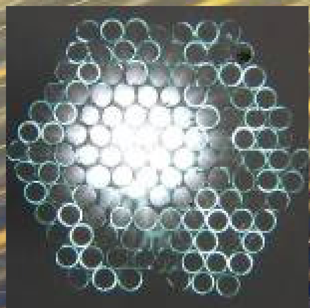
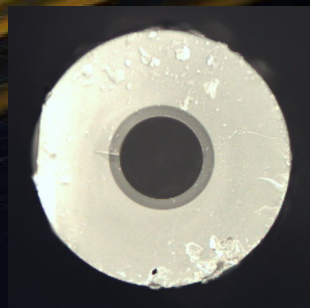
Optická vlákna a vláknové senzory

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.

- součást Akademie věd ČR = základní výzkum, neuniverzitní
- středně velký ústav (cca 100 zaměstnanců)

VÝZKUM:

- fotonika (optické senzory, vlnovodná fotonika, optická vlákna)
- měření (správa etalonu) přesného času, syntéza řeči

Outline

Fiber-optic sensors

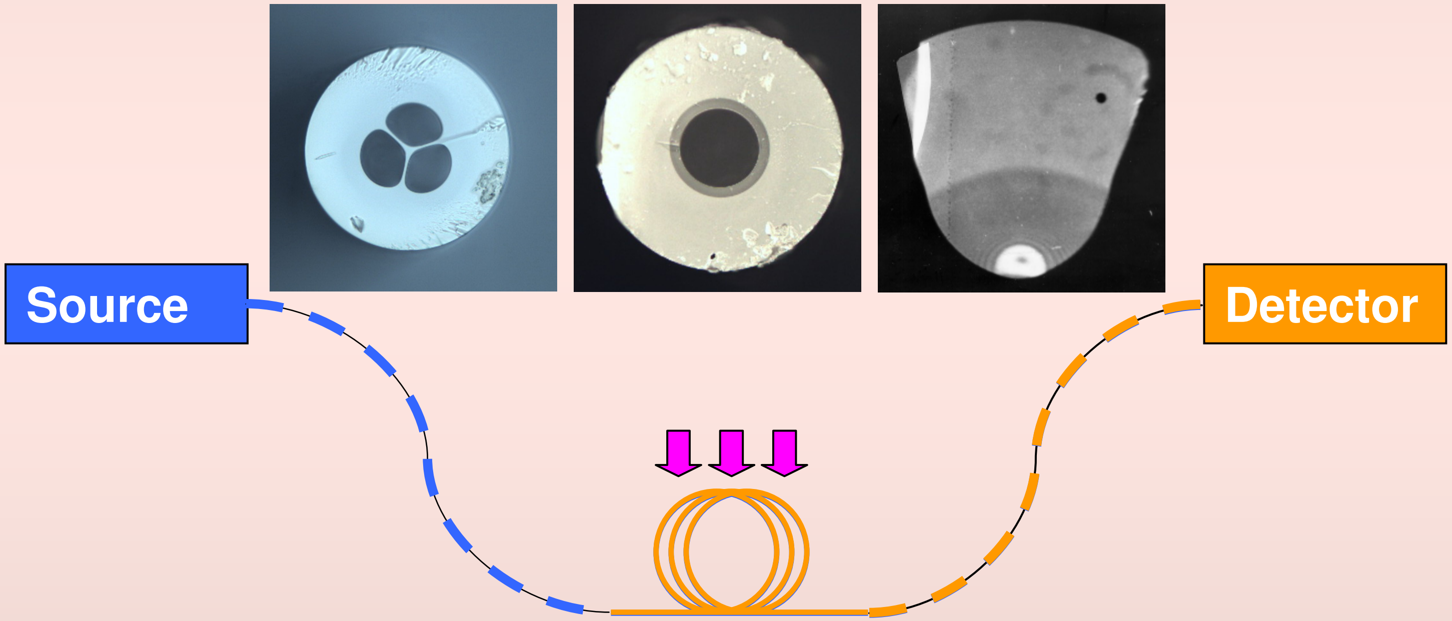
* general consideration
* materials, structures, coatings
* processing and accessories
* examples

Summary

LABO * local pH detection
* gas sensing (angular distribution meas.)
* fluorimeter Jobin-Yvon
* decladding, cleaving, splicing

Fiber-optic SENSORS

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



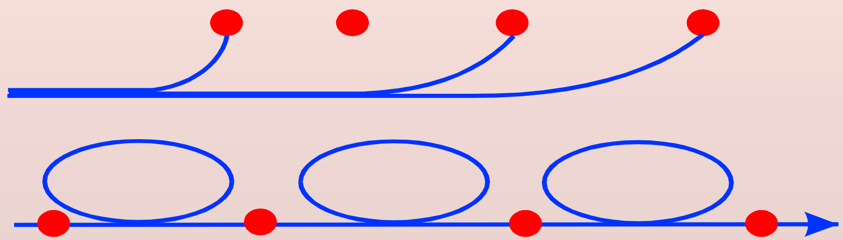
Change of output optical signal due to (bio)chemical changes in fiber vicinity.

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

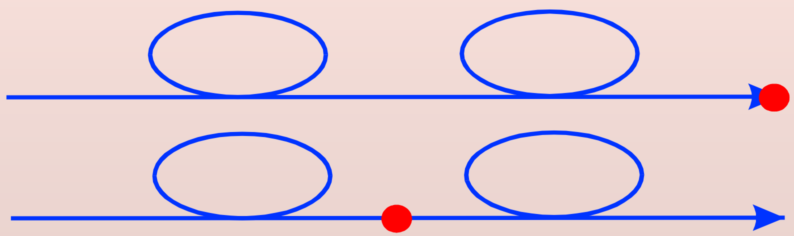
+ Remote sensing
+ **Distributed or micro**
+ **Explosive, high-voltage areas**, human body

Solution : fiber-optic sensors

Multipoint (distributed) detection



Point detection



Optical SENSOR consideration

Requirements:

- sensitivity - LOD
- selectivity
- reproducibility
- dynamics - time response
- reliability-stability ...

- **Method :** optical (fluorescence...)
- Optics & chemistry
  - 1. **Planar / fiber-optic**
  - **2. Transducer & imobilization**
  - **3. Spectral range**
  - **4. Structure OF**
  - **5. Implementation**
- Feasibility ?? *

- Expected utilization (market)
- Price

* **Parkinson** : The more complicated system, the higher probability of its failure.
** **Murphy** : What can go wrong, it will.

Optical HW consideration

- **METHOD** (absorption, fluorescence, refractometry...)

  and chemistry =>

- **SPECTRAL RANGE** : **UV<< VIS+NIR >> IR**

+ compatibility with conventional fiber optics
+ availability of HW of acceptable price
+ low optical losses

- **STRUCTURE : MM** (multimode)

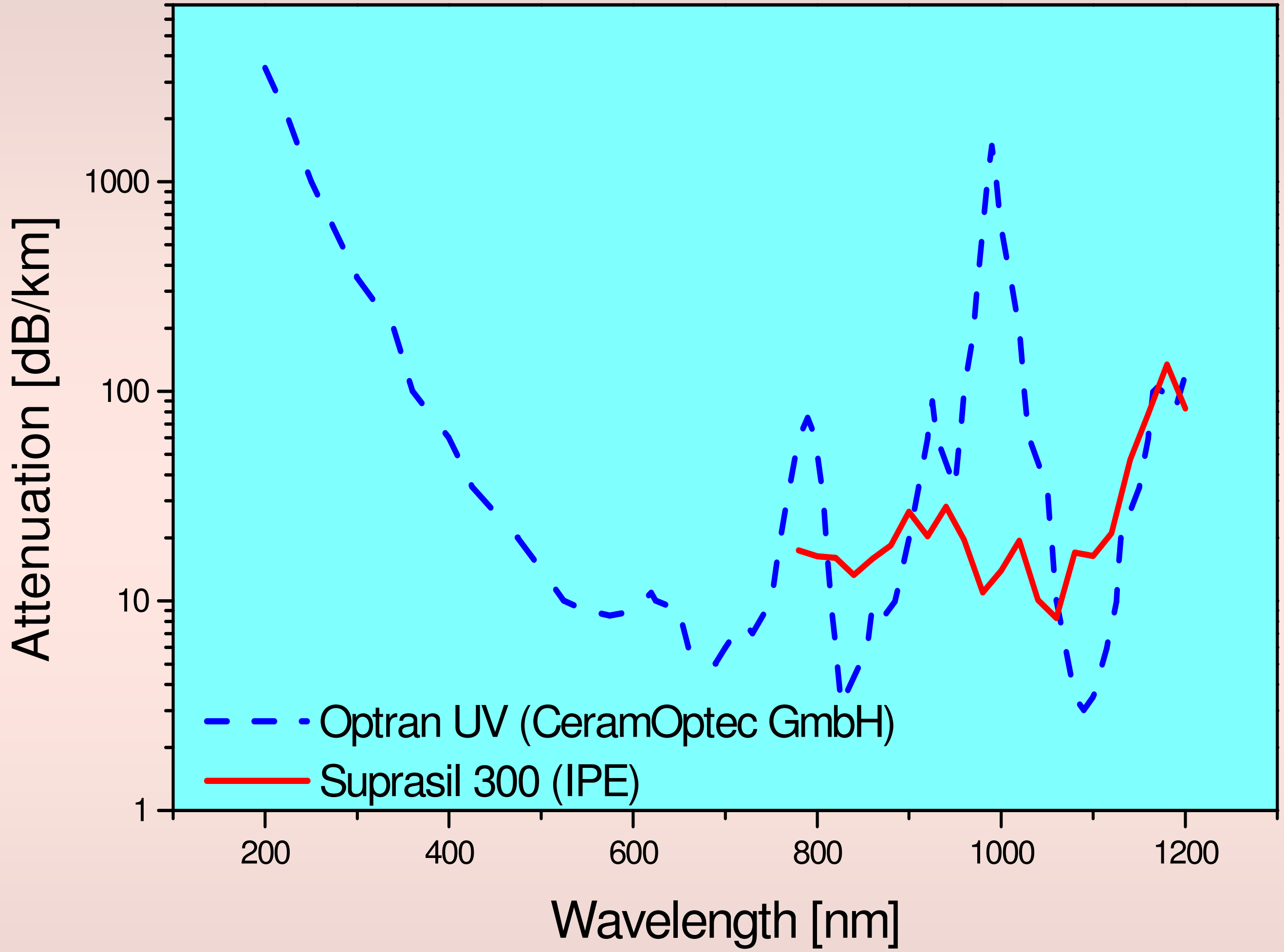
+ larger core & higher NA => cheap components
+ robustness => easy handling, processing

Optical HW requirements

- **Durability** to the analyte
  - (glasses > polymers > crystals)
- High **transparency** in a wide spectral range
  - (VIS-NIR > UV and IR)
- Suitable **refractive index**
- Common **availability** of optical hw
  - (conventional > special; VIS-NIR > UV & IR)

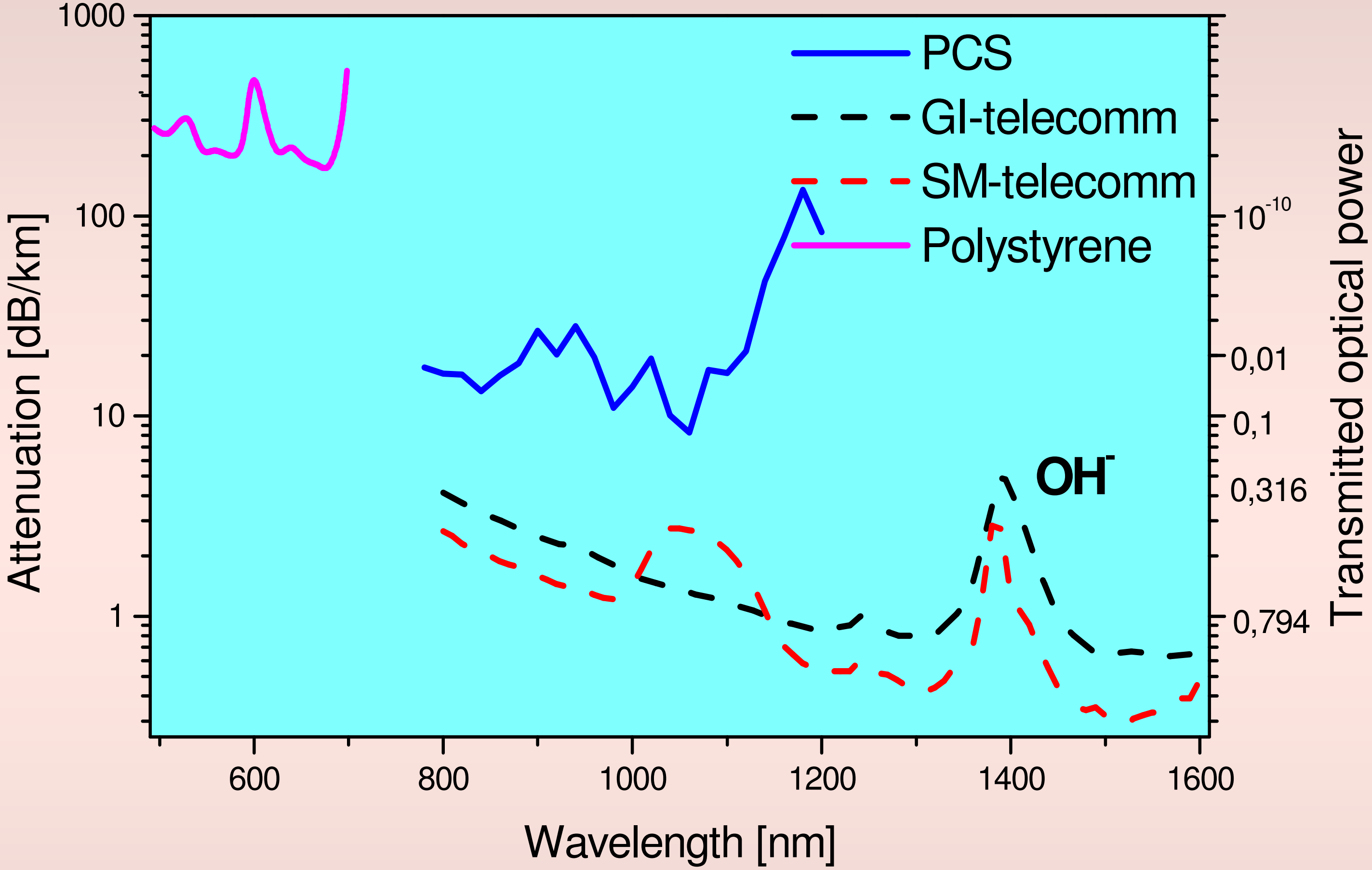
$\Rightarrow$ Material & structure & coating

Optical fibers – MATERIALS - UV



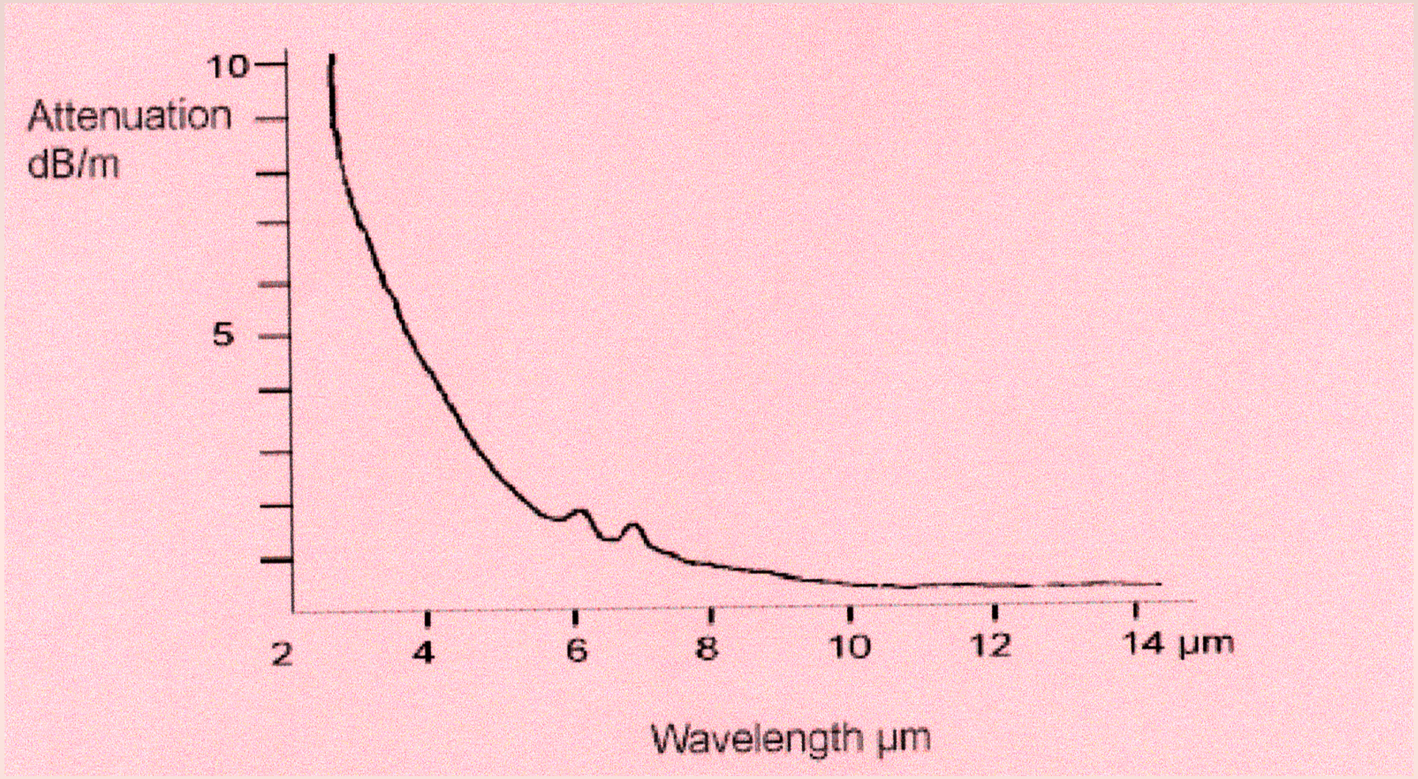
- silica fibers - SUPRASIL $n_{200\ nm} = 1.55$ [ceramoptec.de, OceanO, IPE …]
- planar silica, crystalline CaF_2 (MgF_2) – [edmundoptics, technicalglass …]

Optical fibers – 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 fibers – MATERIALS - IR



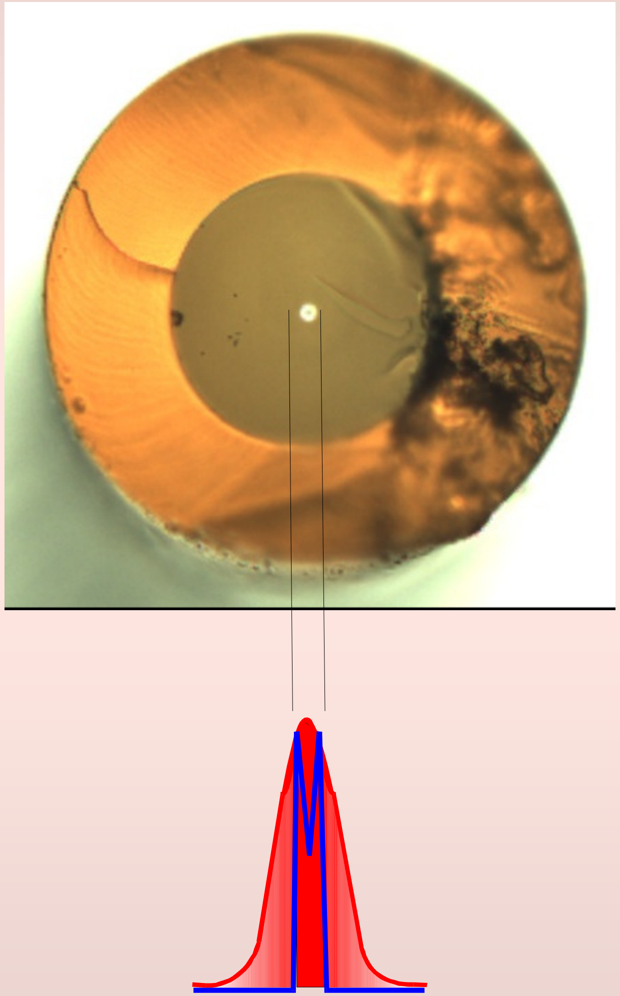
- fluoride glasses [irphotonics.com, univ-rennes1.fr …] (up to ~4 µm)
- sapphire [**CRYTUR**, photran.com, fiberoptictechnology.net …] (up to ~4 µm)
- silver-halides $AgCl_xBr_{1-x}$ (up to 15 µm)
- chalco glasses (Se, As_2S_3, As_2Se_3…) [oxford-electronics, orc.soton.ac.uk] (< 20 µm)
- refractive indexes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

Optical fibers - STREUCTURES

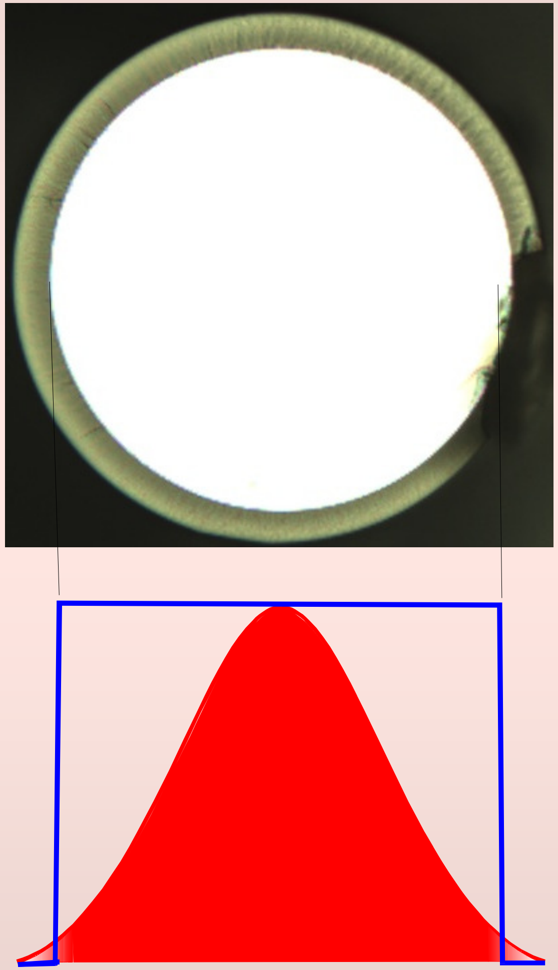
Conventional

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

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

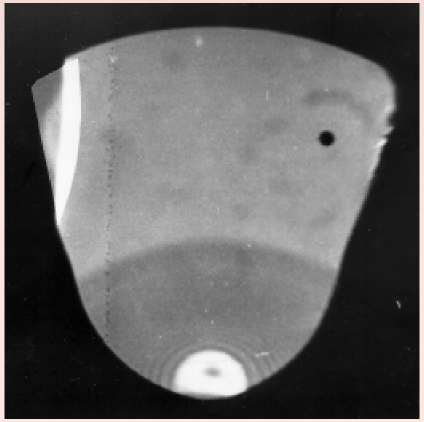


SM 250/125/7 μm

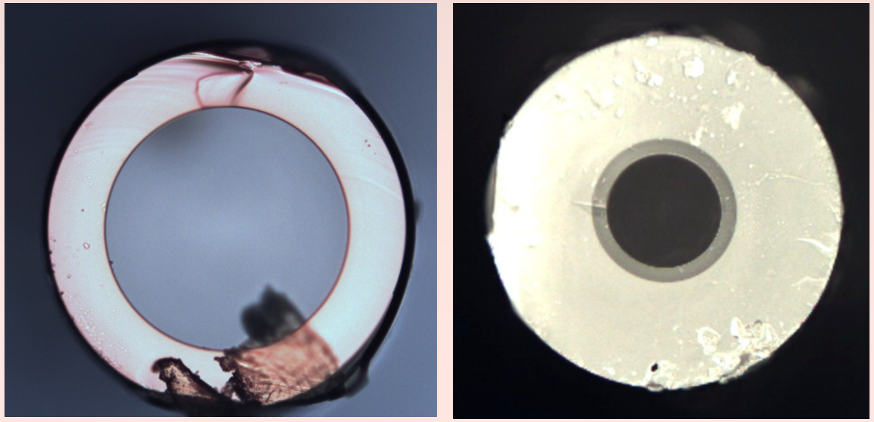


MM 250/200 μm

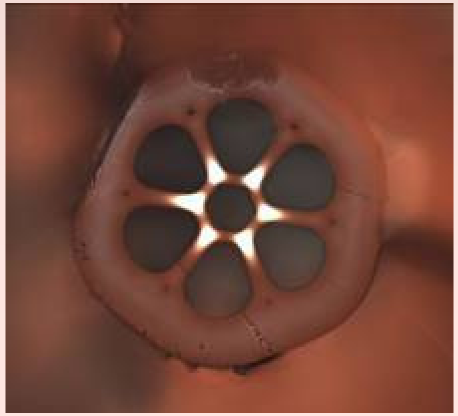
Fiber STRUCTURES for fiber sensors



S-fibers



capillaries

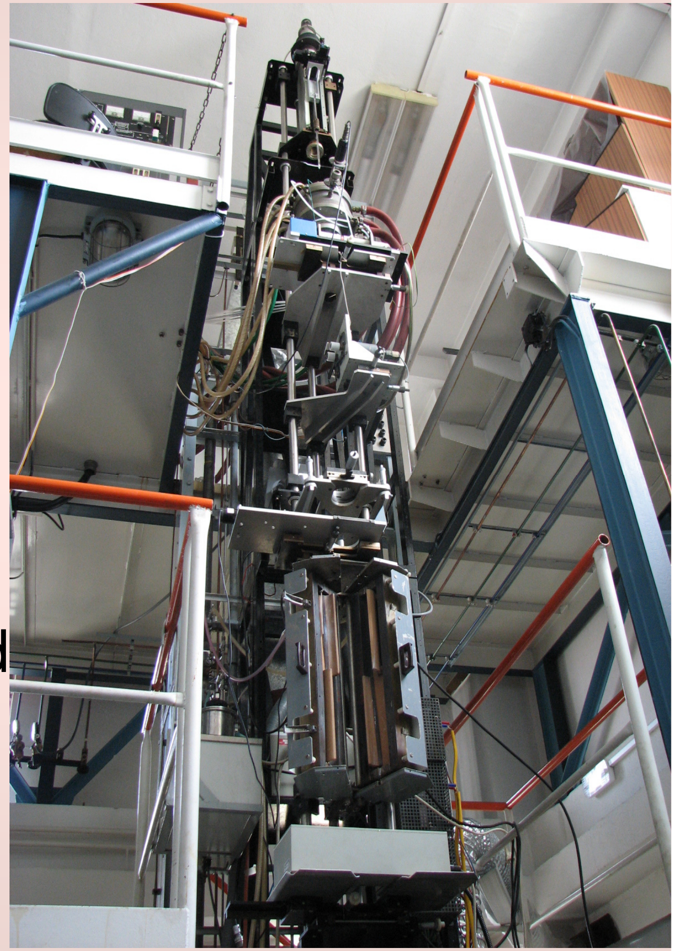


PCF

SM with LPG

Optical fiber COATINGS

- **Conventional** on-line coating
  - **Mechanical protection**
  - thickness 4 μm (hard)–100 μm (soft)



- Polysiloxane (n_D = 1,41), soft
- UV-acrylate (n_D = 1,65), hard
- Fluorinated UV-acrylate (n_D=1,35-1.44), hard
- PI – polyimide (n_D>1,46), hard
- PTFE – teflon (n_D = 1,29)

- [Sylgard, DeSolite, Luvantix, DSM Desoto]

Optical fiber special COATINGS

Special additional coating
sol-gel and/or polymers

- **Immobilizing** of transducers
- **Tailoring of access of analyte** to the detection site

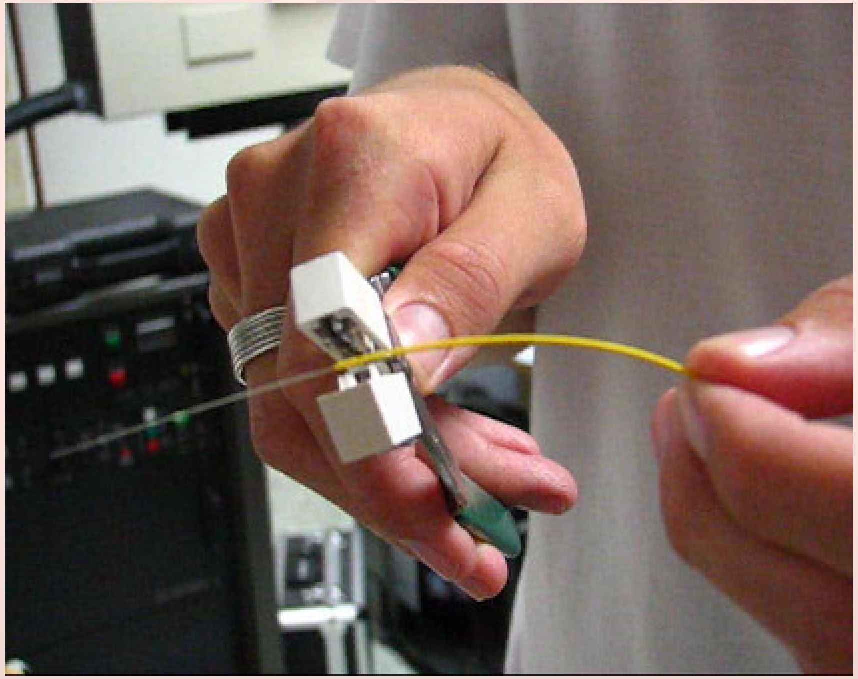
=> (porosity, thickness, phobicity)

- thickness ~10^2 nm (!) – several μm

- Dip coating
- (planar : spin coating)

Optical fiber decladding

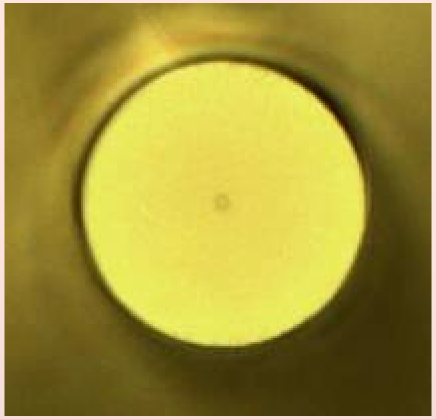
- mechanically
  – stripping tool (pliers) :
- chemically - leaching
  - trichloethylene (acrylates)
  - HF acid (siloxanes)
  - exposition – seconds-minute



Optical fiber cleaving

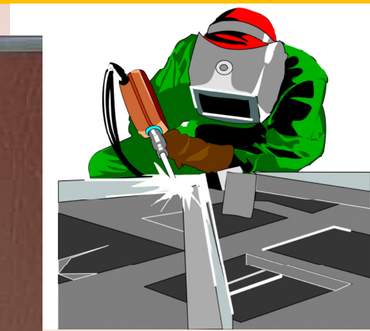
- primitively :

  scissors, knife, razor
  blade (suitable for POF)
- more primitively: fire



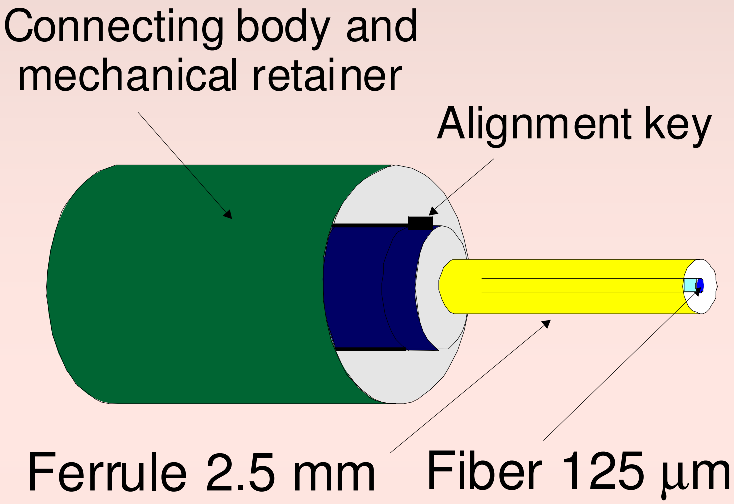
- correctly :
  - **fiber cleaver** FK11
    (York Tech, Ericsson)

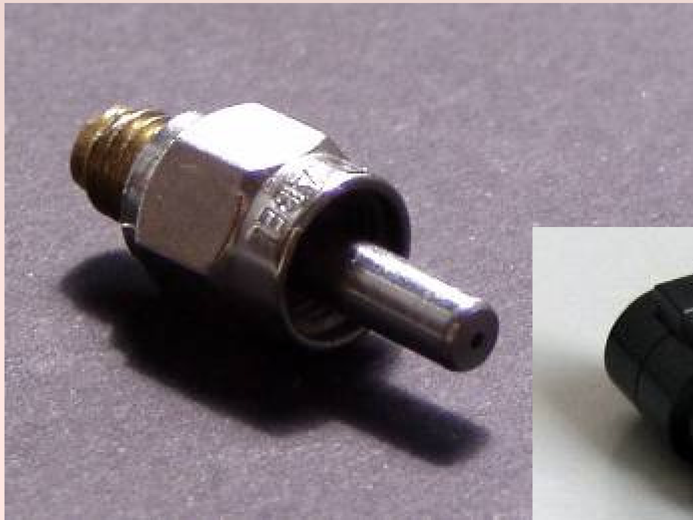
Optical fiber splicing



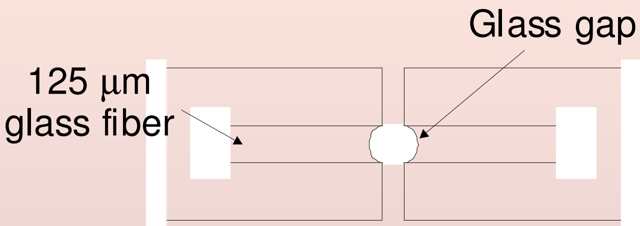
Splicing device (Fujikura, Ericsson), losses ~0.1-0.2 dB

Optical fiber connectoring

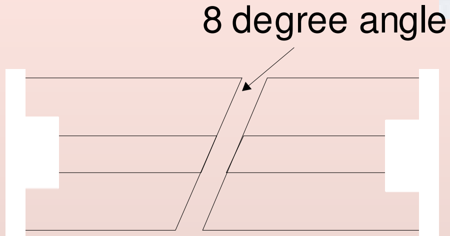




Fiber Connection (FC)



Angled Fiber Connection (APC)

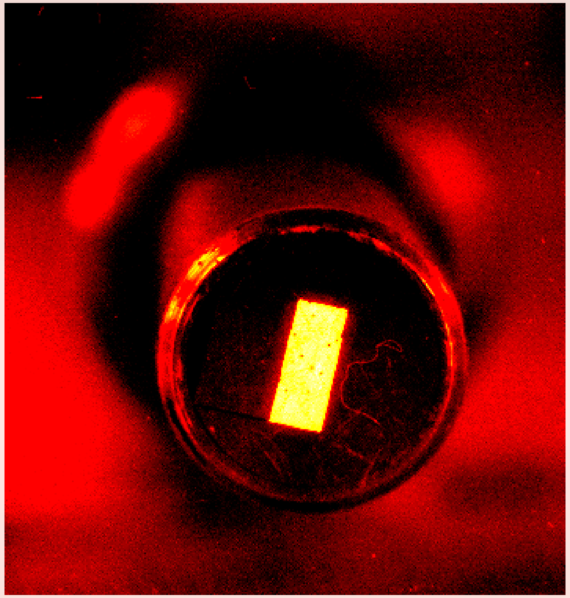


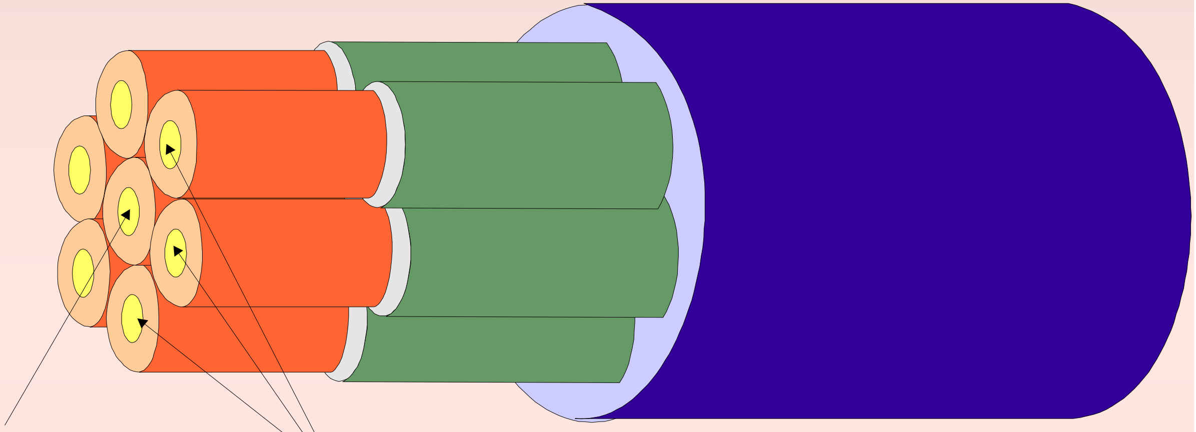
- Types : FC, SMA, APC …; losses ~0.2 dB

Optical fiber connectoring

Types : SMA, FC, APC (Angled Physical Contact)

Optical fibre bundles



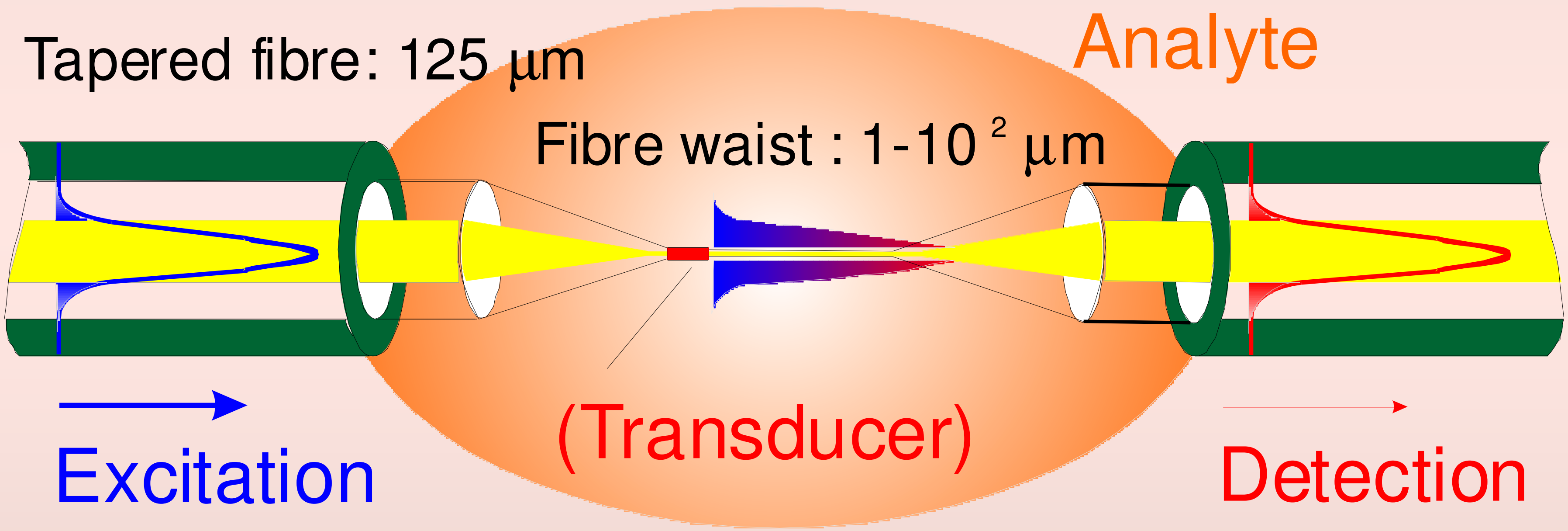


40 x 120 fibers 125 µm

- Reflection sensing arrangement (fluorescence)
- Imaging
- Multianalyte analysis

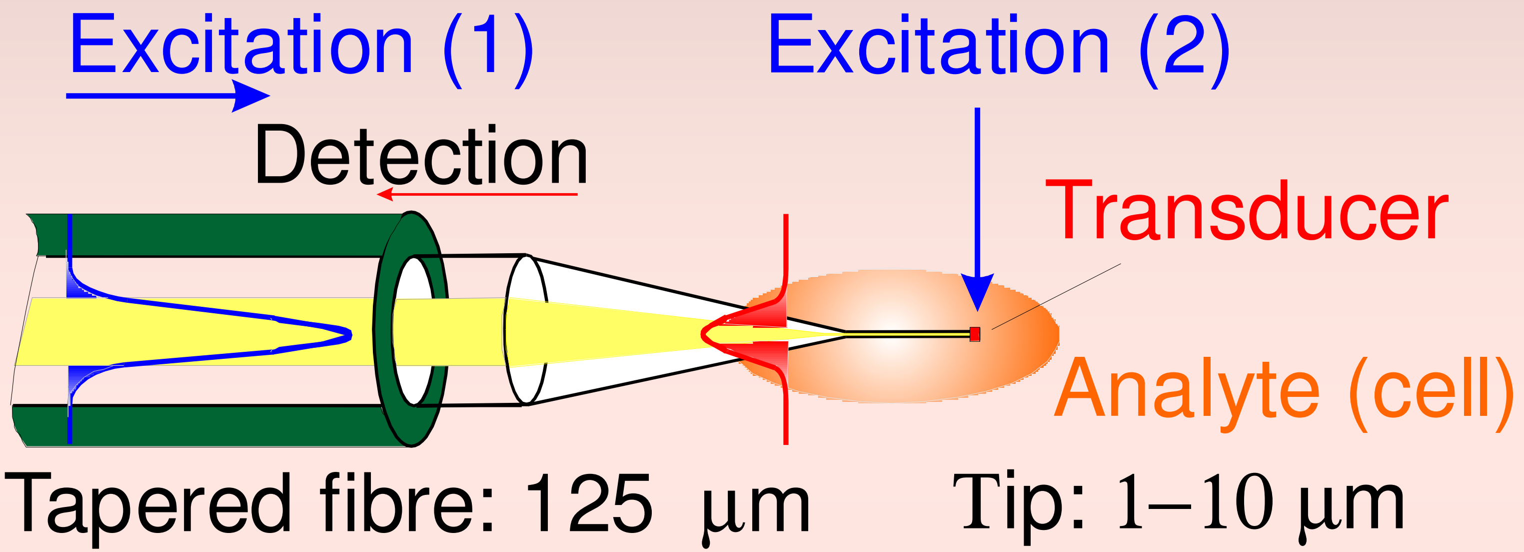
Optical fiber tapers

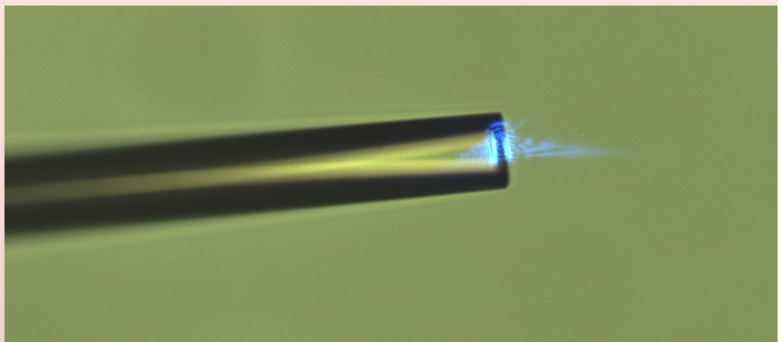
- **Multipoint monitoring**



Optical losses : SM ~ 0.1-0.2 dB

Optical fiber tapers

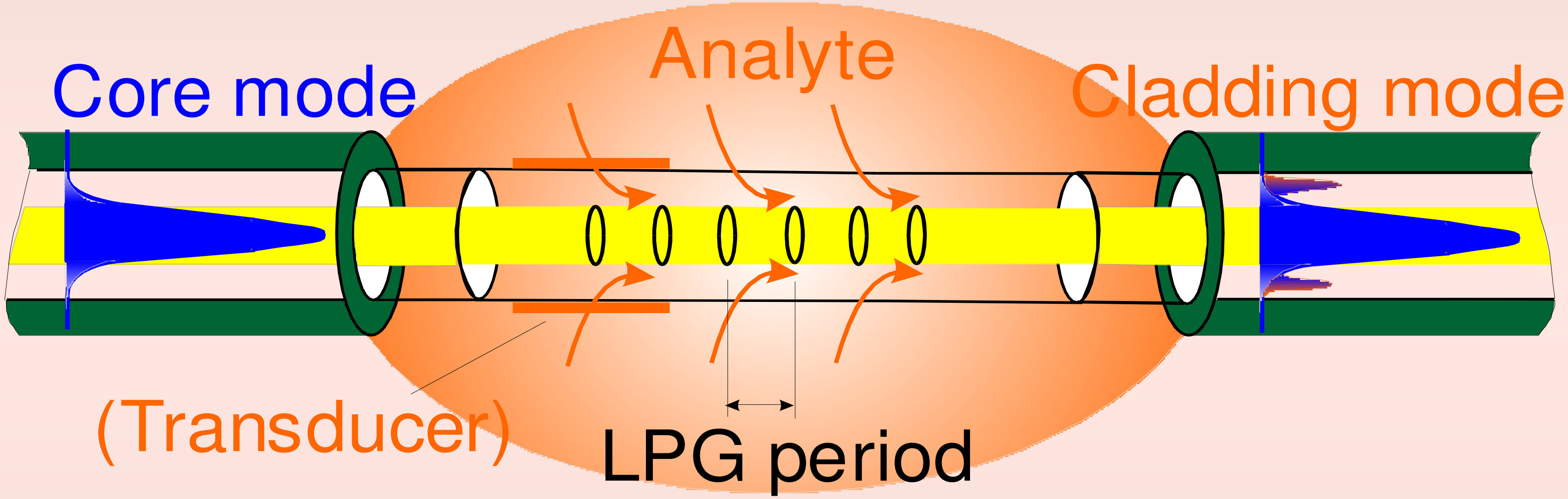




- **Small area monitoring**
- Preparation
  - Flame (laser) processing
  - Slow withdrawing from HF-containing solution

Optical fiber gratings

LPG : Long Period Gratings (~ mm period)



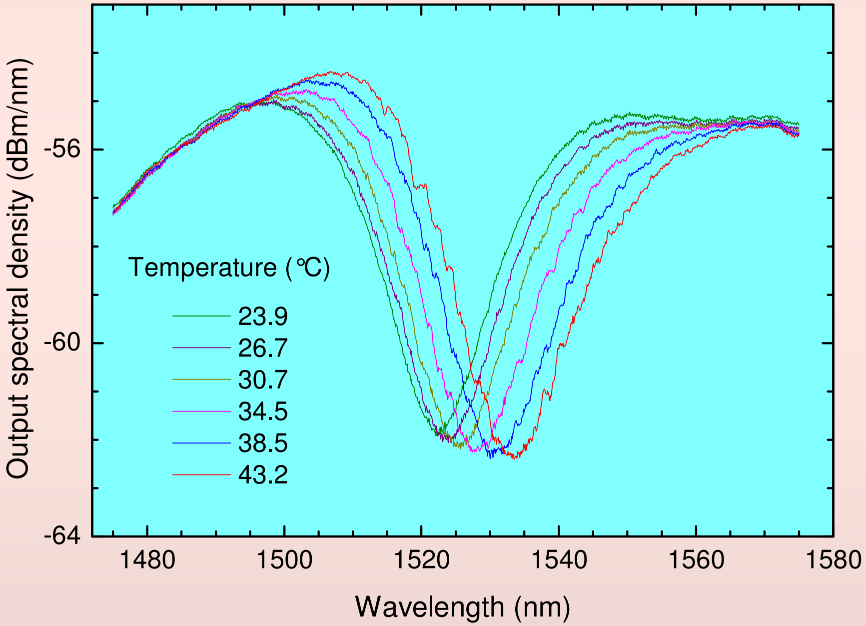
Preparation

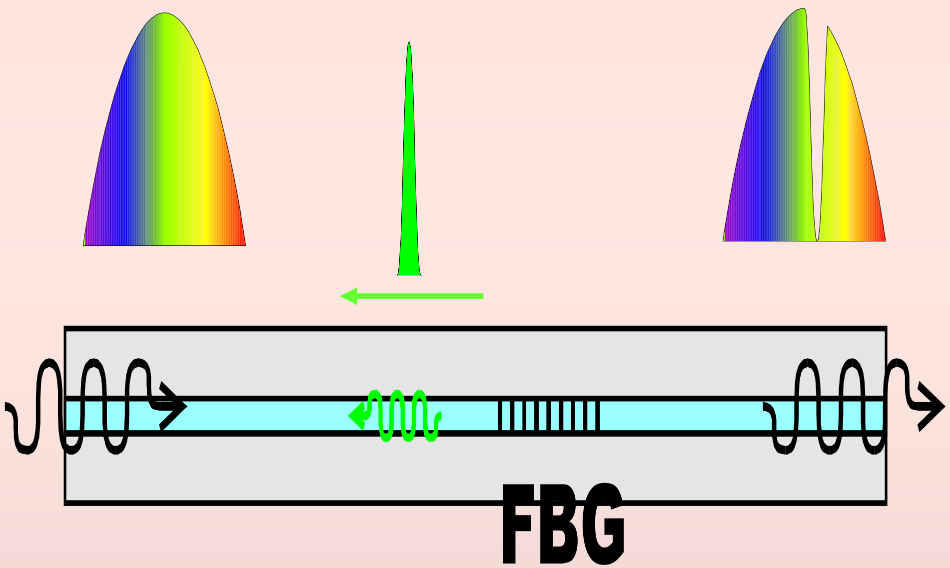
- Laser inscription

Fiber gratings

LPG : Long Period Gratings

FBG : Fibre Bragg Gratings (~ nm period)





LPG : transmission spectrum

FBG : reflection spectrum

EXAMPLES
Refractometric sensor of hydrocarbons

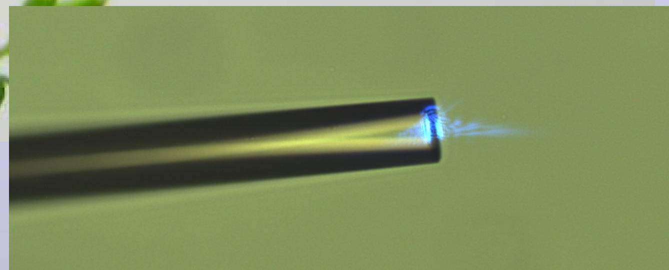
 

+ **sensitivity** : LOD ~ 3-5 mg/l ~ comparable to EU ecological limit
+ **time response** : seconds

In collaboration with Jean Monnet Saint-Etienne, Ecole Centrale de Lyon

EXAMPLES
Local pH detection in microsamples

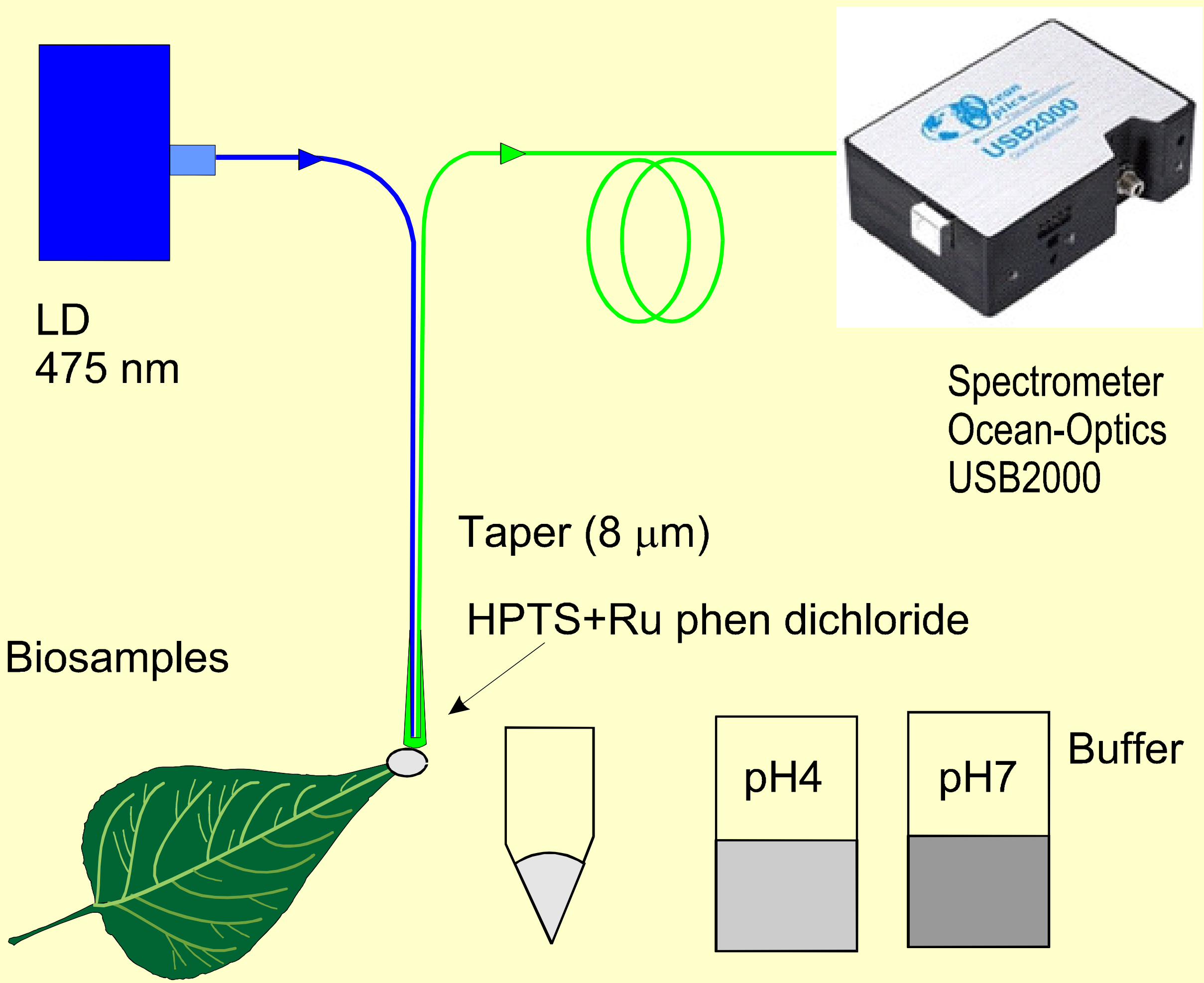
Fiber tapers :



Detection of pH <5; 7> in xylem exudates, intracellular detection

In collaboration with IEB ASCR, UK, MU, VSCHT, MZLU

Local pH detection in microsamples



- **Fluorescence ratiomeric**
- **HPTS + int.standard Ru-phen**
- **Laser diode**
- **taper Ø 8 µm (GI 125/50)**

Methods based on fluorescence

Intenzity measurement

+ easy
- incorrect (influence of set-up)

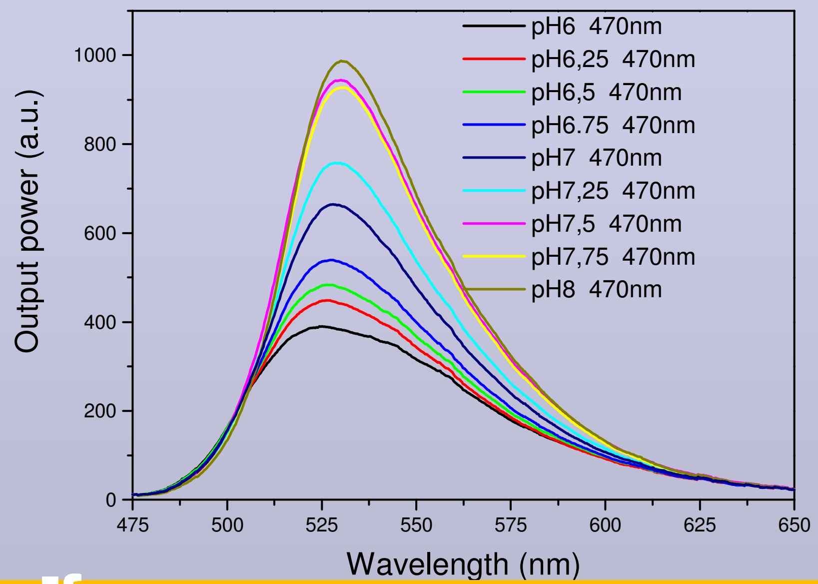
* 1 source + detector

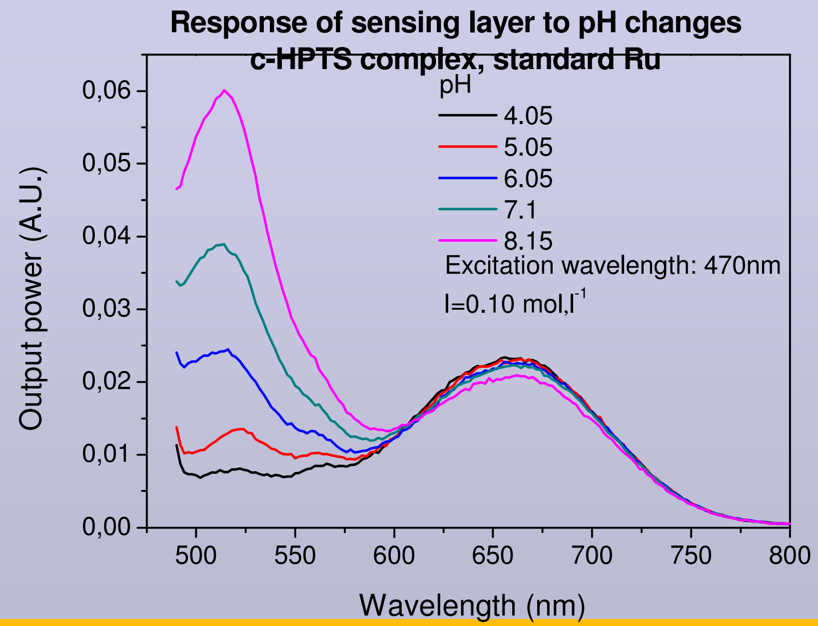
Ratiometric

+ better precision
- more complicated set-up

Self-reference → 1 transducer; 2 sources + detector

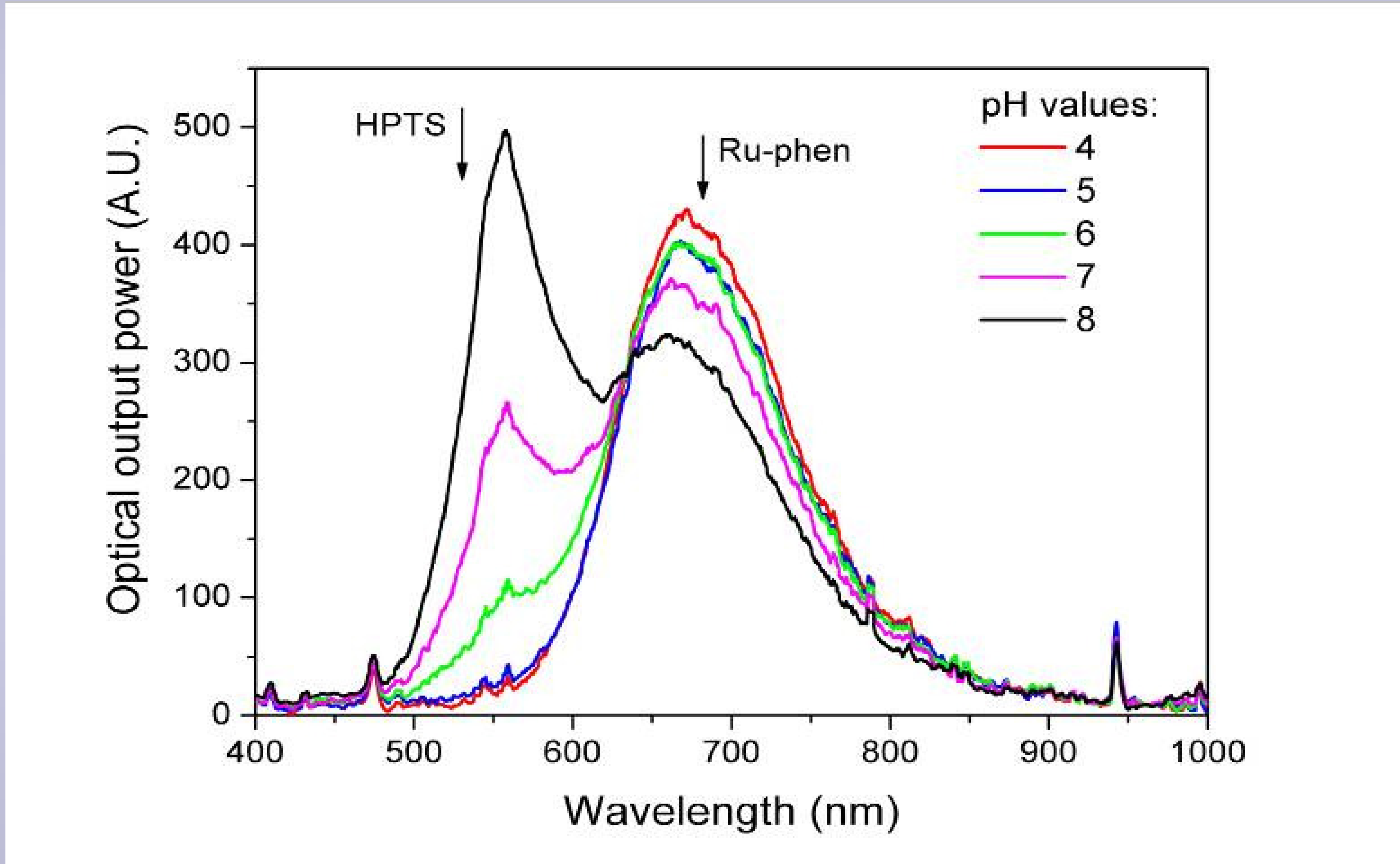
Internal standard → 2 transducers; 1 source +spectrometer





Local pH detection in microsamples

Fluorescence responses to calibration buffers

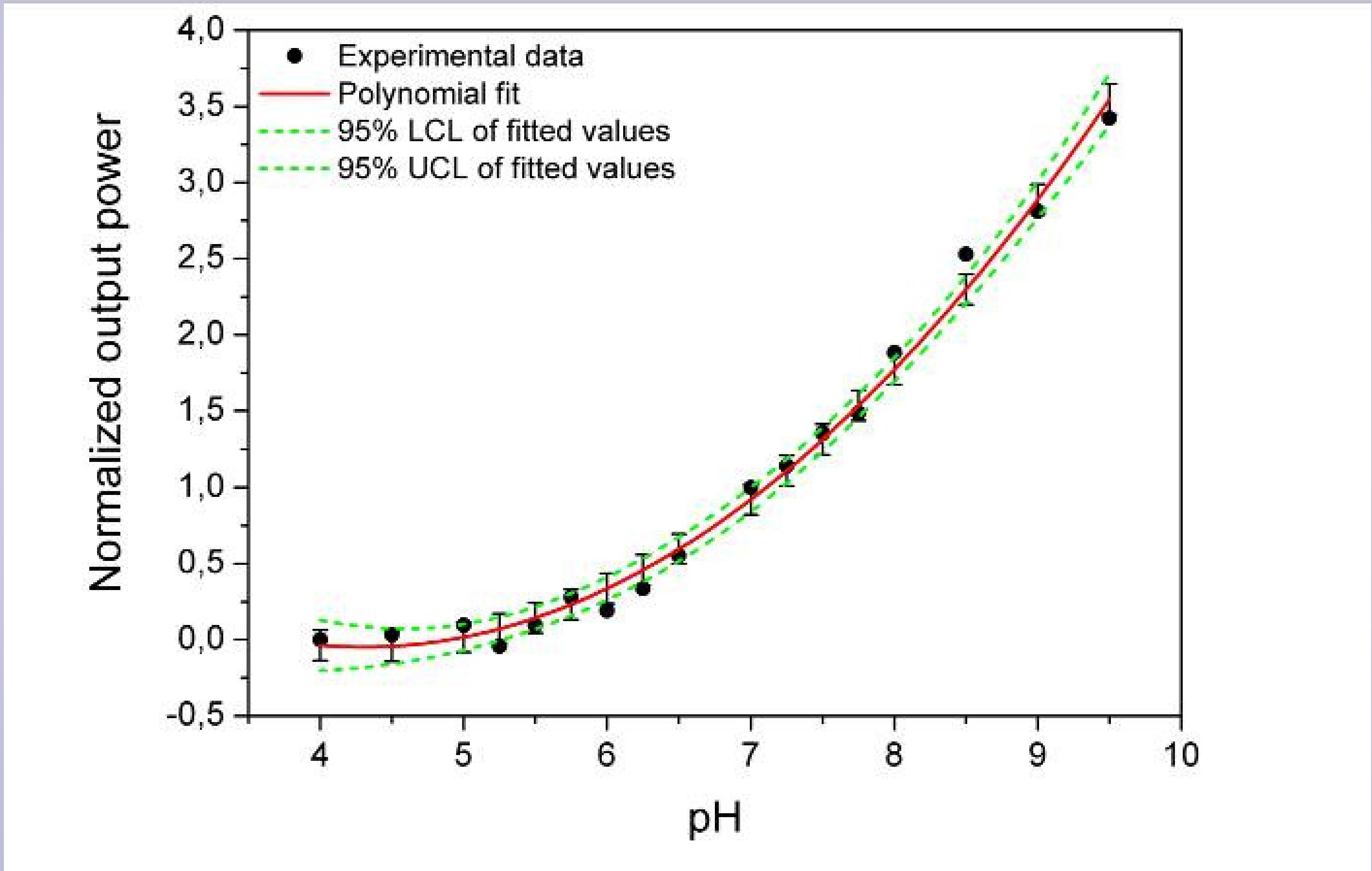


Excitation : 475 nm, taper, 8 um, HPTS+Ru-phen

Local pH detection in microsamples

Calibration curve : output = 2,407 – 1,142 pH + 0,133 pH^2

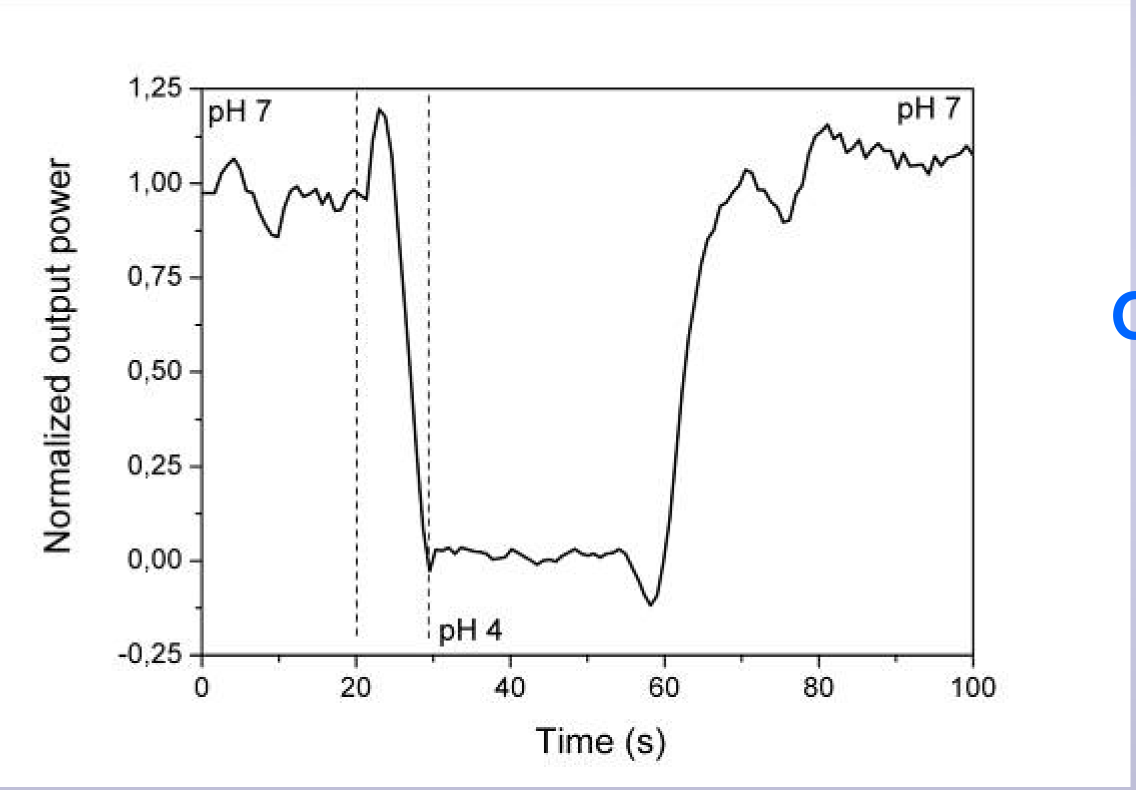
buffers



pH <6; 9> resolution 0.2; pH <5; 6> resolution 0.5 (pH meter ±0,08)

Local pH detection in microsamples

Time response (10 s)



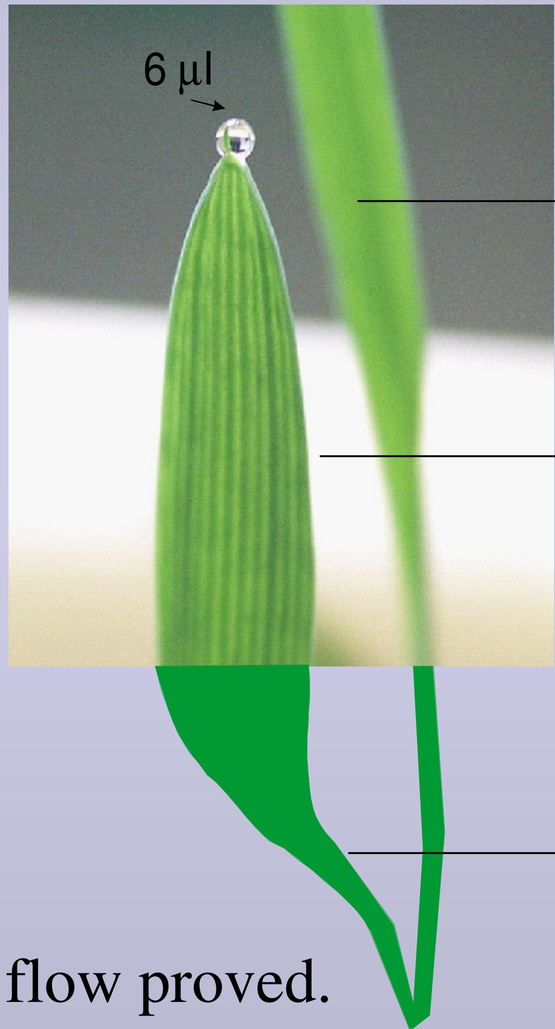
Validation

	exudate
Opticaly	**conventionaly**
5.6	**5.3**
5.5	**5.0**

within experimental error

Local pH detection in microsamples

Implementation for pH detection of drops (**6 µl**) of xylem exudate of oat



pH drops	pH volume
5.0	5.4
5.6	5.4
5.5	6.0

No gradient of xylem flow proved.

SUMMARY

1. Fiber technology : preparation of structures of high preciseness from materials of ultra-high purity (impurities in ppbs only). Two steps : preform preparation and fiber drawing.

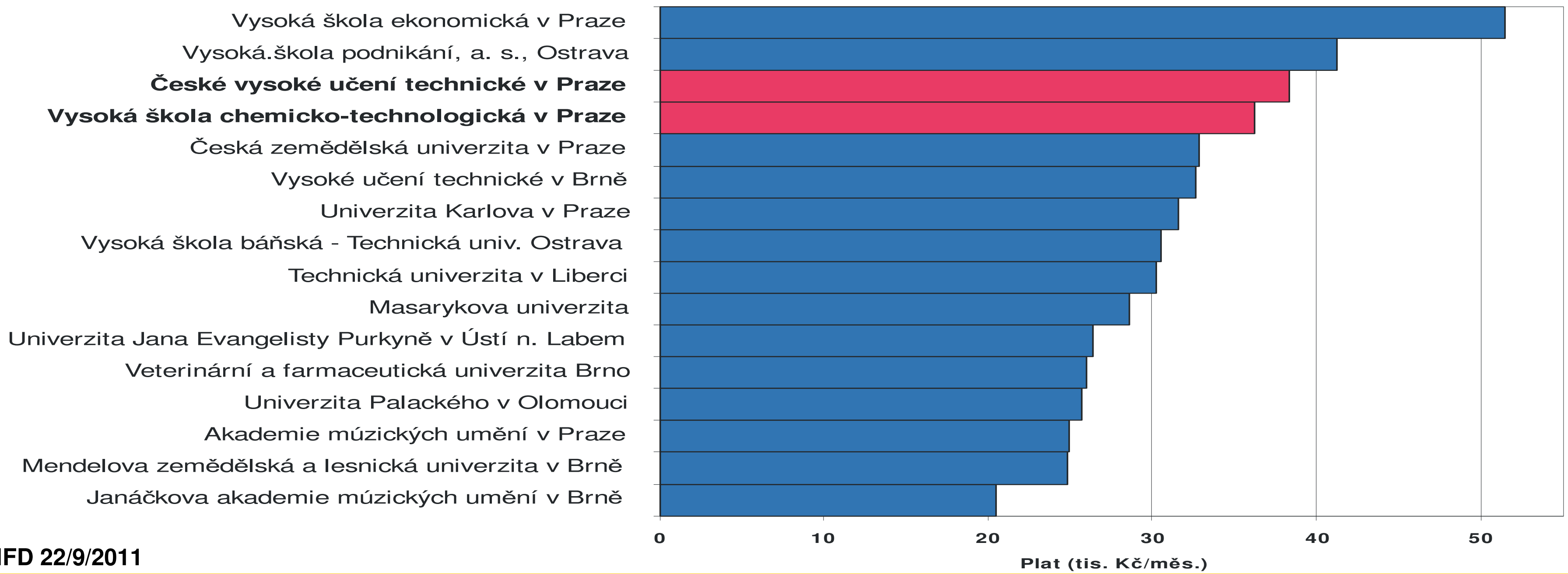
2. Despite of long history of optical fiber sensing, the field is still under development (hot topics – news ~each 3-4 years)

3. Challenges : intracelular & (bio)detection, hydrogen (fuel), distributed environmental monitoring … ?

I TY se staň UFEm !

UPLATNĚNÍ V OBORU

Příjmy absolventů VŠ po 5 letech praxe



MFD 22/9/2011

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