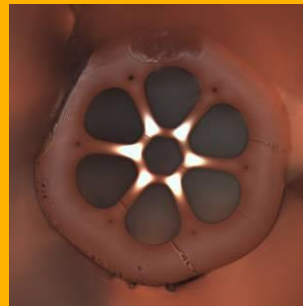
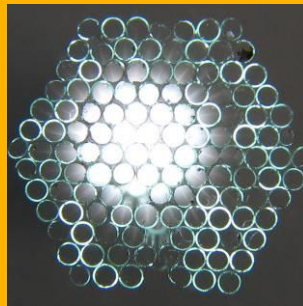




ÚFE

Kouzlo optických vláken a vláknových laserů

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



ÚFE

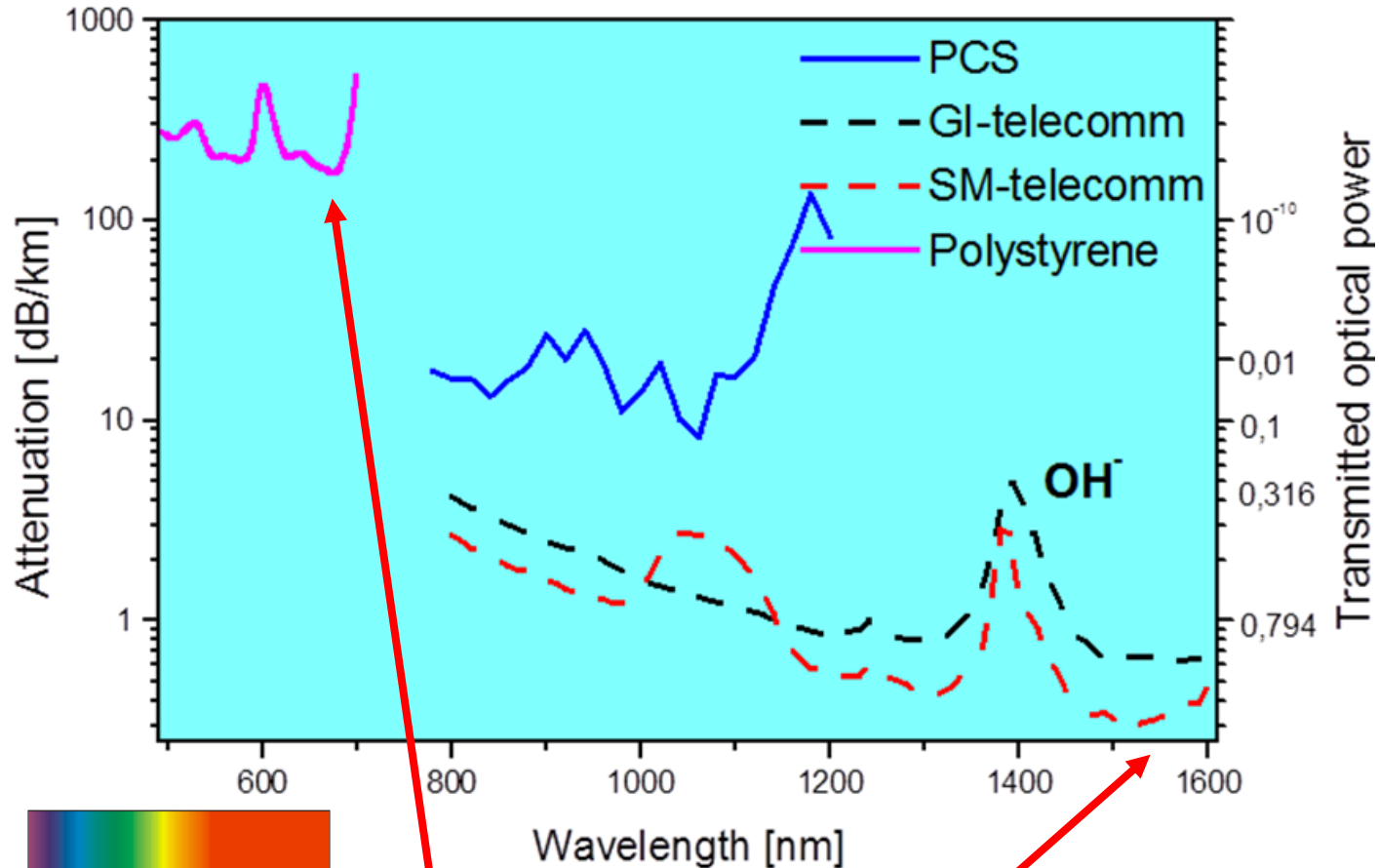


www.ufe.cz

Optical fiber

Dielectric structure, $L \gg r$, $n_{\text{core}} > n_{\text{cladd}}$

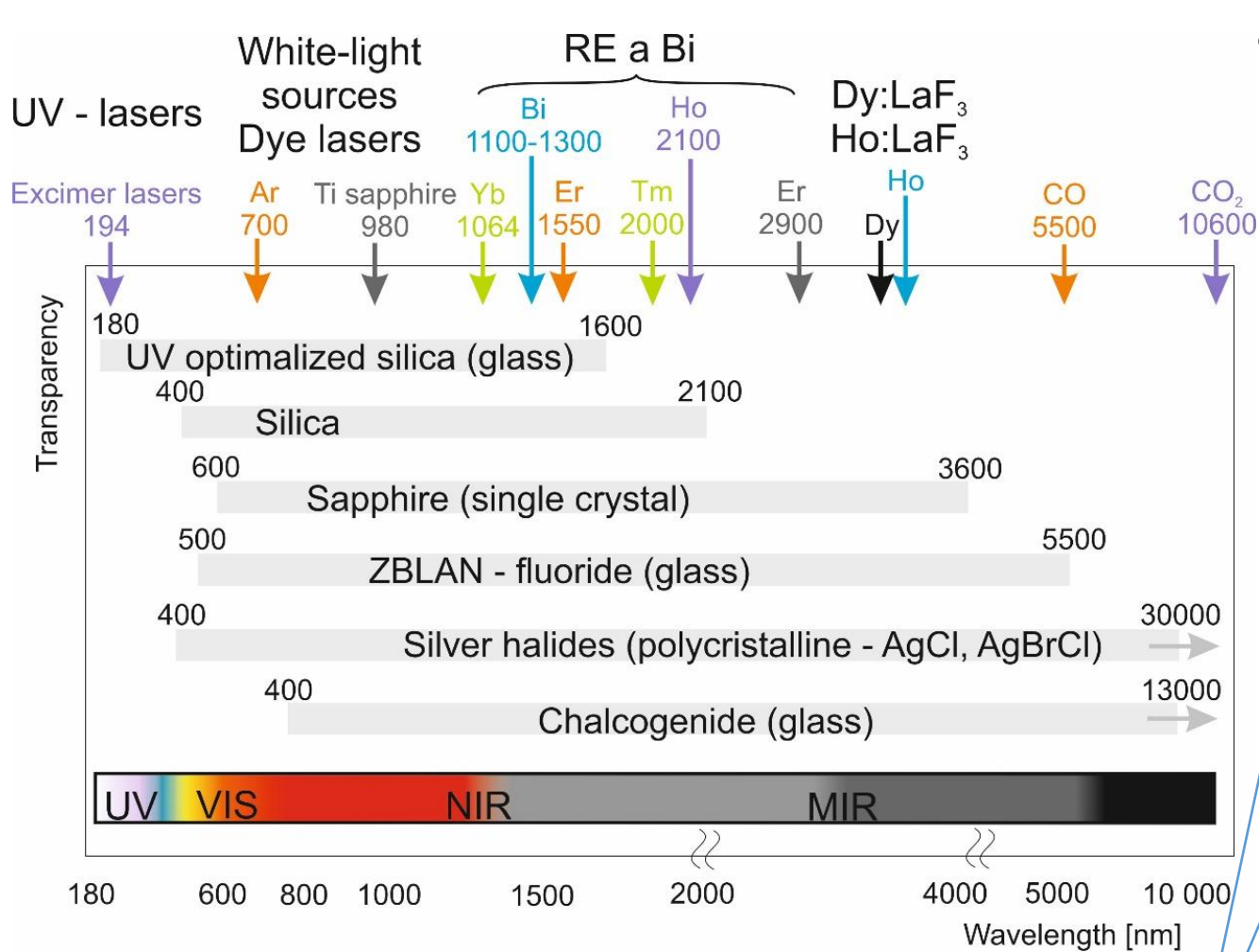
Total reflection



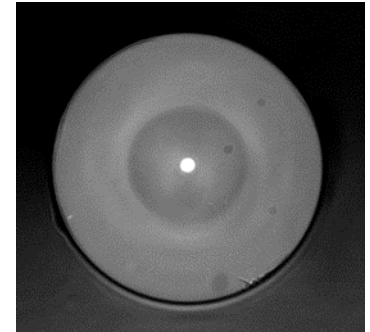
Intrinsic losses

Silica RI = 1,457

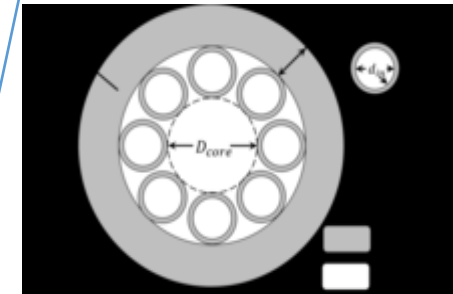
Optical fibers



Solid core



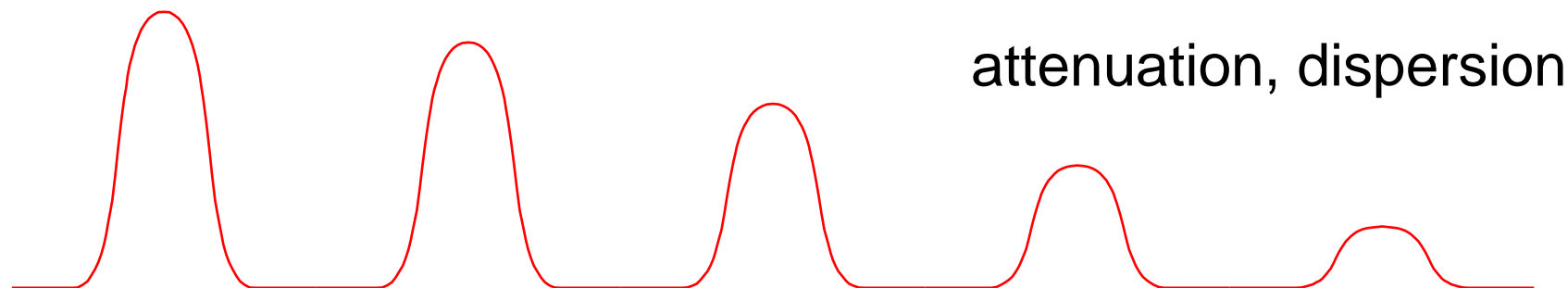
Hollow core



[Komsomol]



Optical fiber : material of high purity



Optical losses in optical fibers

- transparency of 3 mm of window-glass \approx 2 km of optical fiber



Charles K. Kao

**Nobel prize
2009**

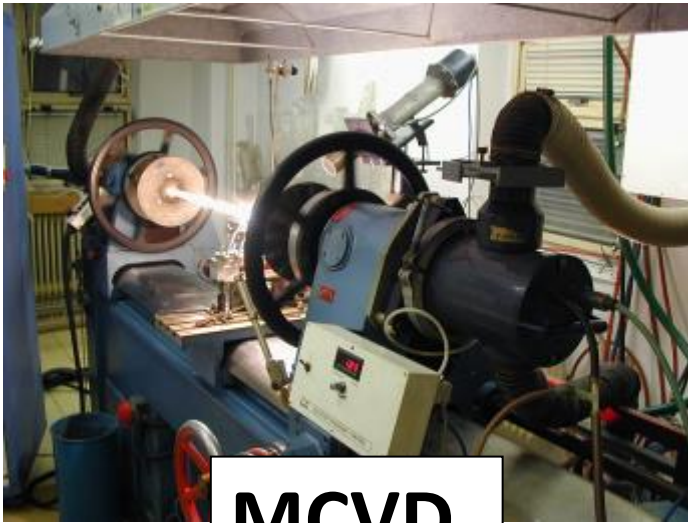


**high-purity materials
max impurities
acceptable in ppb (10^{-9})**



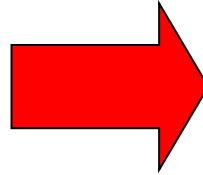
ULTRA-PURE TECHNOLOGIES

Optical fiber technology

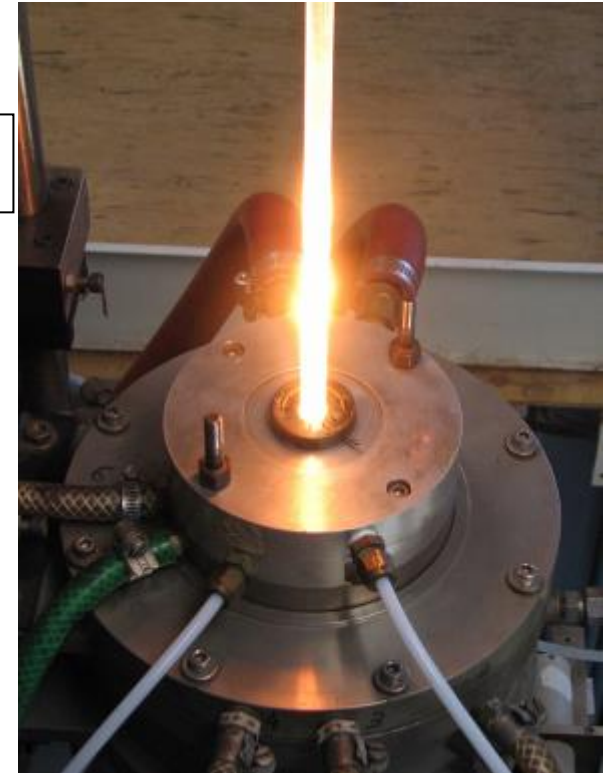


MCVD

1. Preform



2. Fiber drawing

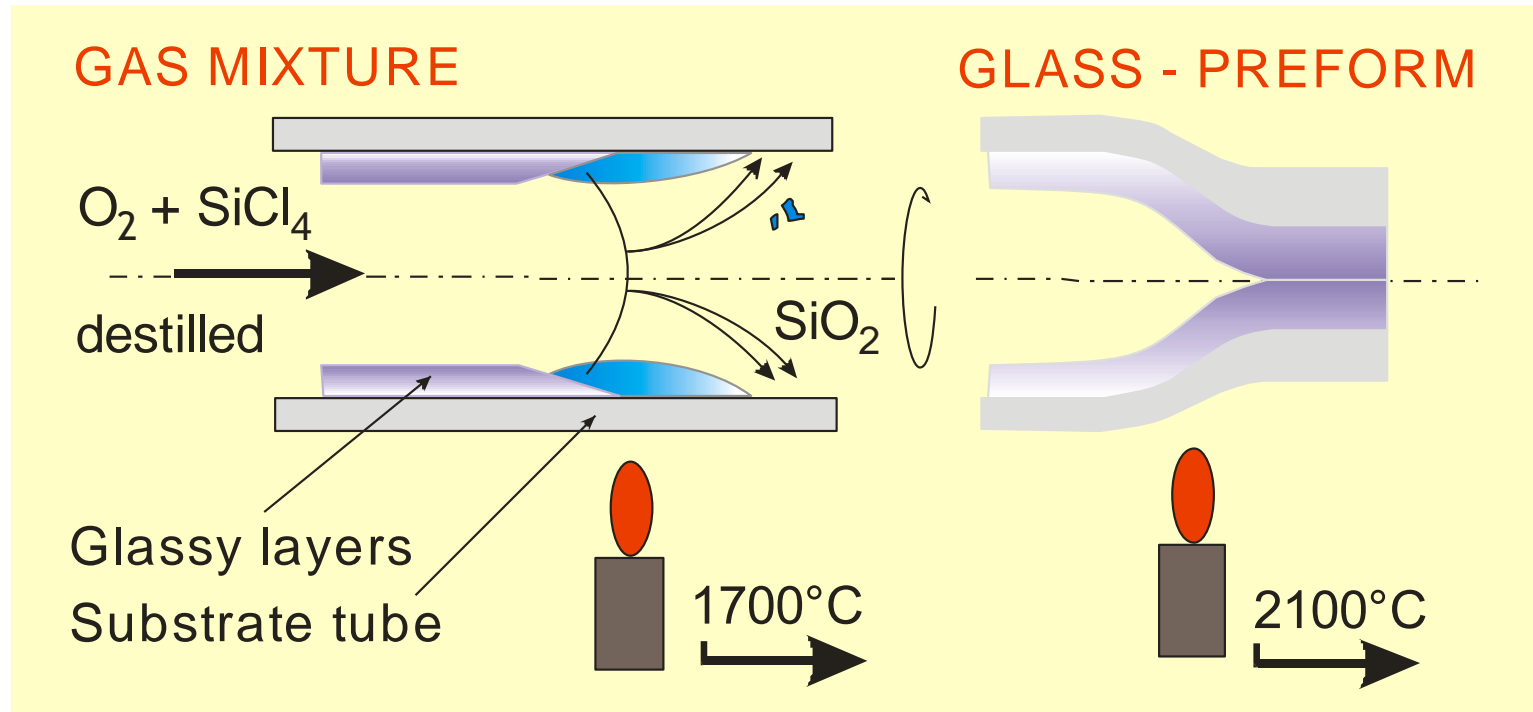


Preform fabrication

MCVD – (Modified) Chemical Vapor Deposition

1. Deposition of layers

2. Collapse



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

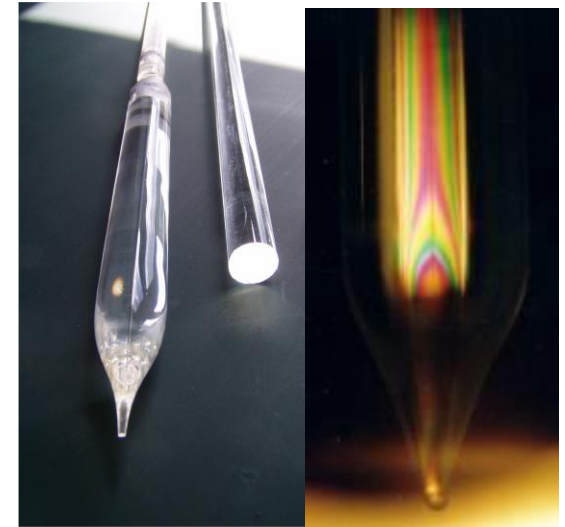
Preform fabrication



Distilled
halogenides

Deposition
of layers

Preform
collapse

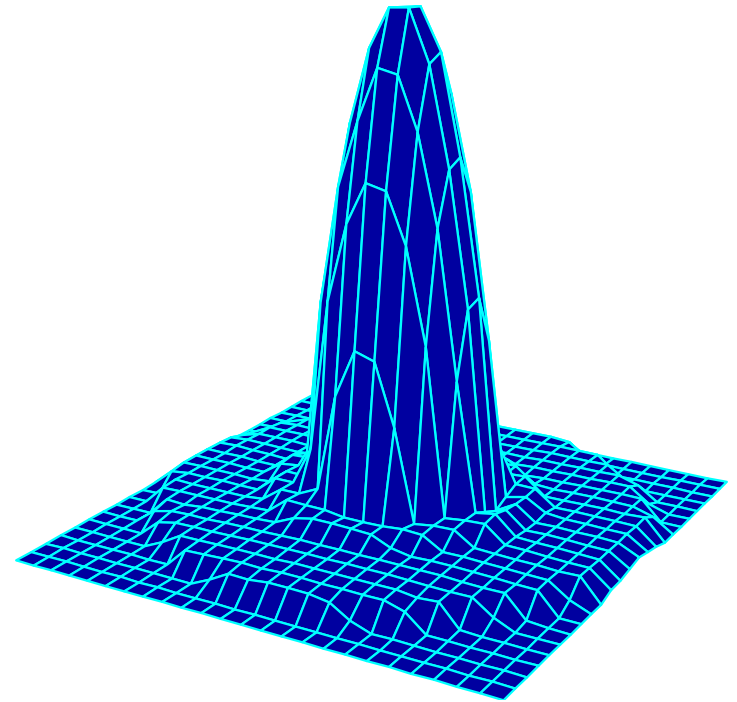


Preforms

Preform fabrication



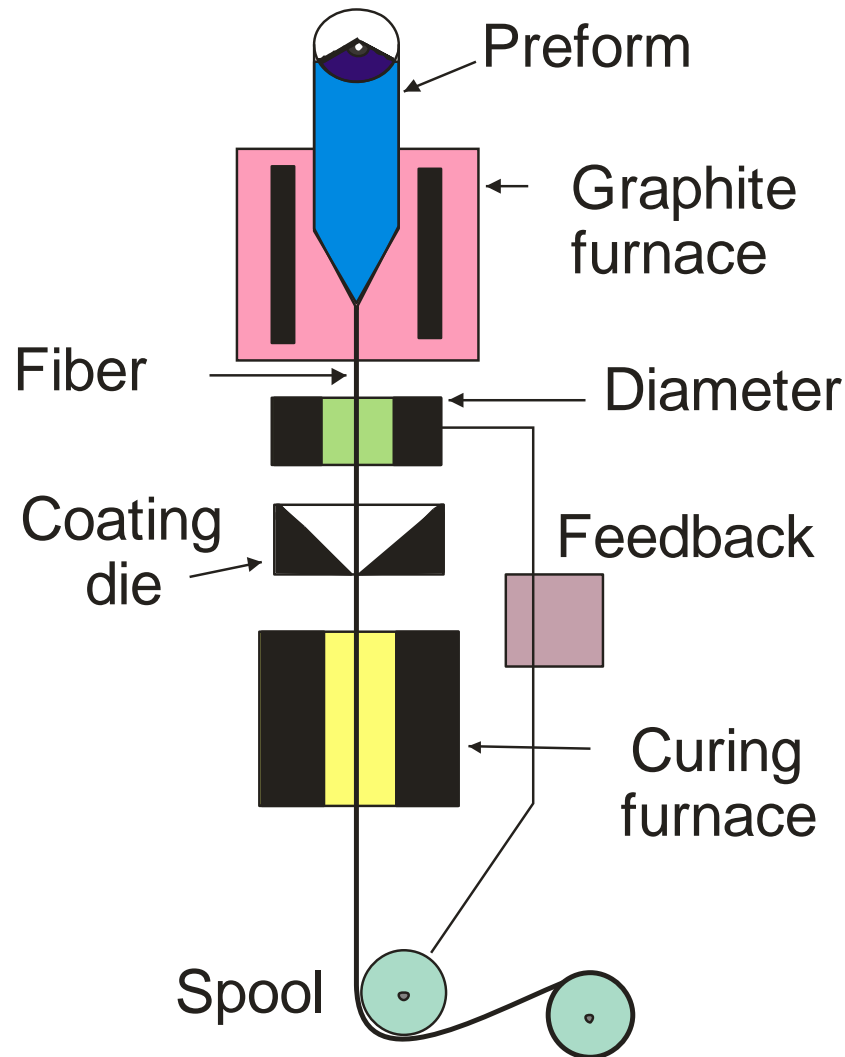
Microphoto of cross section of produced preform



Tomography of the refractive-index profile of preform

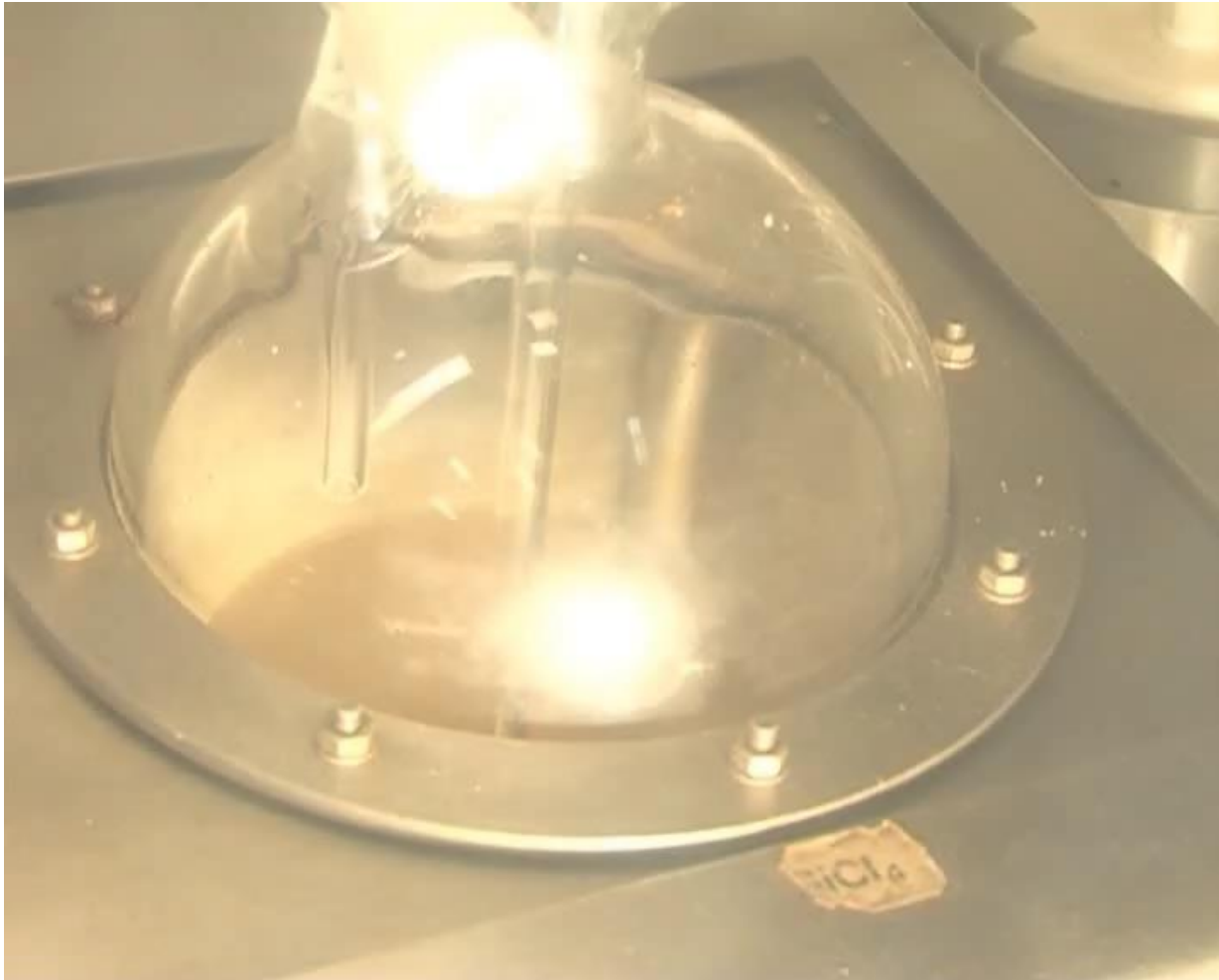
- High purity material thanks to FO-Optipur purity starting mats.
- High quenching rate ranging from 10^2 to 10^3 °C/s.

Drawing of optical fibers from preforms



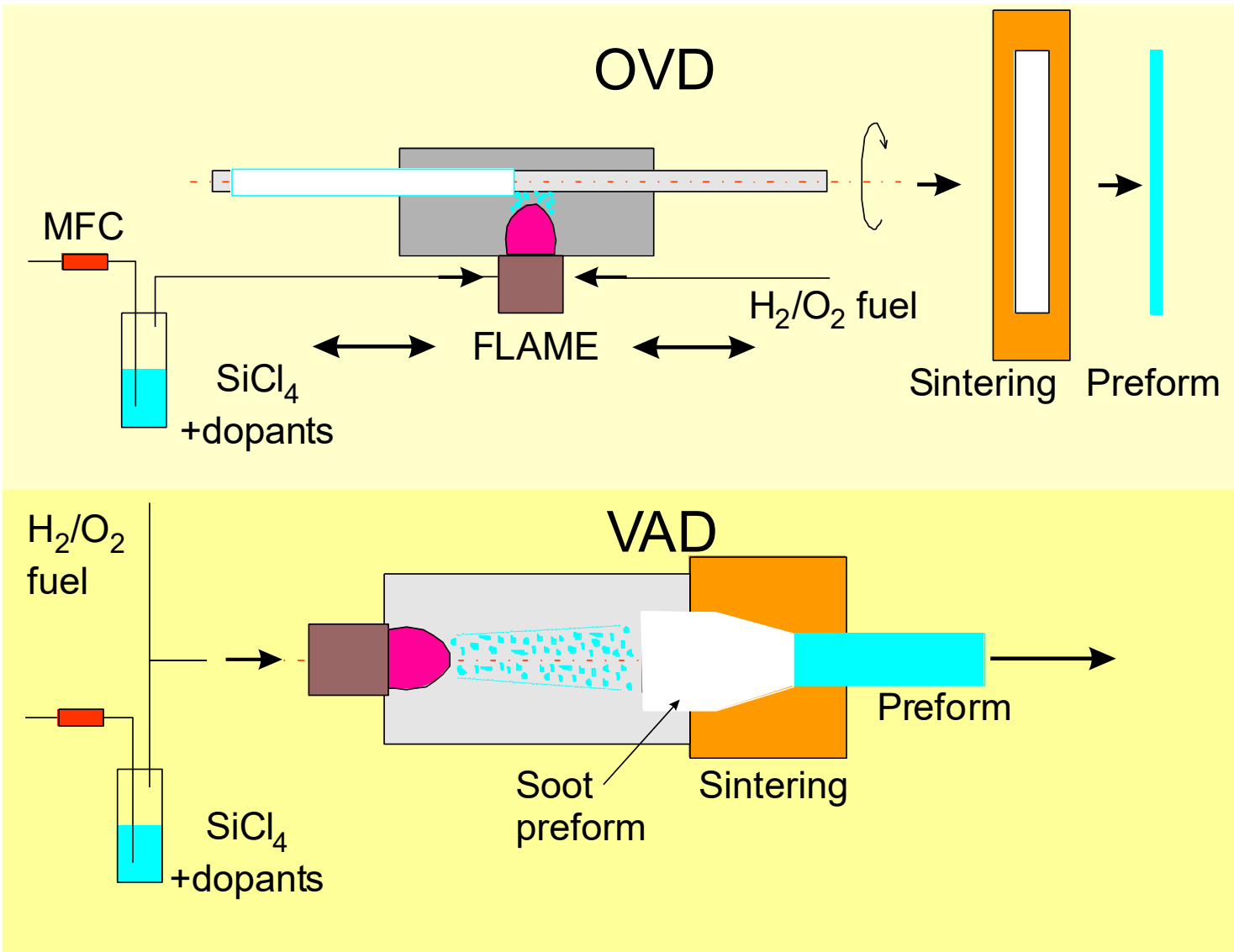
- Diameter
- 80-1000 μm
- Temperature
- 1800-2100 $^{\circ}\text{C}$
- No textile
- No thermo-insulation

Optical fiber drawing

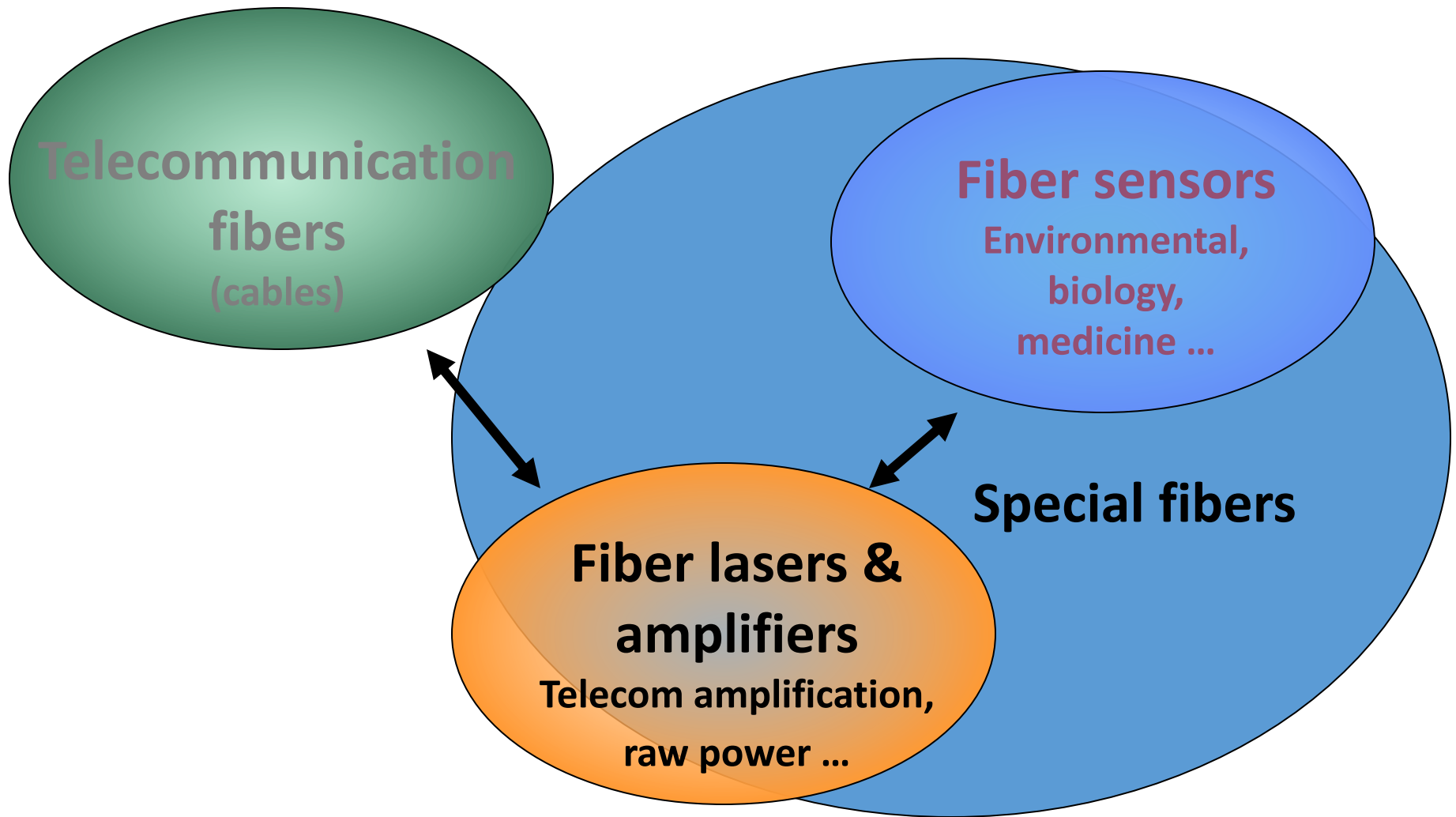


[J. Šerých & students of SPS SD Panska]

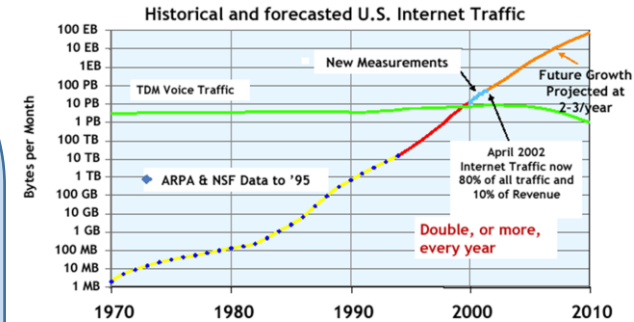
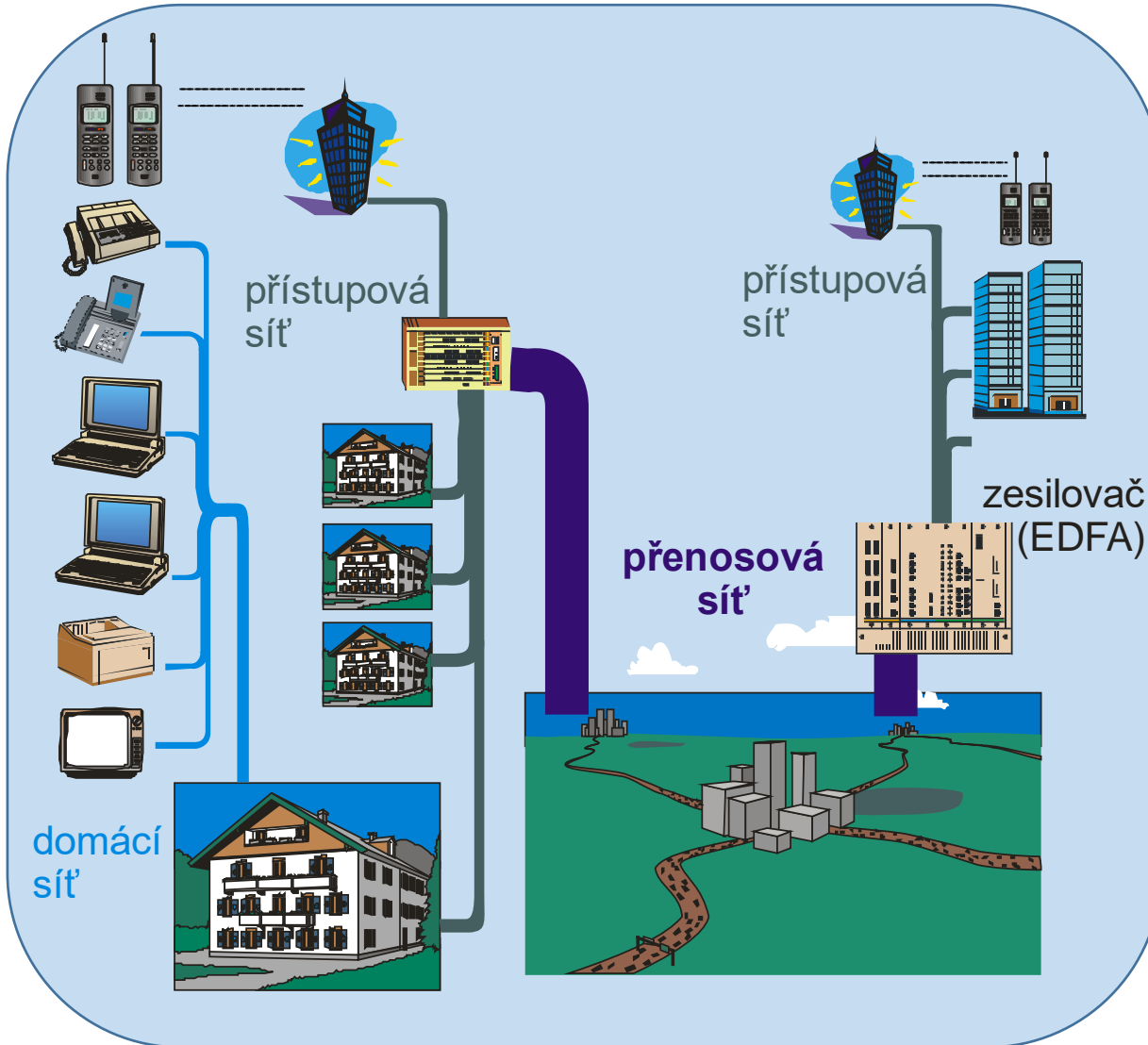
Other CVD technologies



Application



Telecomm – optical communication



Y axis = Log

~2017 O₂ 40Mbps

~2022 O₂ 1Gbps

vers.

Sat 2021 O₂
3000Kc/month

=> Full optical
processing

Telecomm – optical communication



[P. Peterka, JMO, 2015]

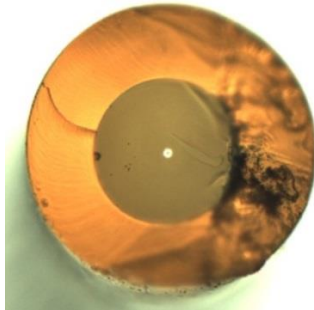
1966 : free space optical transmission
Kobylisy (ÚŘE) – Novodvorská (VÚST)
1983 : **optical fiber** transmission
Karlův most (Česká televize)



36 [kB/s] => [TB/s]
Full optical transmission & processing

Telecomm – optical communication

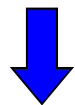
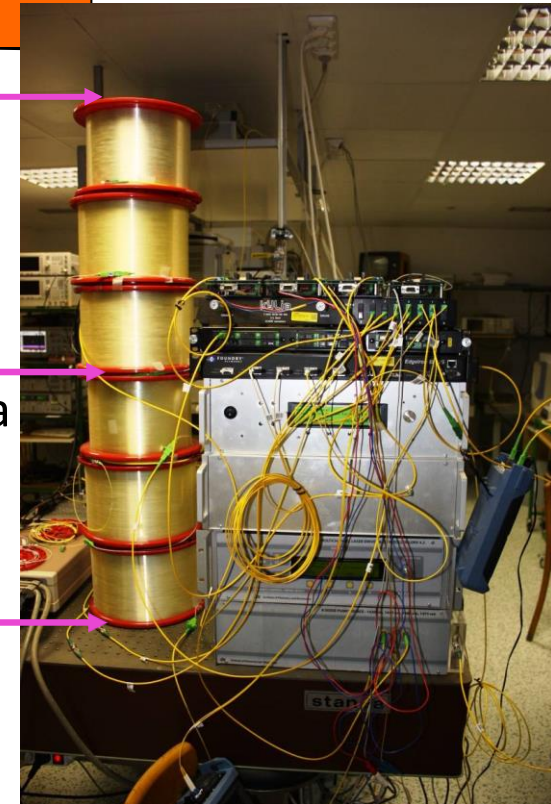
Passive (transmission) & **active** (amplification, sources) fibers



Praha

Jihlava

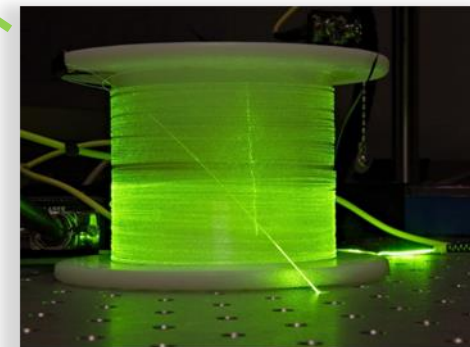
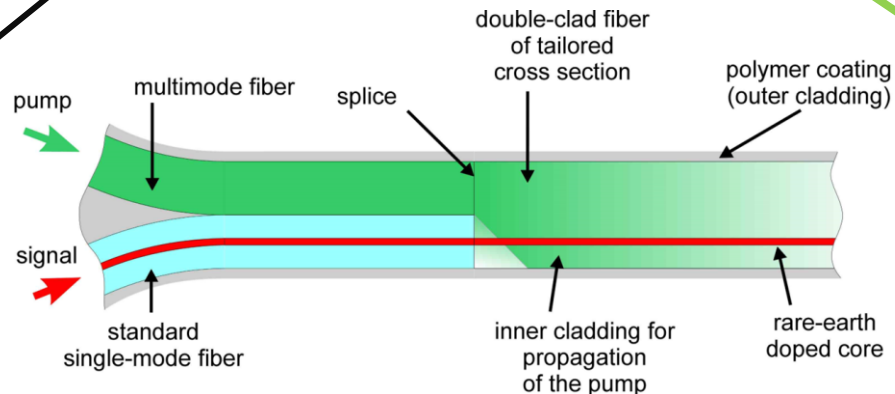
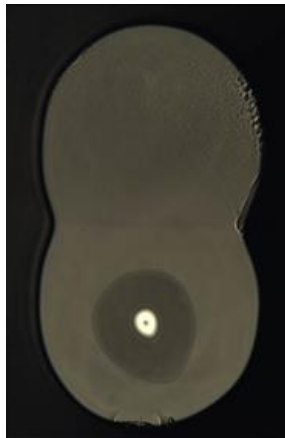
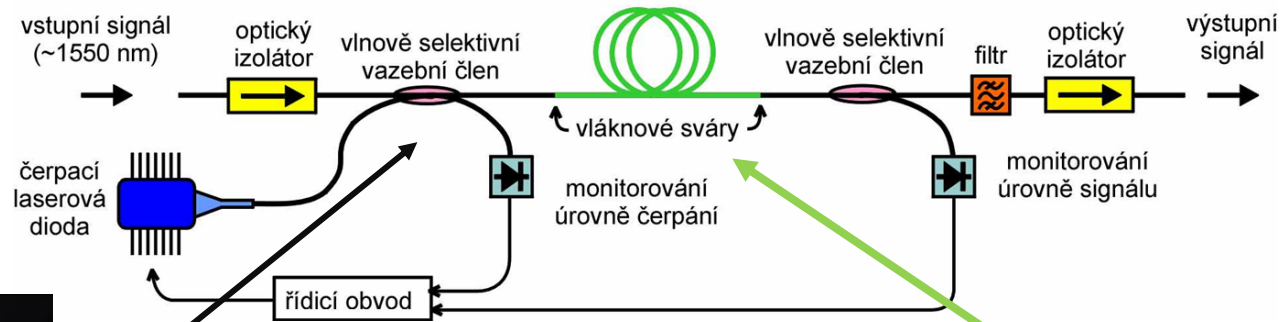
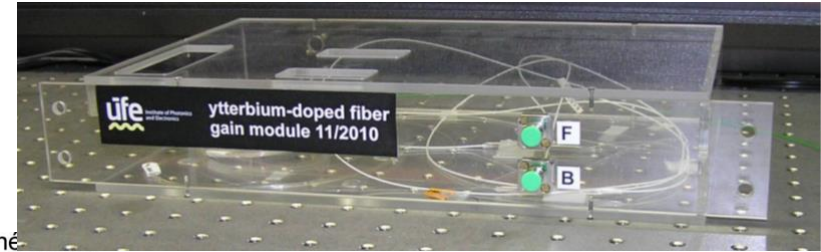
Brno



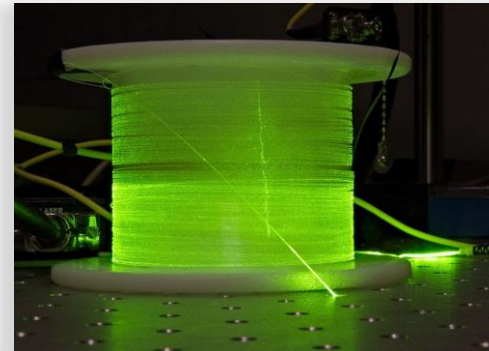
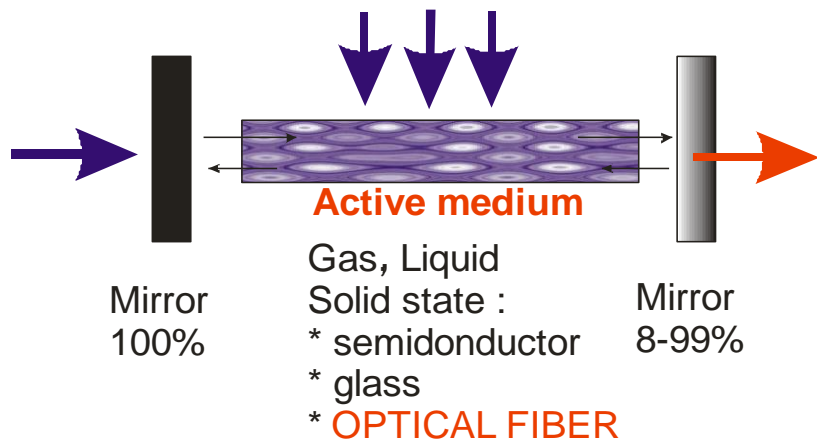
Fiber amplifier (FA)
Fiber laser (FL)

Fiber amplifiers (EDFA - Telecomm) [mW]

1550 nm



Fiber lasers (& amplifiers)

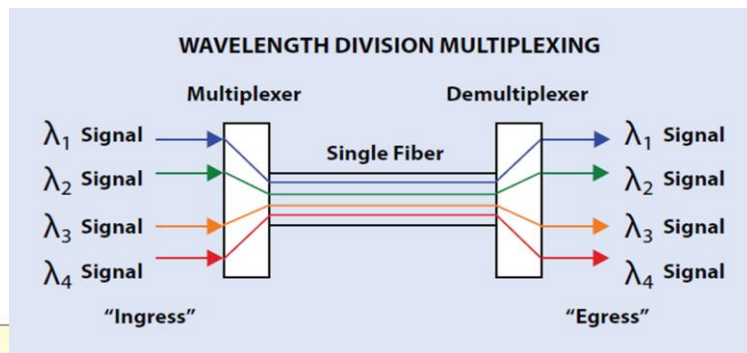


Er³⁺ 1550 nm
RARE EARTHS
Stimulated emission

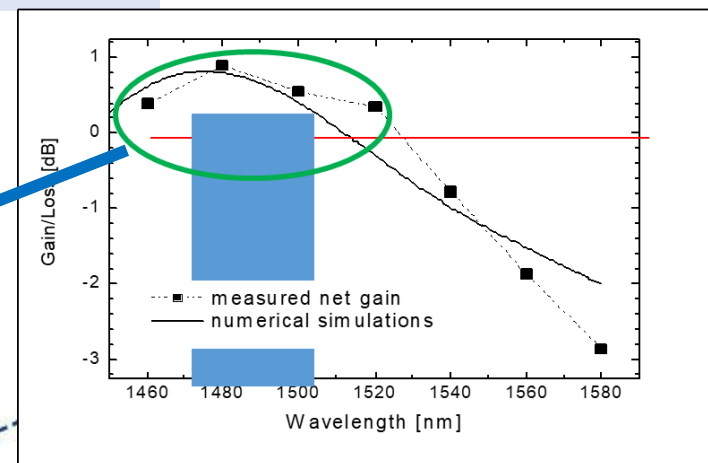
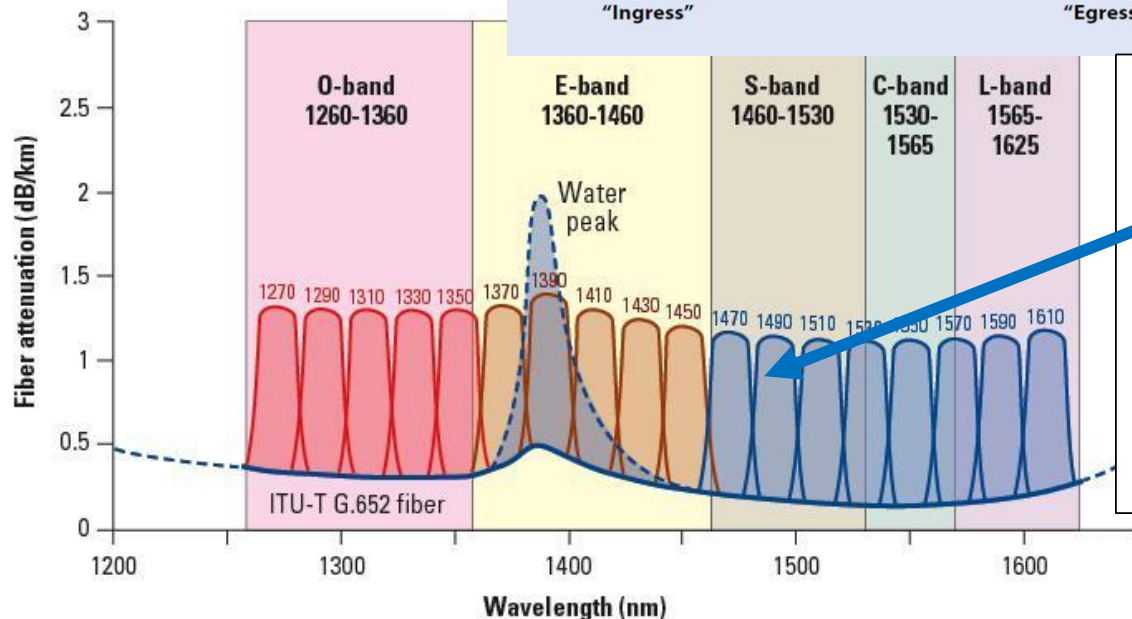
[C.J. Koester, E. Snitzer, Appl.Opt. (3) 1964, 1182] , [S.B. Poole, J.Lightwave Tech. LT-4 (1986), 870], [E.Desurvire, J.Lightwave Tech. LT-7 (1987), 835]

Fiber amplifiers (telecomm [mW]) => Full optical processing

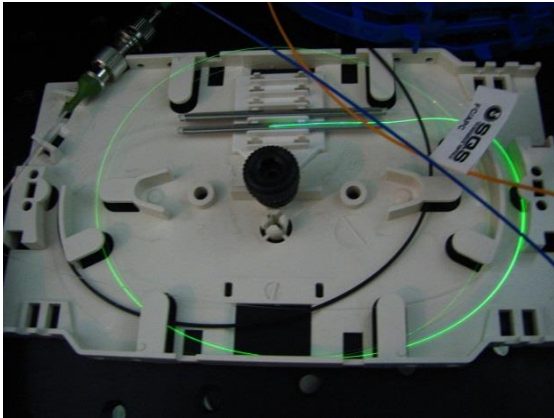
Wavelength Division Multiplexing (WDM)



Tm³⁺ TDFA



Fiber lasers [mW] → [kW]



Er/Yb - fiber laser \leftrightarrow 10 cm



[IPG photonics.com]

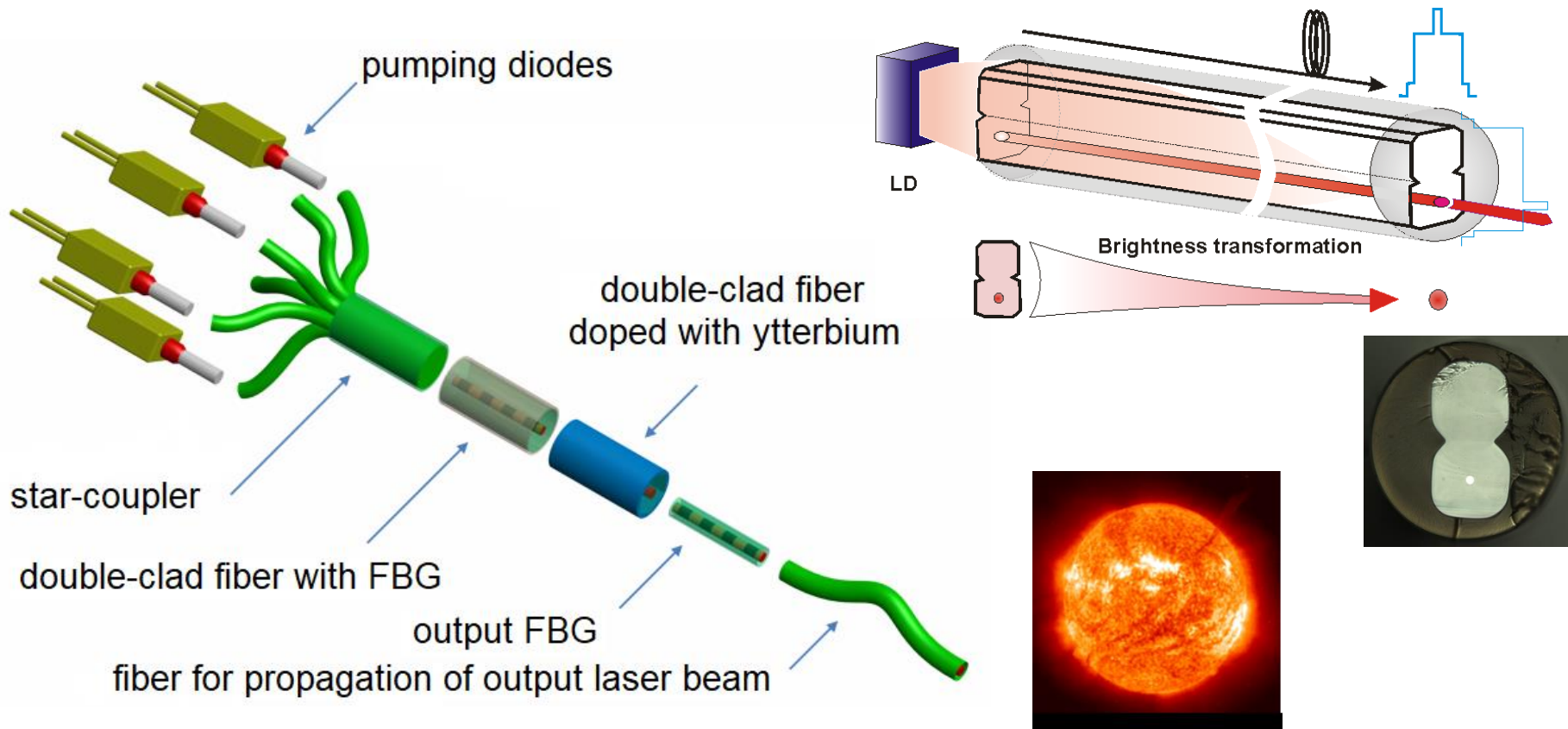
Welding, cutting ~ 2kW

IPG Photonics CW 40- 100 kW / 10 μm^2

~ ELI Beamlines



Fiber lasers - specialty (DC) optical fibers



sun	63 MW/m ²
fiber laser	12.7 GW/m ²

SUMMARY

1. **Fiber technology** : preparation of structures of **high preciseness (<1%)** from materials of **ultra-high purity (impurities in ppb 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 : special case of Solid State Lasers (SSL).**

I TY se staň UFEm !

- STUDIUM

ČVUT – FJFI, FEL ...

fyzikální elektronika,
elektromagnetické pole,
mikro/opto elektronika,

UK – MFF

chemická fyzika a optika,
fyzika

VŠCHT

Sklo – anorganické nekovové
materiály



Studentské projekty

Diplomové práce

Doktorské práce



LABO – safety first

1. Příprava preforem MCVD + tažení
2. Příprava vlastního vlákna + ?



Během exkurze se, prosím, zdržte vlastní nezávislé výzkumné činnosti.

References

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- **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
- Československý časopis pro fyziku 1/2010, 4-5/2010, 1/2011
- Jemná mechanika a optika 5-6/2015
- Sdělovací technika 3/2011