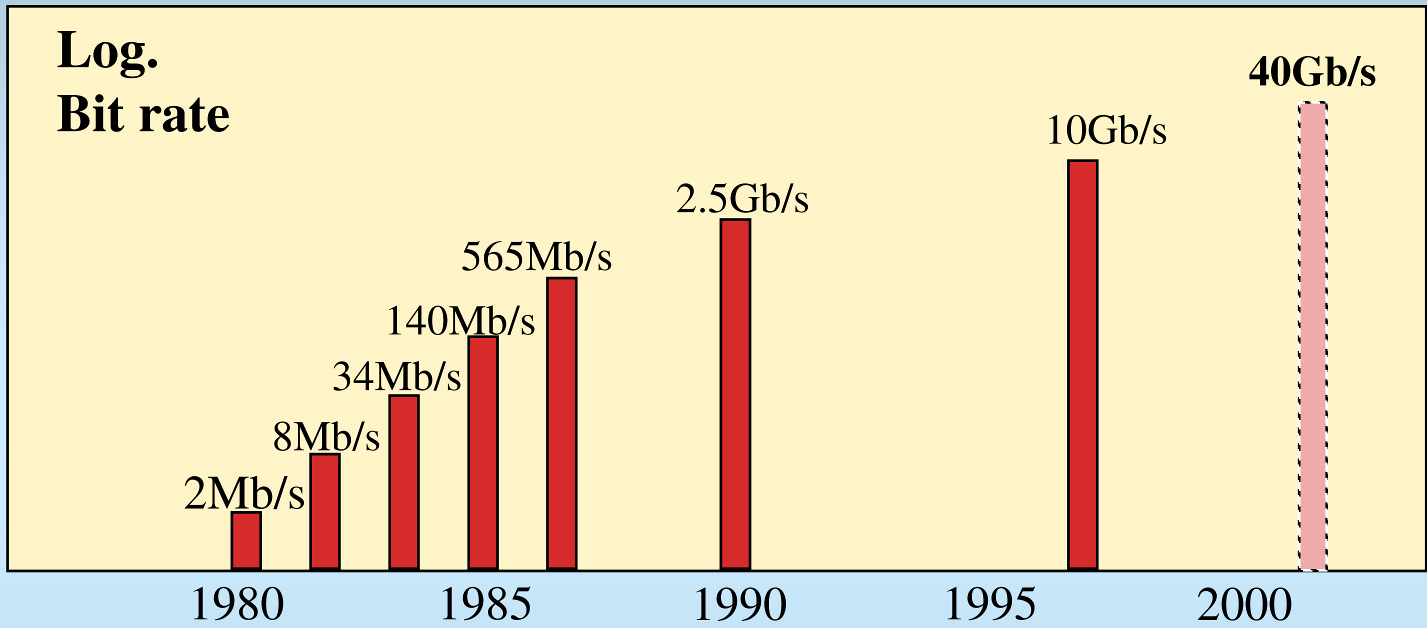






Maiman
1960

Communications : increasing requirements on speed and ammount of information



Information Society - IST - Priority of 7 FP

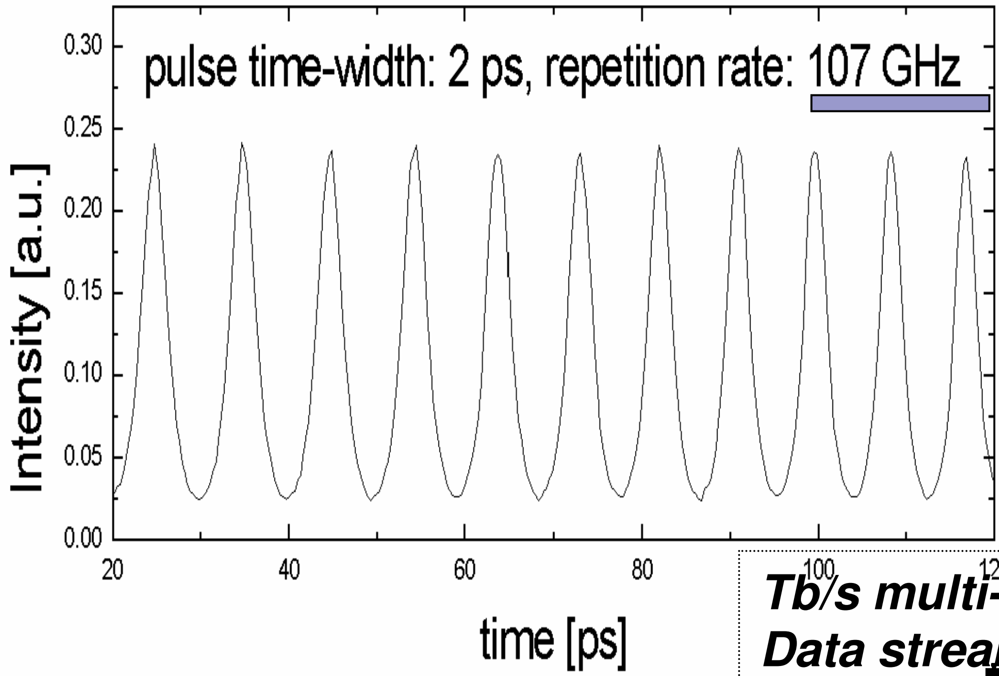
Solution : multiplexing

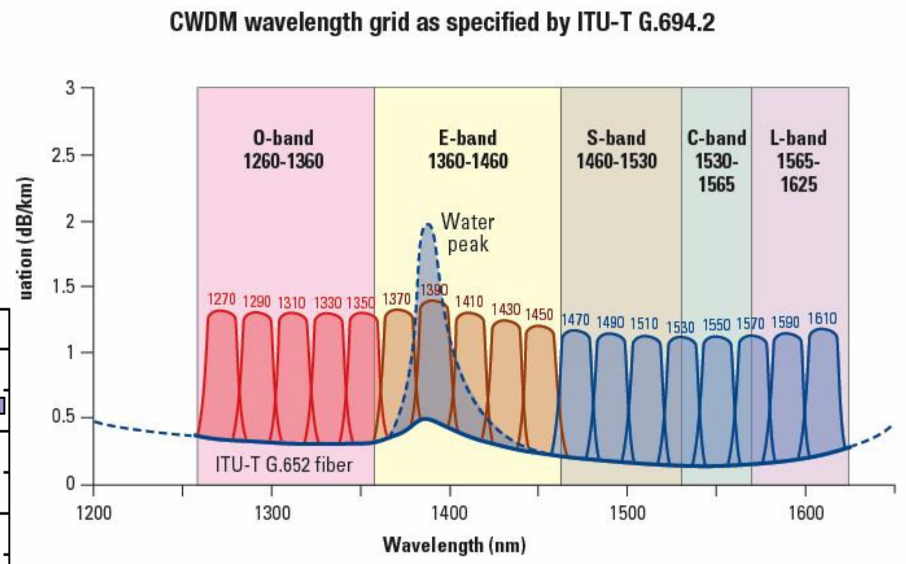
Time domain (TDM) **Spectral domain (WDM)**

TDM

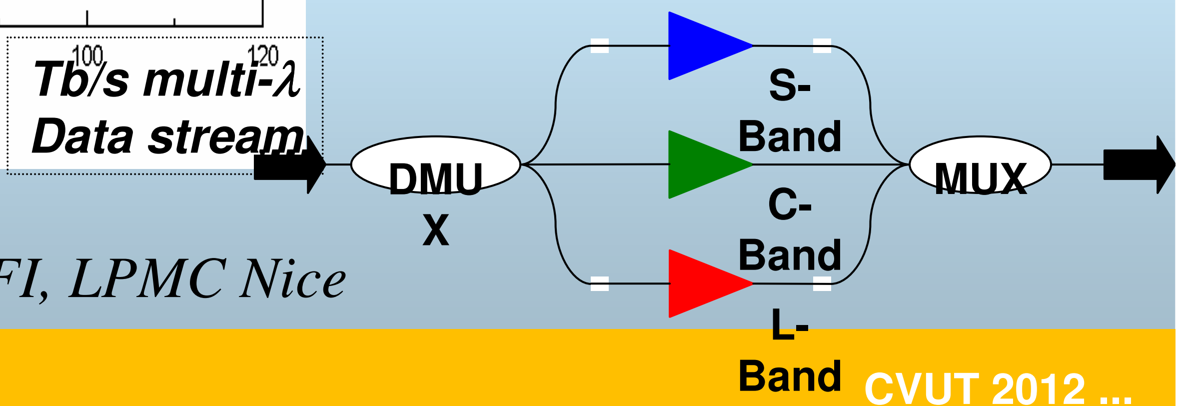
WDM

Time Division Multiplexing (TDM)





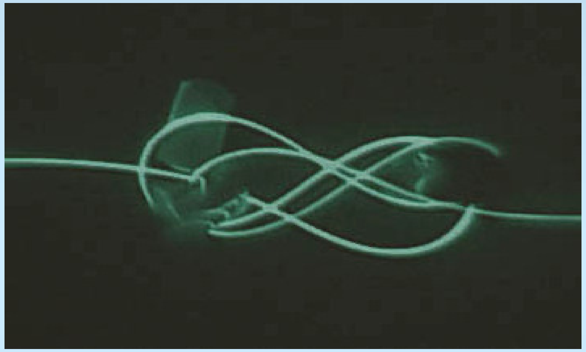
Wavelength Division Multiplexing (WDM)



In collaboration with CTU-FJFI, LPMC Nice

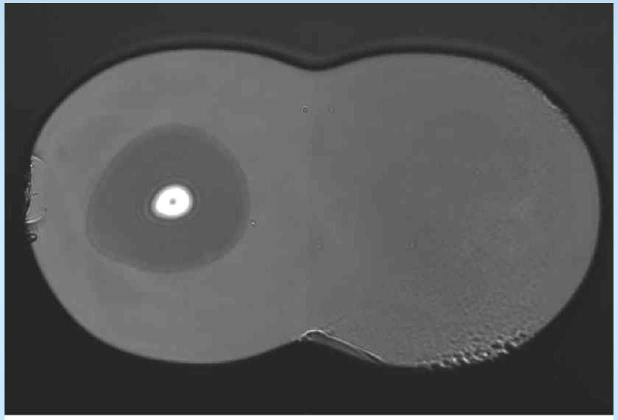
SPECIAL OPTICAL FIBERS
for fiber lasers, amlifiers

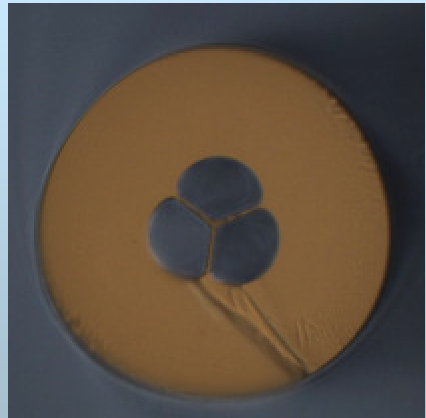
Doped fibers



Yb/Er, Tm

Components

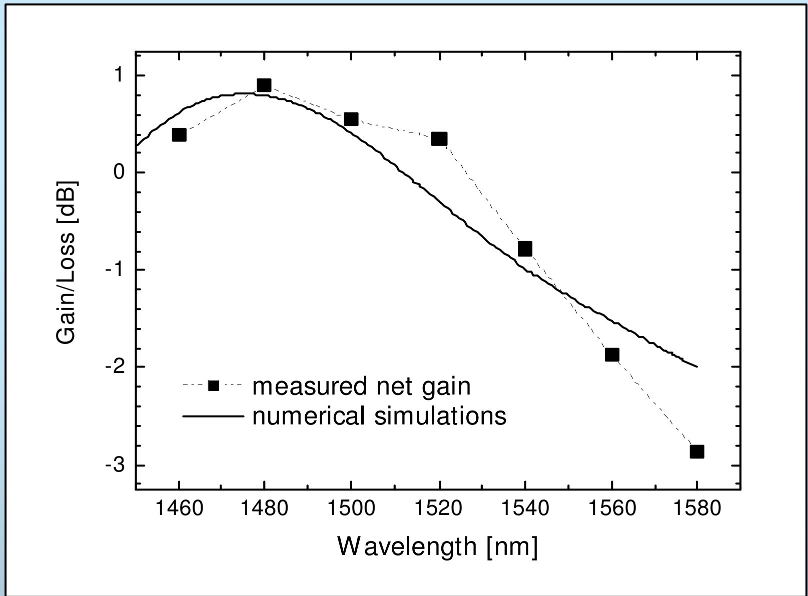


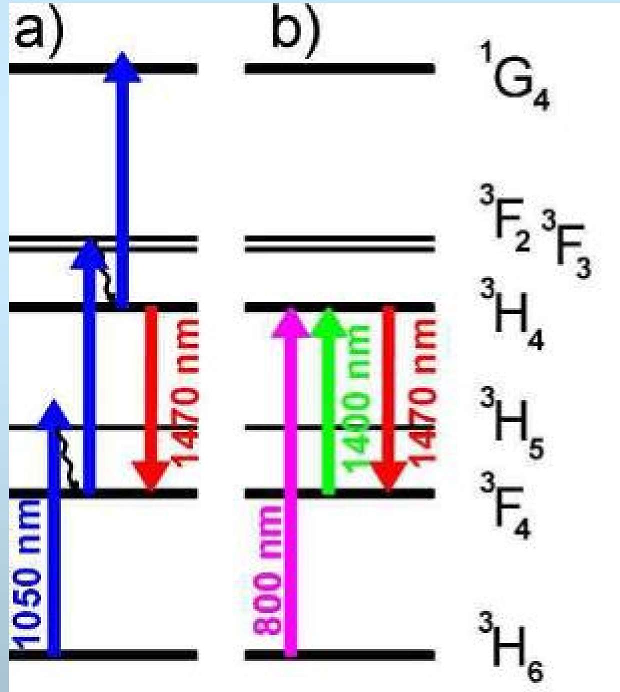


Twin-core (TCF)
Photonic crystal (PCF)
Double-clad (DC)

Tm $^{3+}$ -doped fibers

- Goal : amplification at S-band - WDM
- Technol. challenge : special optical fiber fiber efficiently operating at S-band (~1470 nm) and compatible with network. Tm^{3+}-Al_2O_3-GeO_2-SiO_2 high NA, narrow core fiber.

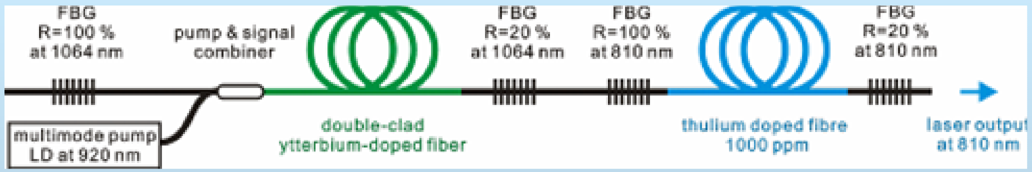


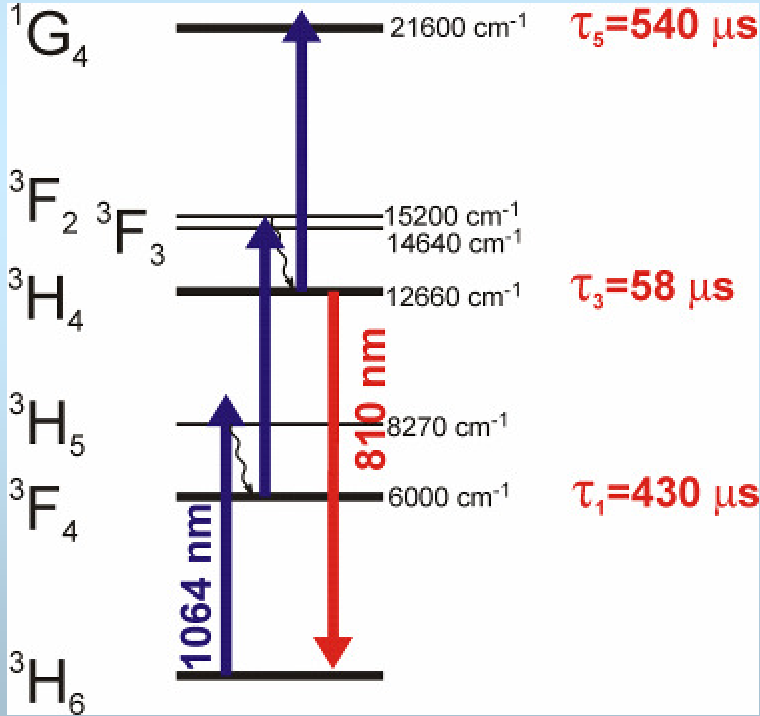


- *P.Peterka - in collaboration with LPMC Nice*

Tm^{3+} -doped fibers

- Goal : a compact upconversion fiber laser operating ~810 nm
- Technol. challenge : special optical fiber efficiently operating (~810 nm) - Tm^{3+}-Al_2O_3-SiO_2 with enhanced 3H4 lifetime.

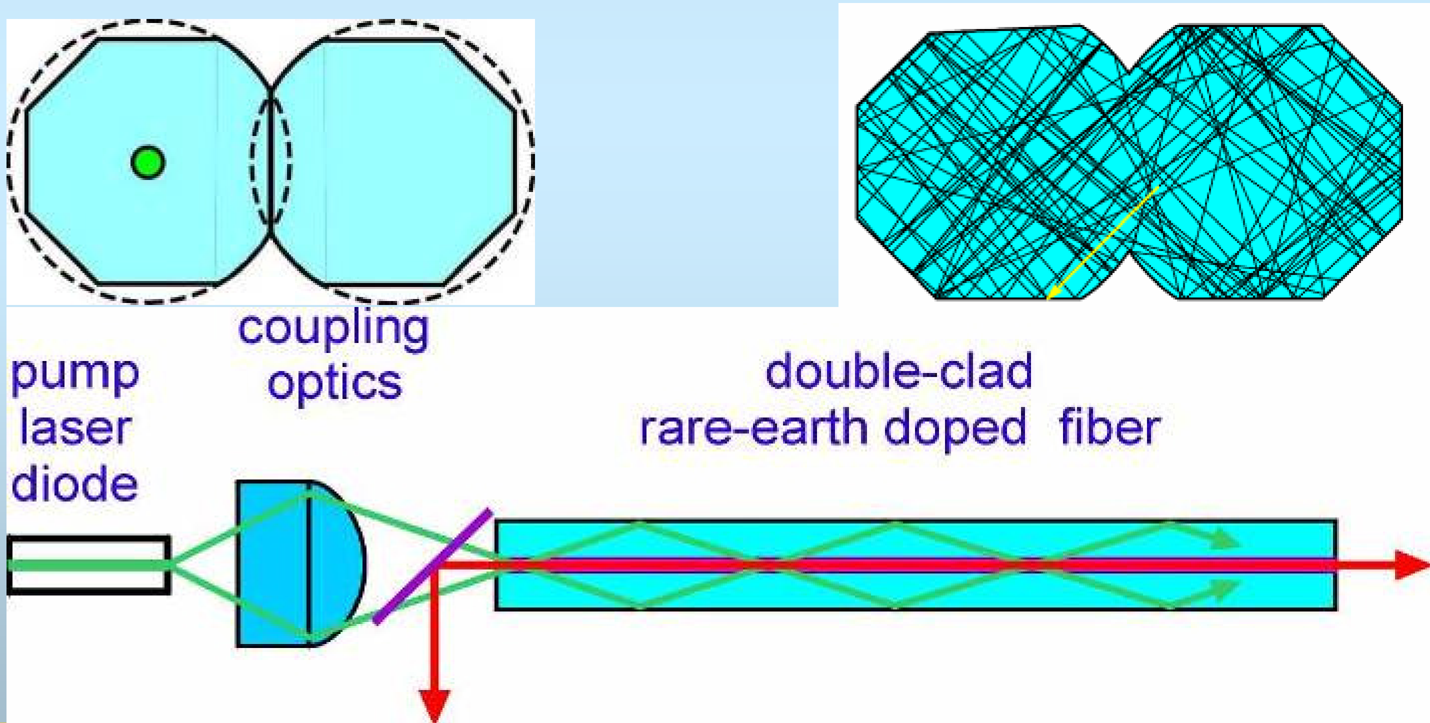




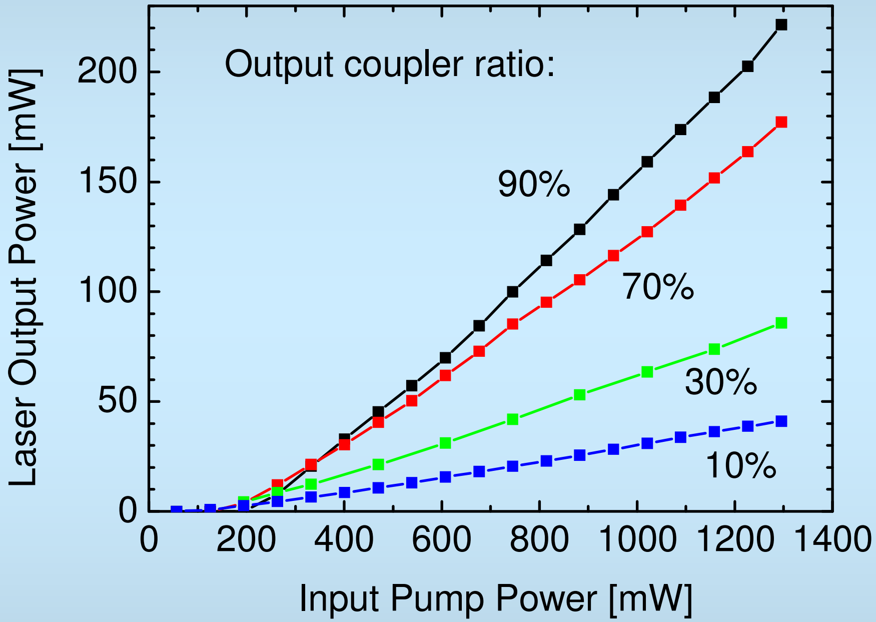
Fiber-optic components

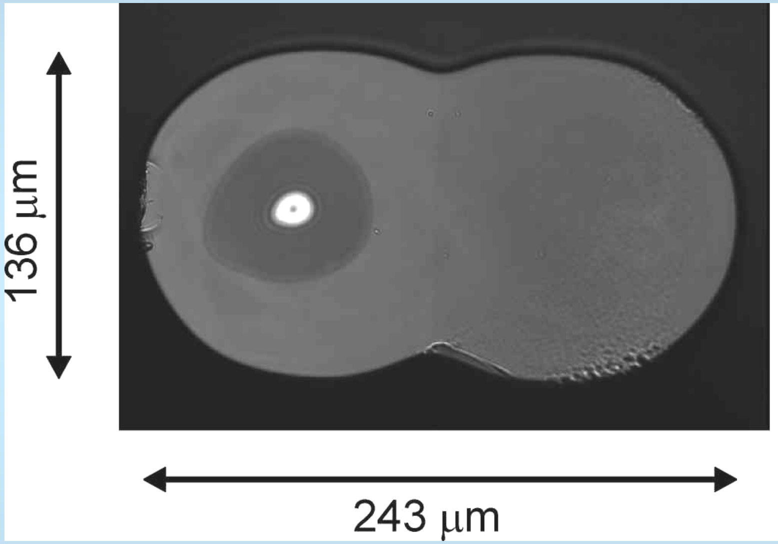
Double-clad (DC) doped optical fiber

- Goal: efficient pumping of fiber lasers (using LD, LED)
- Technol. challenge : special optical fiber of Double-clad (DC) structure and doped core of suitable shape for coupling



Fiber-optic components
Double-clad (DC) doped optical fiber



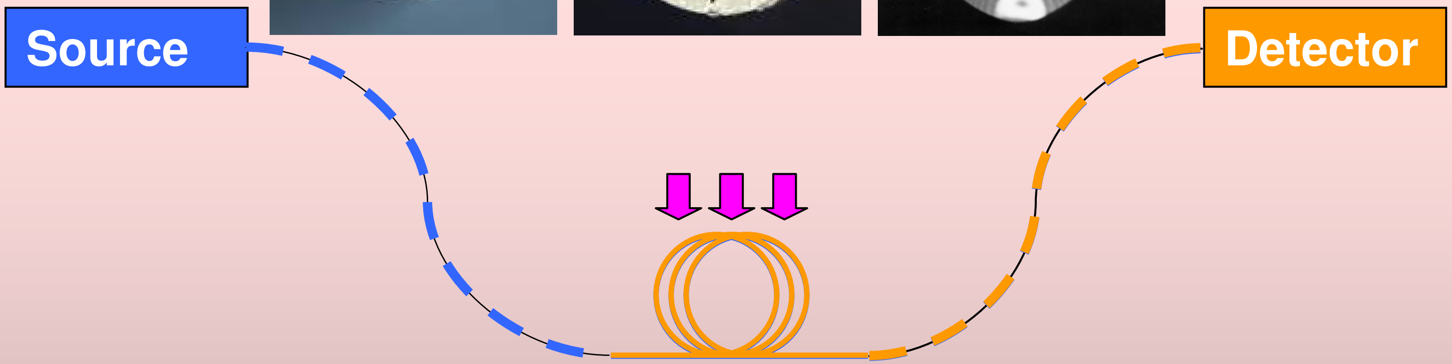


Max. PCE=19%; Yb/Er-doped DC fiber

In collaboration with FJFI CTU

Fiber-optic sensors

Continual reversible monitoring of (bio)chemical species and their concentration



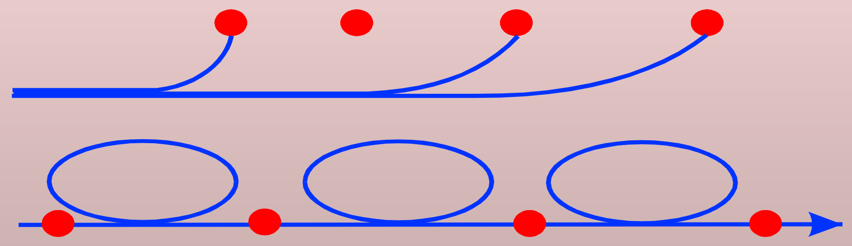
Change of output optical signal due to (bio)chemical changes in fiber vicinity.

Environmental monitoring, medicine, biology, homeland security ....

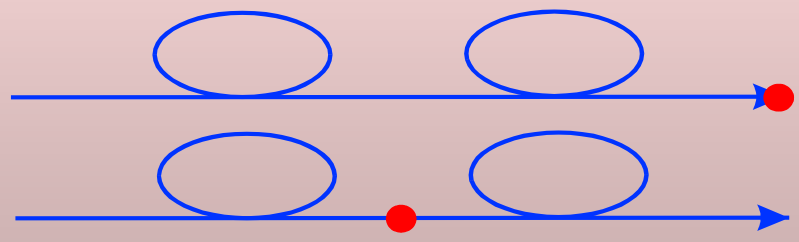
+ Remote sensing
+ Distributed
+ Explosive, high-voltage areas, human body

Solution : fiber-optic sensors

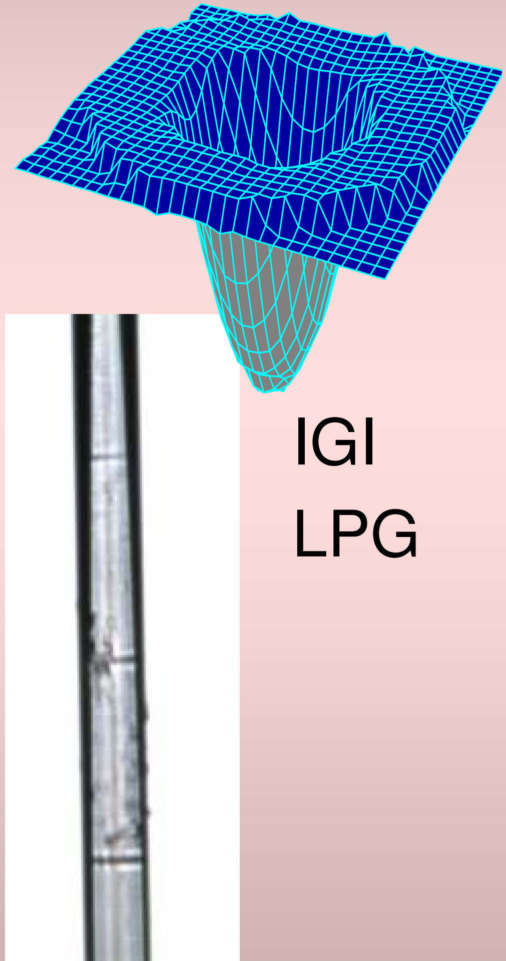
Multipoint (distributed) detection



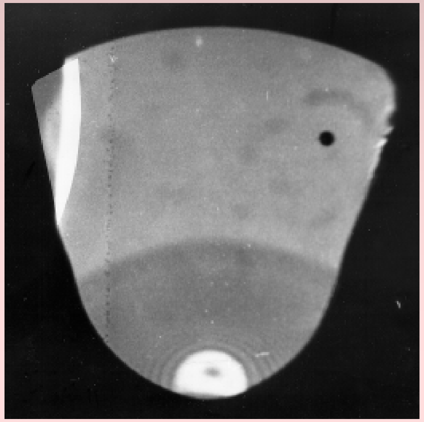
Point detection



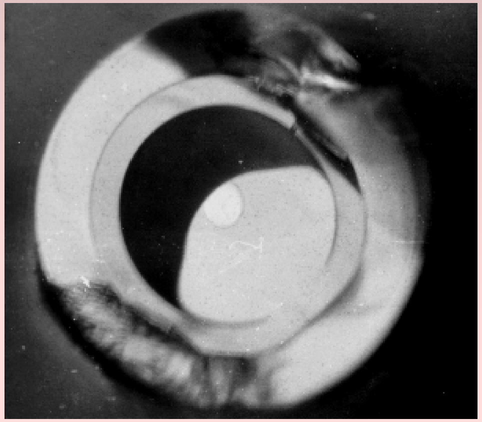
SPECIAL OPTICAL FIBERS for fiber sensors



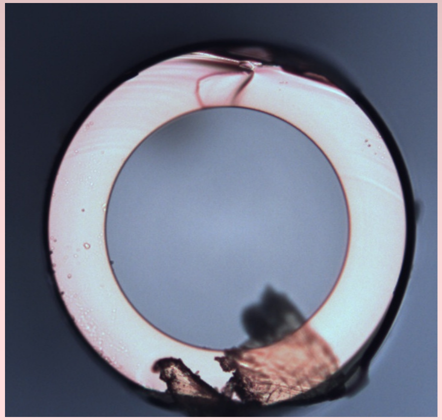
IGI
LPG



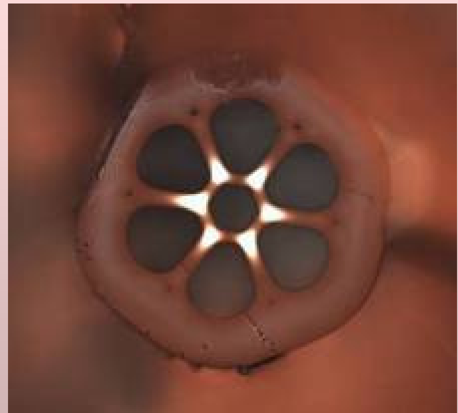
S-fibers

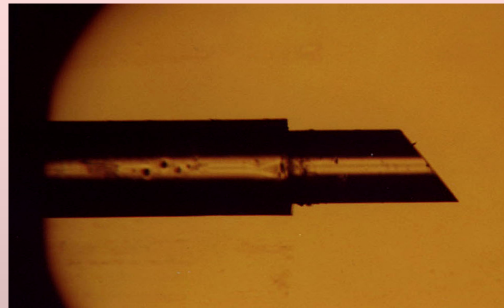


COF-fibers



capillaries





[PCF], tapers

Refractometric sensor of hydrocarbons

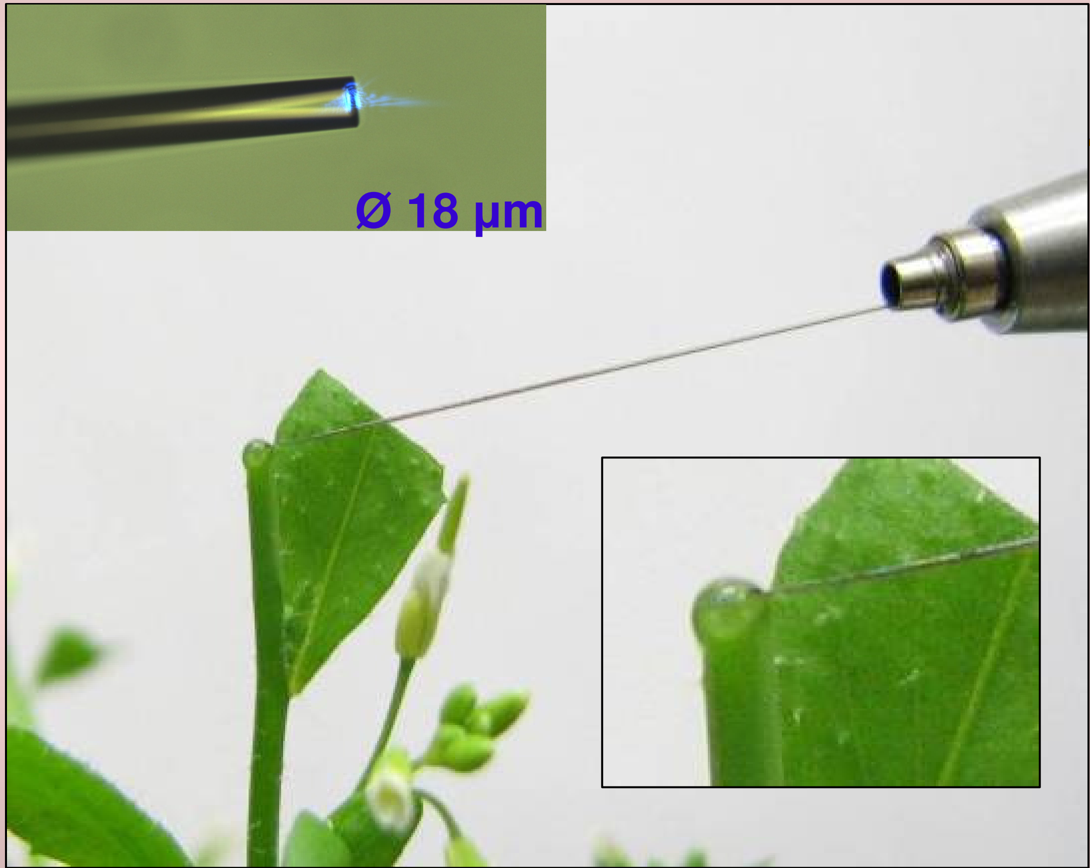
Detection of leakage

LOD ~ 3-5 mg/l (comparable to EU limits)

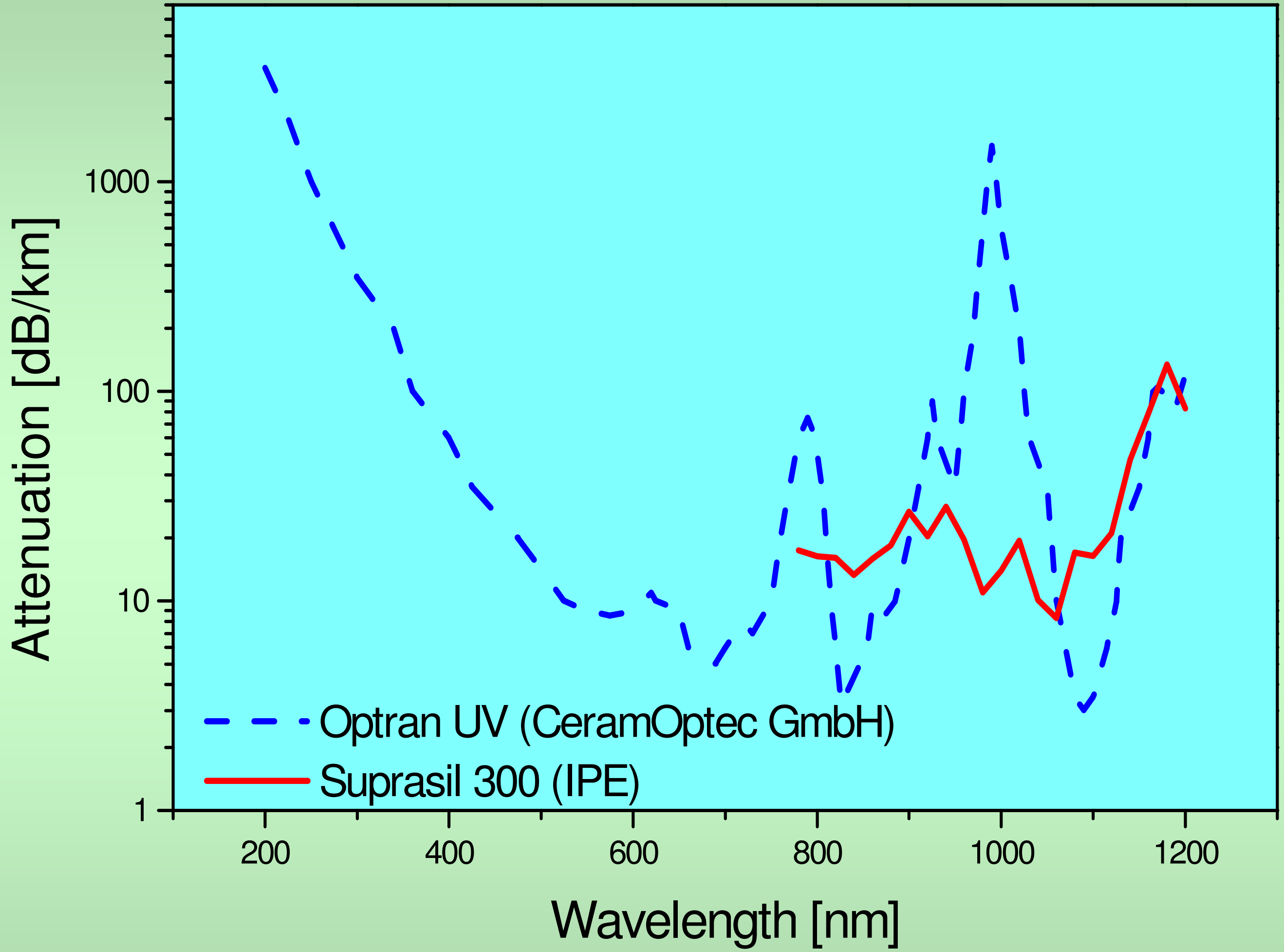
POZVÁNKA : TVT 15.11. 2012 Akademie věd Národní 3

Optical fiber sensors

Detectionof pH in small samples (droplets, cells)

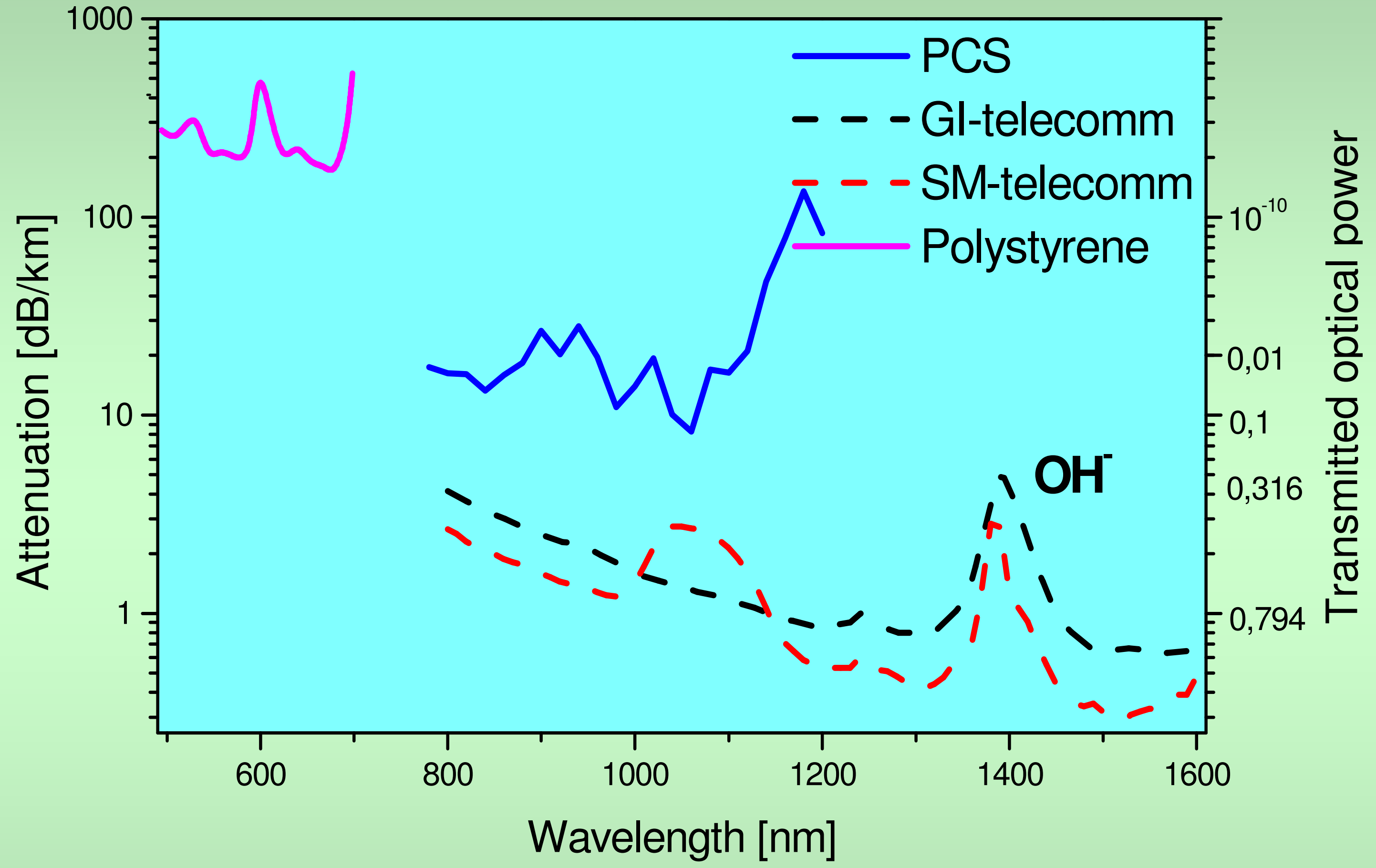


OPTICAL FIBRES – Materials - UV



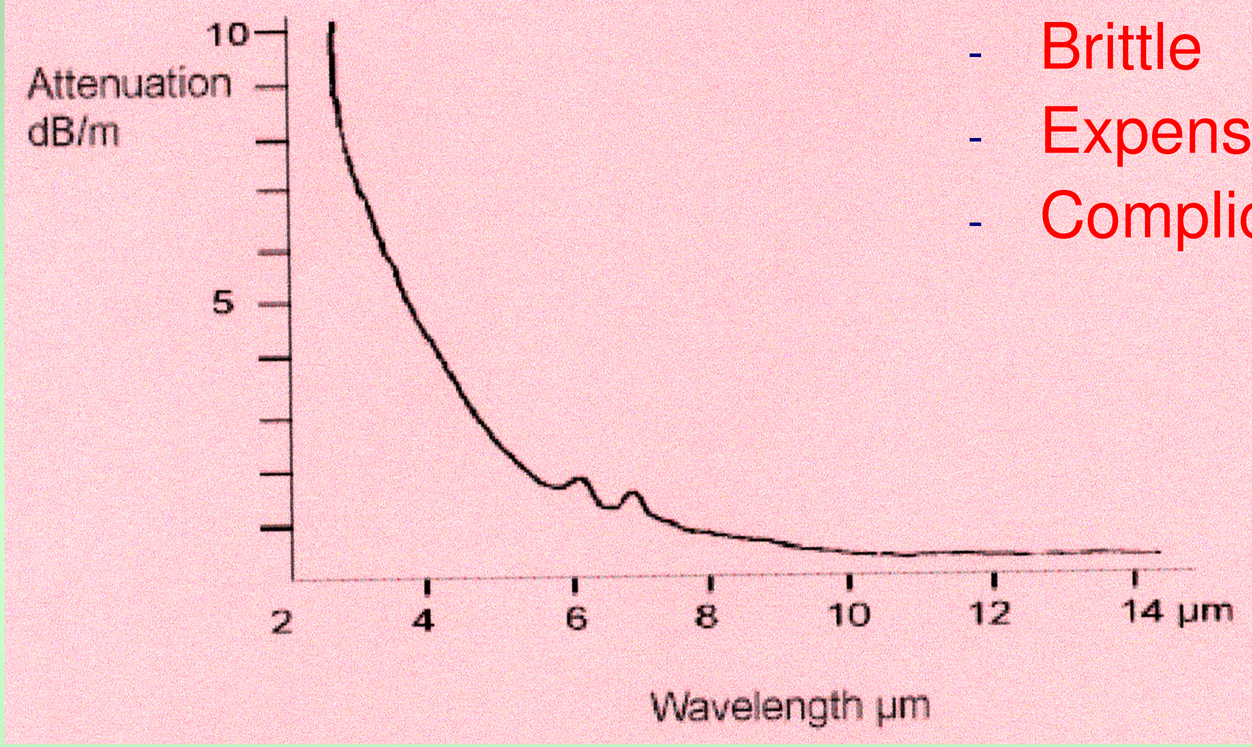
- silica fibres - SUPRASIL $n_{200\ nm}$ = 1.55 [ceramoptec.de, OceanO, IPE …]
- planar silica, crystalline CaF_2 (MgF_2) – [edmundoptics, technicalglass …]

OPTICAL FIBRES – Materials – VIS/NIR



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…]

OPTICAL FIBRES – Materials - IR



- Brittle
- Expensive
- Complicated

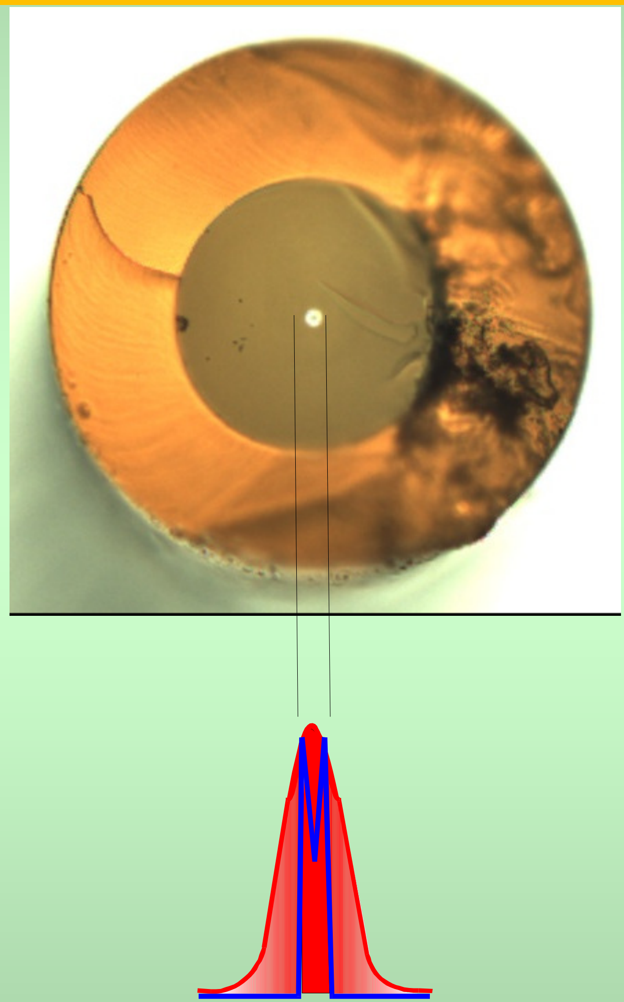
- fluoride glasses [univ-rennes1.fr …] (up to ~4 µm)
- sapphire [CRYTUR] (up to ~4 µm)
- silver-halides $AgCl_xBr_{1-x}$ (up to 15 µm)
- chalco glasses (Se, As_2S_3, As_2Se_3…) [oxford-electronics, orc.soton.ac.uk] (< 20 µm)
- refractive indexes $_{2\text{-}20um}$ ~ 2 – 2.5 >> silicate glasses [LiFaTec]

OPTICAL FIBRES - Structures

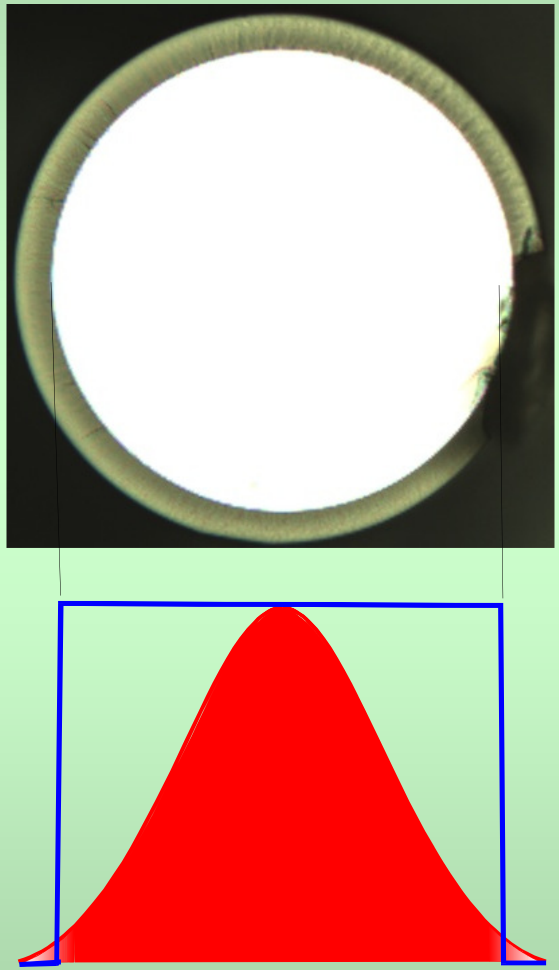
Single-mode
Ø$_{core}$ 2-15 μm
NA 0.1-0.25

Multimode
Ø$_{core}$50-1000 μm
NA 0.2-0.5

+ coupling !
+ connectoring !



SM 250/125/7 μm



MM 250/200 μm

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 specialty (active).
4. Research of optical fibers (CR) : ÚFE

References

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- **A. Mendez, F.T. Morse** : Specialty optical fibers handbook, Elsevier Science & Technol, USA, 2006.
- **J. Schrofel, K. Novotný** : Optické vlnovody, SNTL, 1986
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- **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

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