Fiber Lasers and Nonlinear Optics Research Team

Pavel Honzátko

March 8, 2019

Outline

- **Introduction – mission, resources**
- **Facilities**
- **Significant achievements**

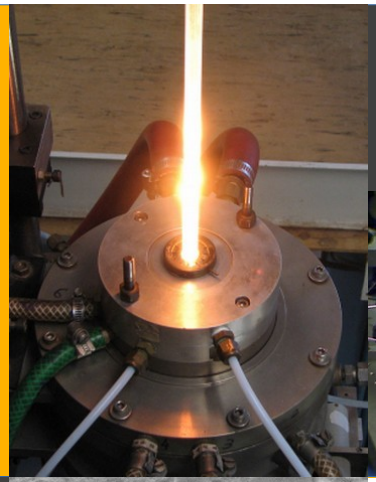
FILANO – Mission, expertise, key persons

Fiber lasers for scientific, medical, and industrial app.

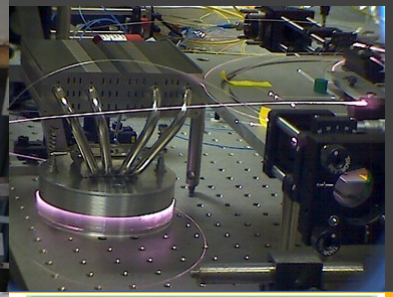
MCVD technology and fiber drawing

Active fibers
Special passive fibers

Ivan Kašík
Ondřej Podrazký



Fiber components, lasers and nonlinear optics

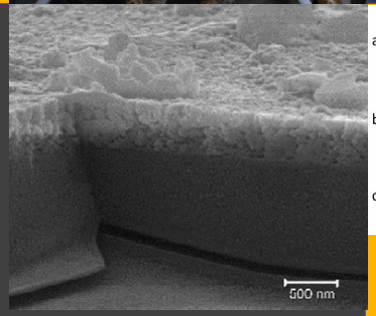


CW and mode-locked fiber lasers
Yb-, Er-, Tm- and Ho-doped fiber lasers

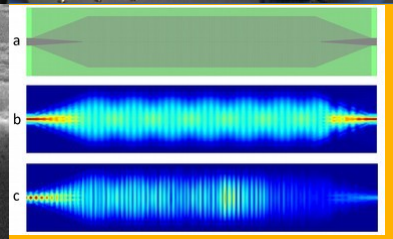
Pavel Honzátko
Pavel Peterka

Material Science

Efficient rare-earth- and nanoparticle-doped silica glasses for active optical fibers



Jan Mrázek
Vlastimil Matějec



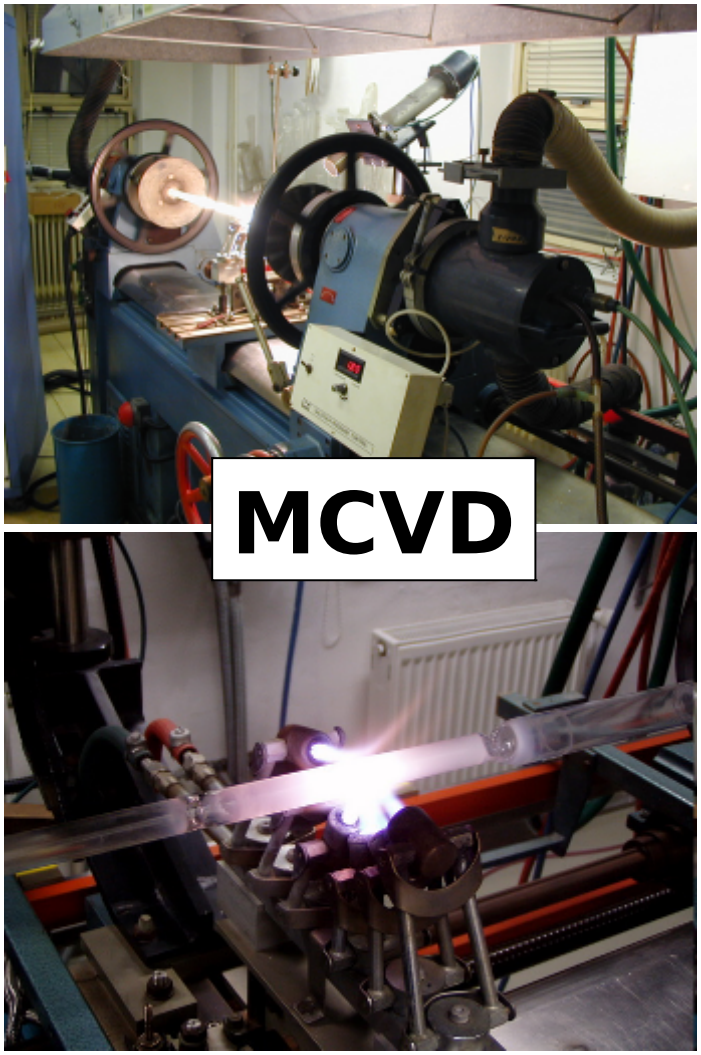
Numerical methods

Development of FMM, FDTD, FEM-BPM
Research of sub-λ structures

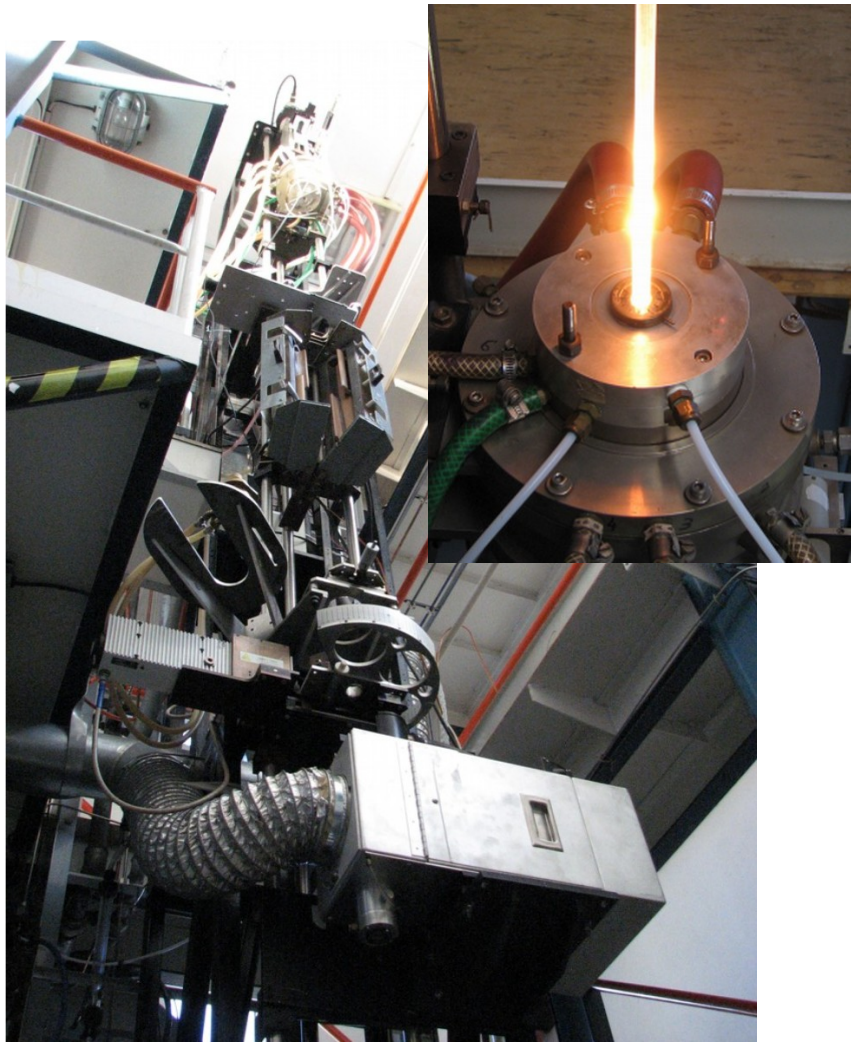
prof. Jiří Čtyroký
Vladimír Kuzmiak

FACILITIES

MCVD – preform fabrication

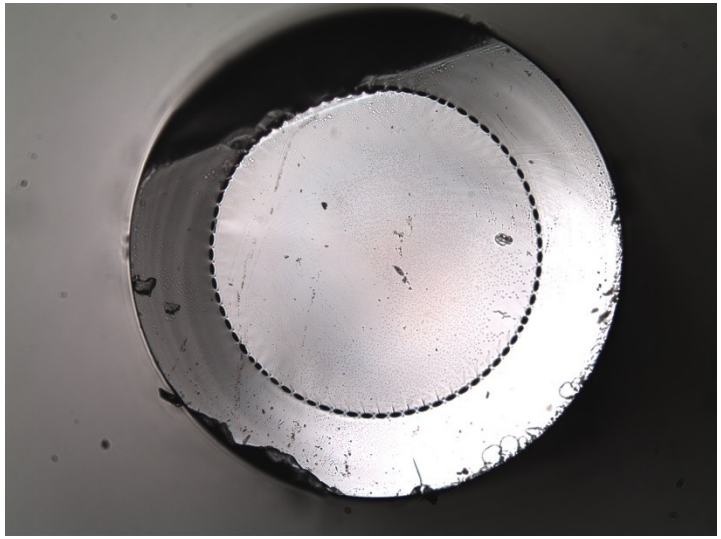


Fiber drawing



FACILITIES

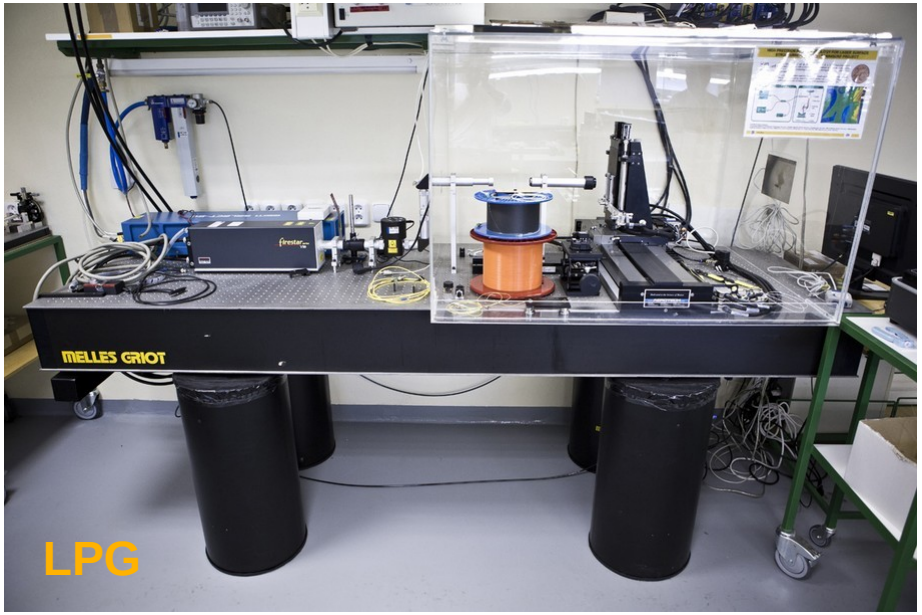
GLASS CAPILLARIES DRAWING SYSTEM



First air-clad fibre drawn in ÚFE (Ali J. Jasim, 2018)

FACILITIES

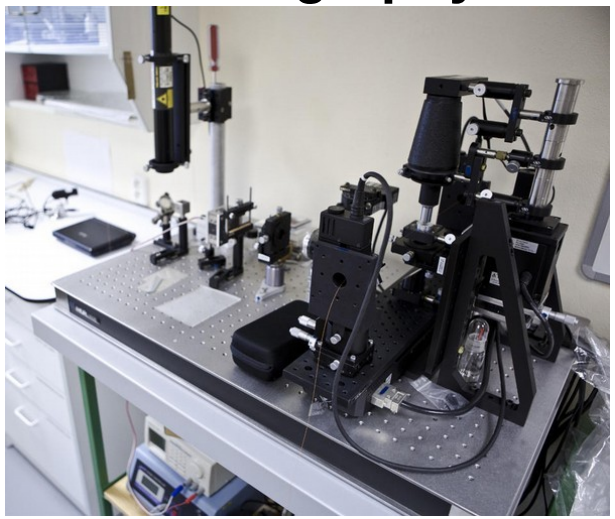
Long-periods gratings inscription



CO2 processing

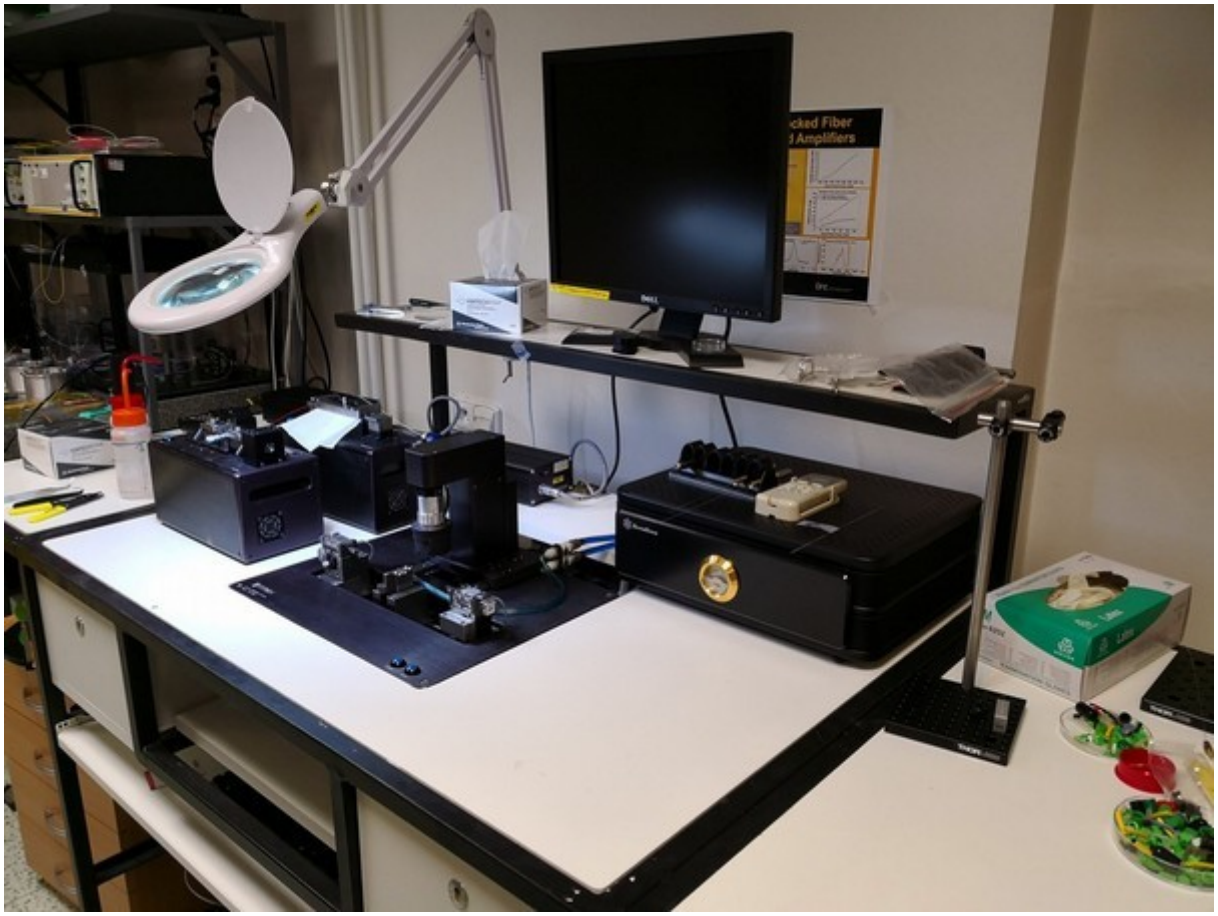
- Fibre component fabrication
- Preform shaping

Fiber tomography



FACILITIES

Vytran splicing and tapering system

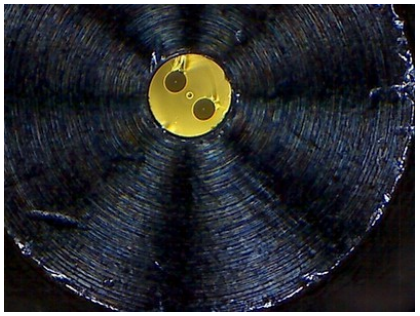


Processes:

- **Cleaving PM fibers**
- **Cleaving LMA fibers**
- **Cleaving MOF**

Splicing
400 µm fibers, R_{crit}=25mm
240 µm fibers
125 µm fibers

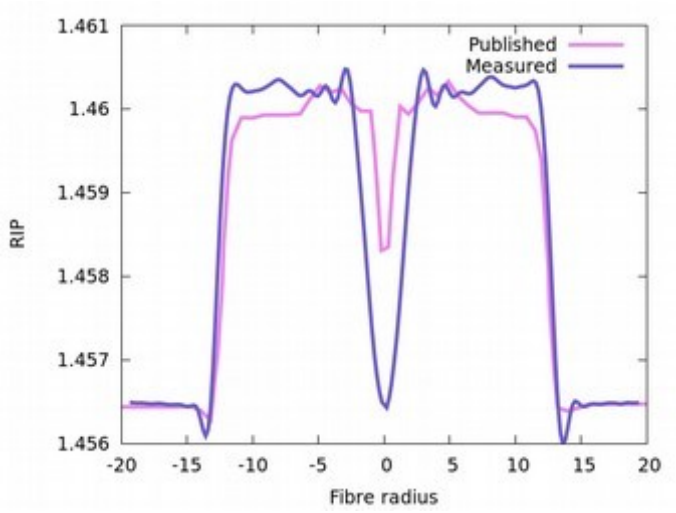
PM & Standards SMF



FACILIES

Interferometric fibre refractive index profile measurement
IFA-100, Interfiber Analysis, USA

- 1D profily až do průměru vlákna 400 um
- 2D profily rotačně nesymetrických struktur
- Měření mechanického napětí ve strukturách

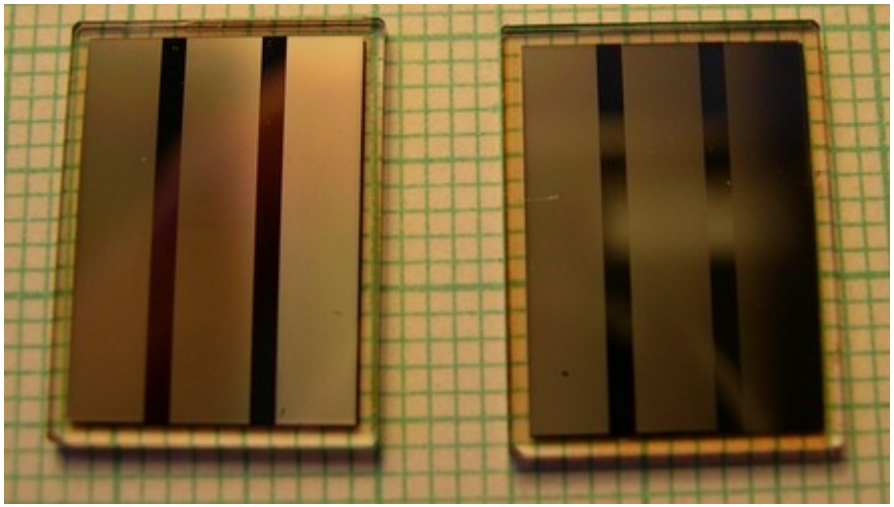


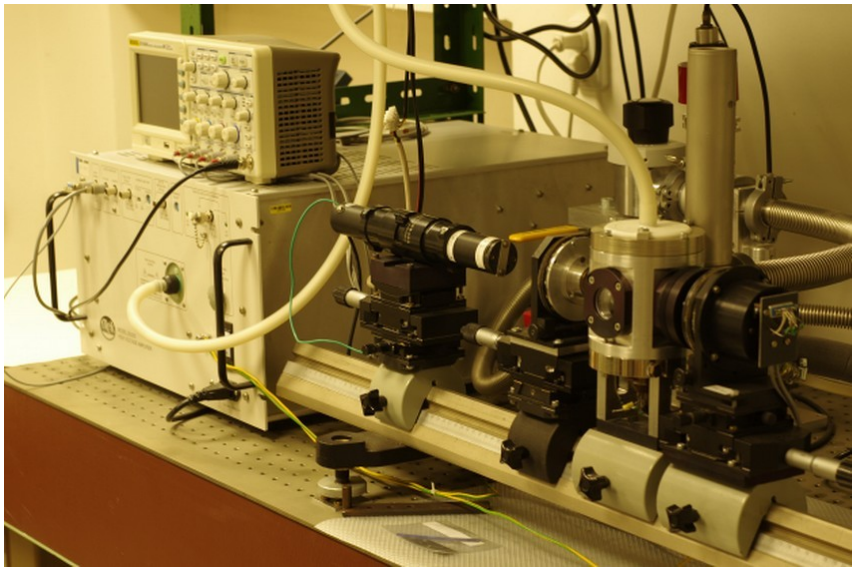
Profil indexu lomu jádra vlákna Nufern PLMA-GDF-25/400

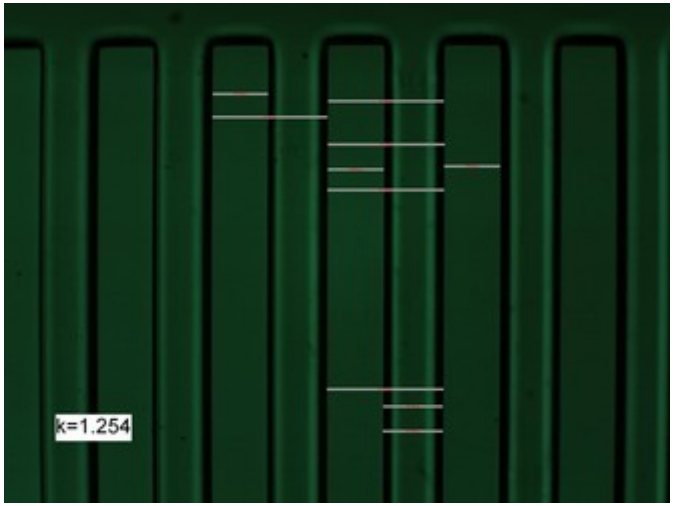
FACILITIES

Poling KTP and KTA crystals

- Nonlinear signal conversions
- Mid-infrared signal sources







SIGNIFICANT

ACHIEVEMENTS

Material science

NP doped TDF $^3F_4$ Lifetime: 756 µs

Efficient rare-earth-doped fibers

- **high doping concetration**
- **long metastable state lifetime**

Solution doping $RECl_3 . 6H_2O$

RE=Yb, Er, Tm, Ho, Sm, Dy

low miscibility of RE with silica

→ phase separation

matrix modifiers: Al_2O_3, Sb_2O_3, P_2O_5, ..

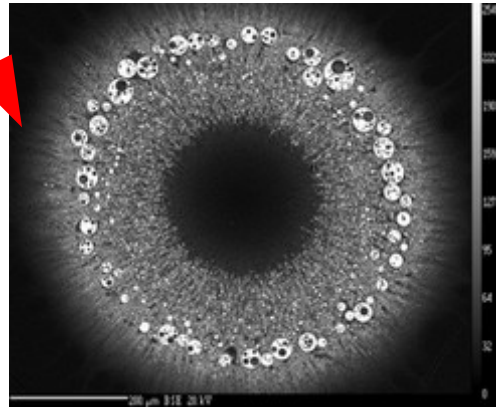
RE-doped nanocrystals

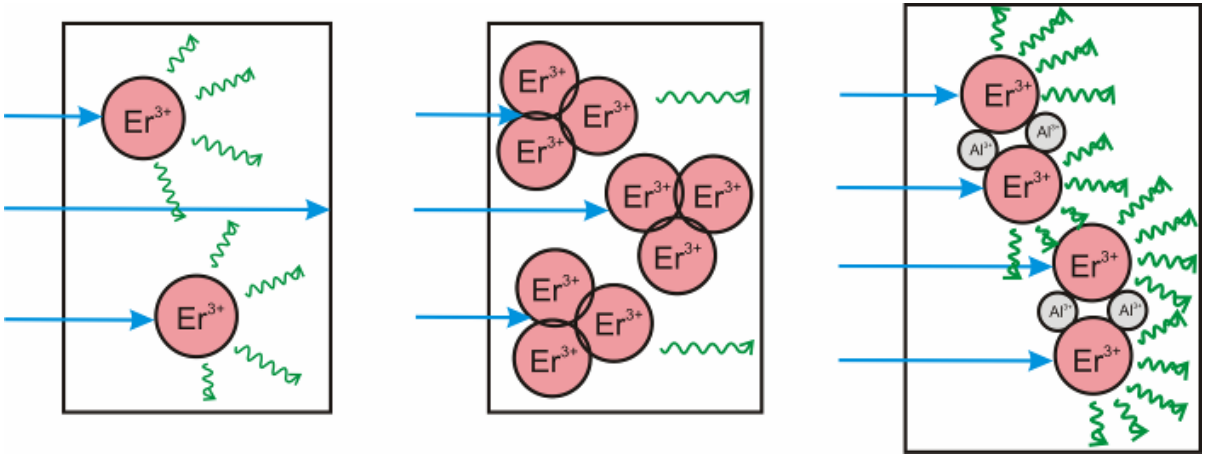
Noble metals (Watekar), SmC (Moon),

Ceramics (UFE): γ-Al_2O_3, YTO

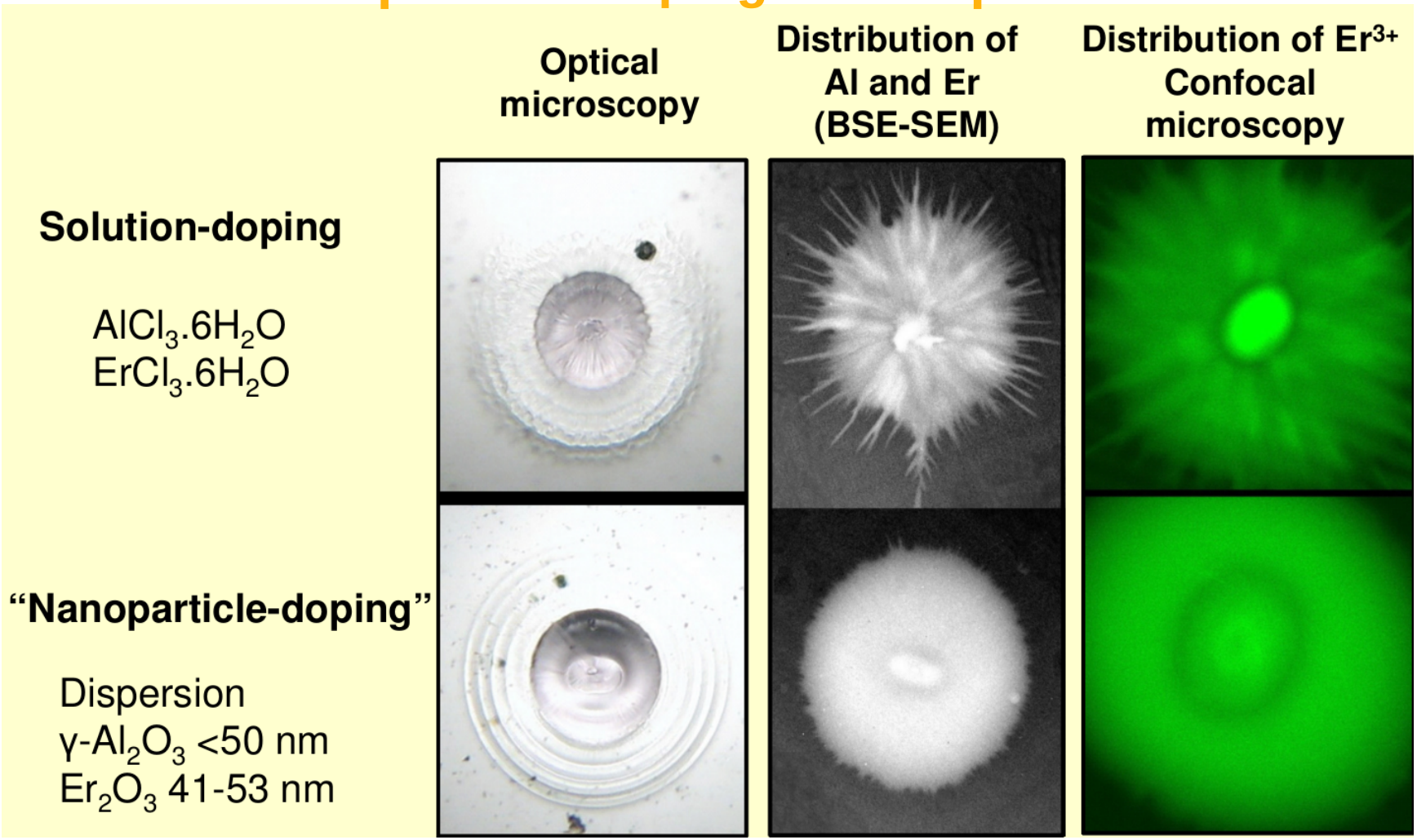
High transparency: Rayleigh scattering

$$\alpha\,(dB/m) \sim \frac{d^6}{\lambda^4}$$





Ceramic nanoparticle doping technique

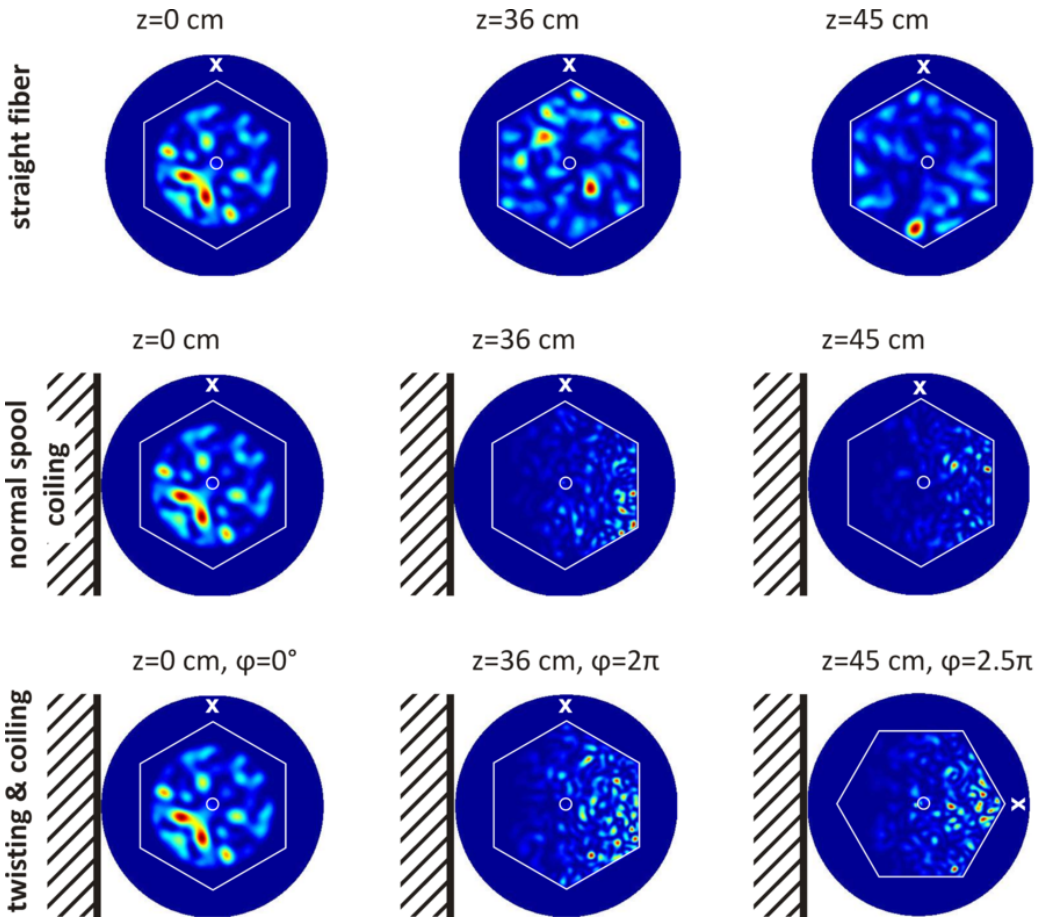


J. Mrázek *et al.*, 10 CCC Budapest 2012

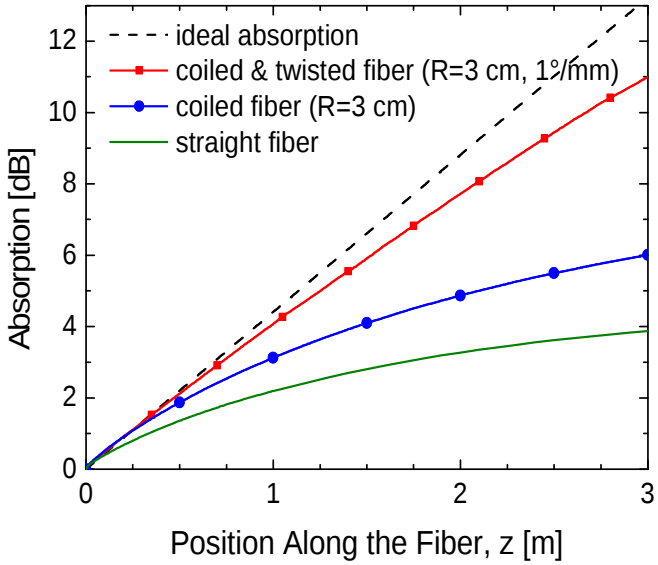
J. Mrázek, et al., Advances in Electrical and Electronic Engineering **12**, 567-574, 2014

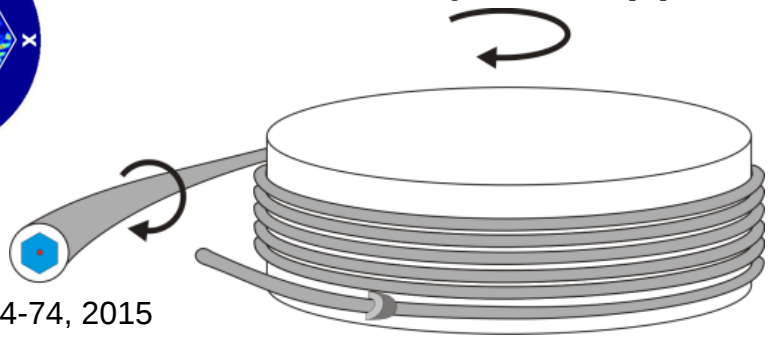
I. Kašík, P. Peterka, J. Mrázek, P. Honzátko, Current Nanoscience **12**, 277-290, 2016

Double-clad fibers with increased pump absorption



Pump absorption efficiency increased by >6 dB

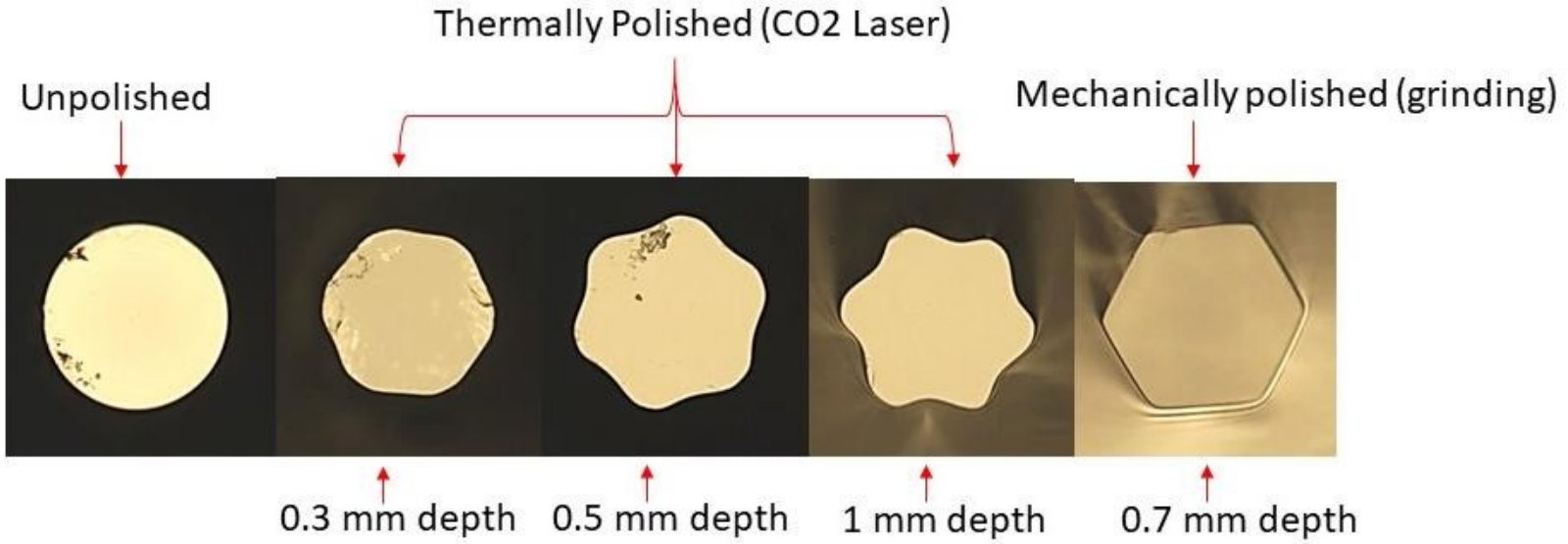




Patent pending, PV2015-72, filed 5 Feb 2015
P. Koška et al., ASSL, ATu2A.23, 2015
P. Koška, P. Peterka, et al., SPIE Optics+Optoelectronics 8775, 2013
P. Peterka, P. Honzátko, P. Koška et al., SPIE Photonics West, p. 9344-74, 2015
P. Koska, P. Peterka, V. Doya, IEEE J. Sel. Top. in Quantum Electronics, 22, 55-62, 2016

CO2 PREFORM SHAPING

- **LabView program to control the device**
- **Parameters has been found to make various shapes of double clad fibres**
- **Shaped fibres drawn with varying twisting rate**
- **Losses of coreless fibres were investigated**

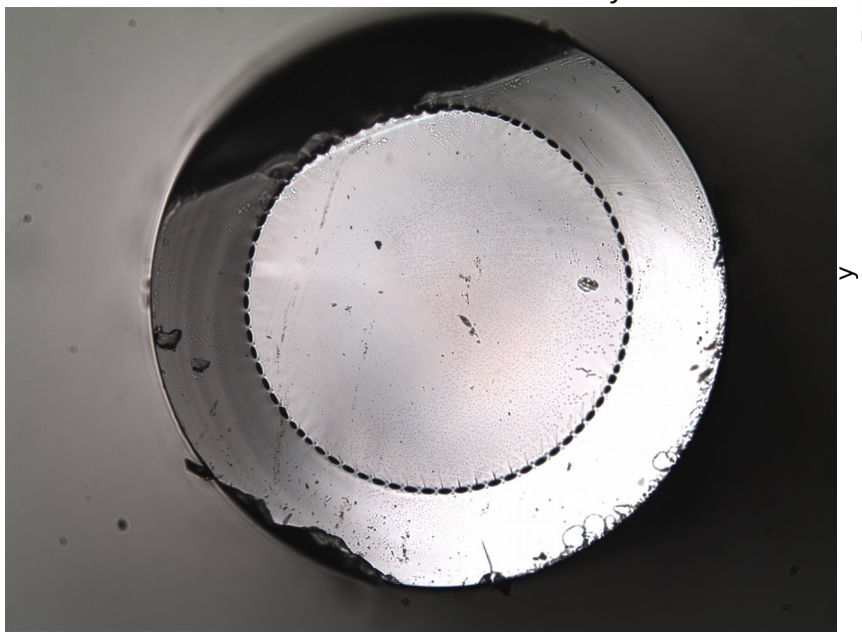


Courtesy: Ali A. Jasim

AIR CLAD AND HOLLOW CORE FIBRES

Research of air-clad optical fibres

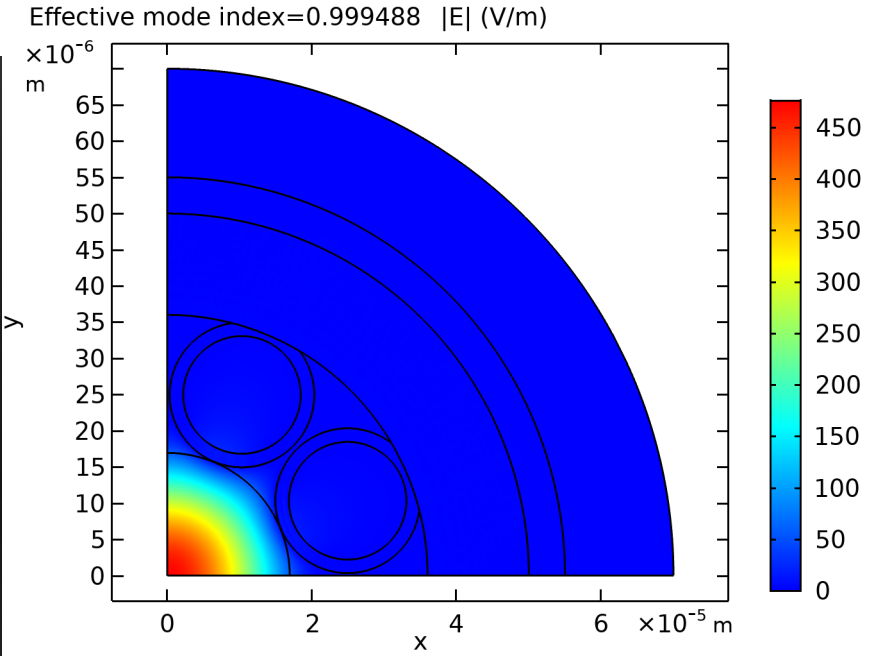
Courtesy: Ali A. Jasim



- Inner cladding with high NA in high-power fibre lasers
- High NA fibre in scintilators

Research of negative curvature hollow core fibres

Courtesy: M. Grábner



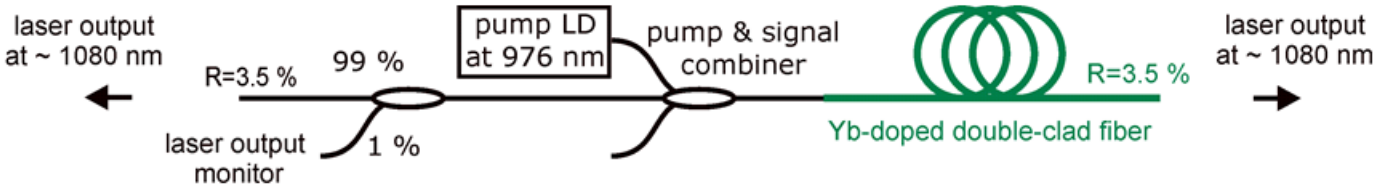
- Silica optical fibres with transmission range enhanced to UV or MIR
- Fibres for delivery of giant pulses
- Fibres for gas lasers
- Fibres for pulse compression

Fibre laser dynamics

First observation of SLLS in YDFL, EDFL, and HDFL

Spontaneous laser line sweeping – result of spectral hole burning

a)



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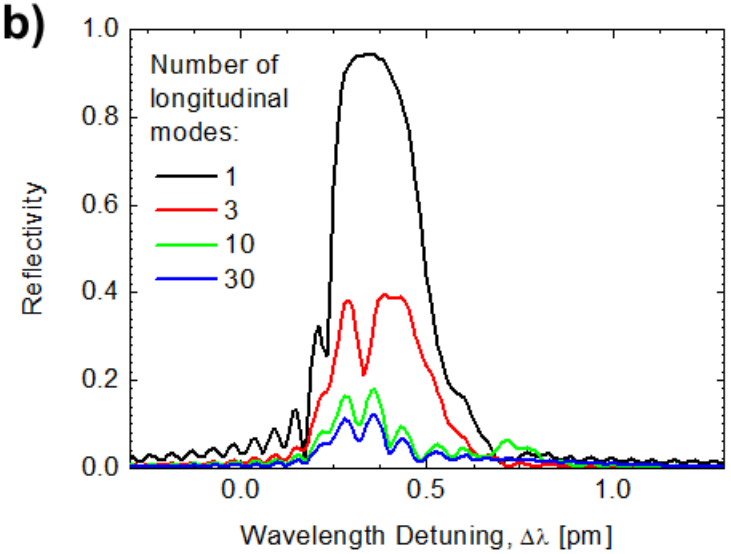
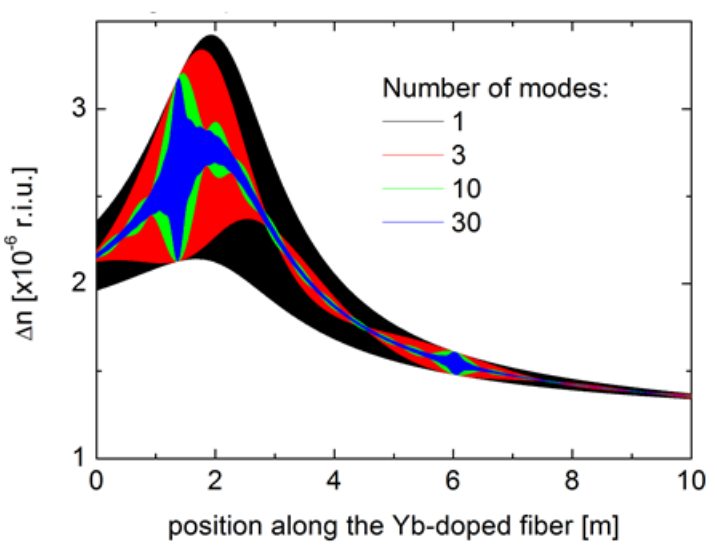


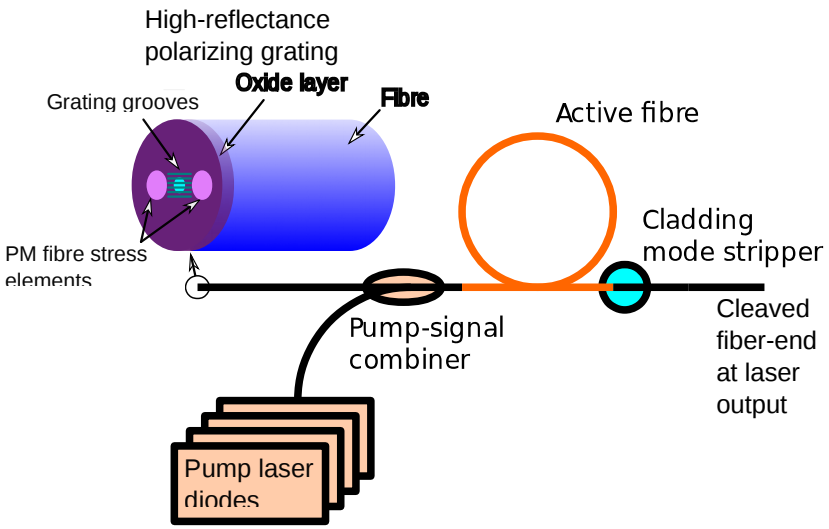
c)

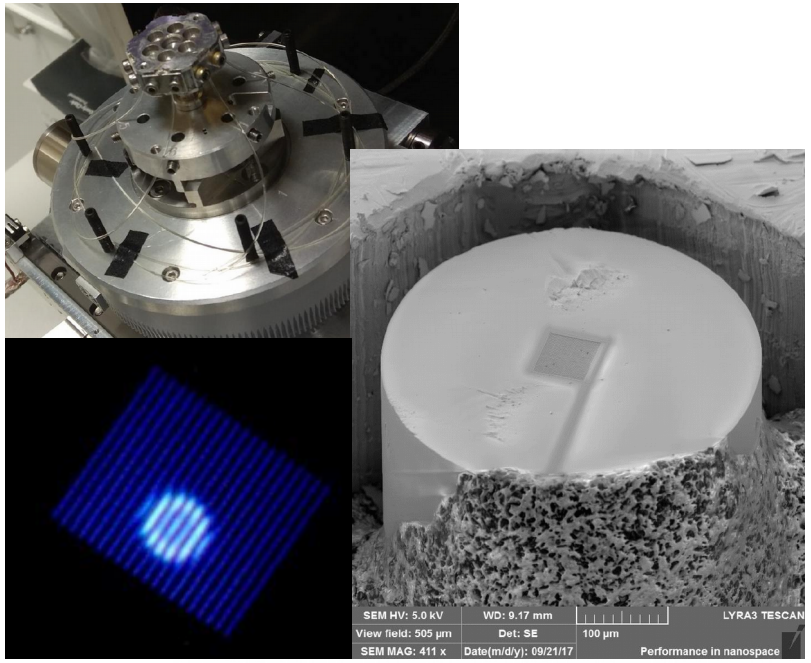


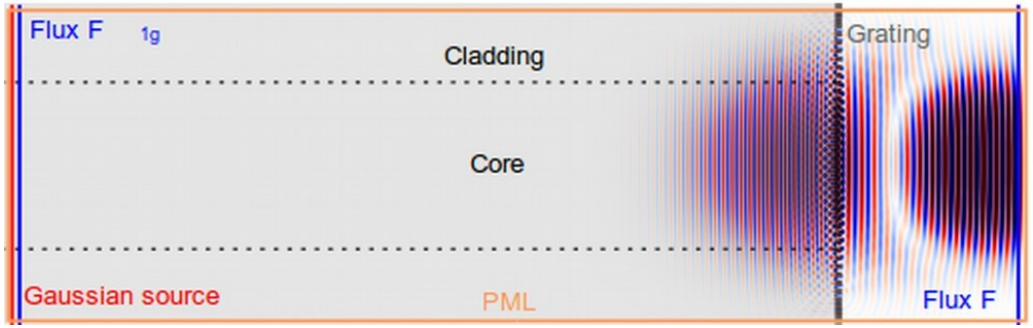
P. Peterka, et al., Laser Phys. Lett. 9, 445-450, 2012
P. Peterka, et al., Opt. Express 22:30024-30031, 2014
P. Navratil, et al., Laser Phys. Lett. 14, 035102, 2017

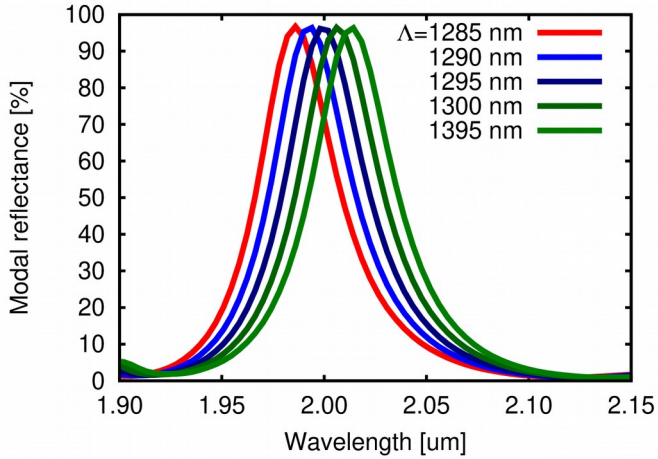
J Aubrecht *et al.*, Opt. Express 25, 4120-4125, 2017
P. Peterka *et al.*, *IEEE J. Sel. Topics Quantum Electron.* **24**(3), 0902608 (2018).
P. Navratil *et al.*, *Opto-Electron. Rev.* **26**(1), 29-34 (2018)

Diffraction elements on fiber facets







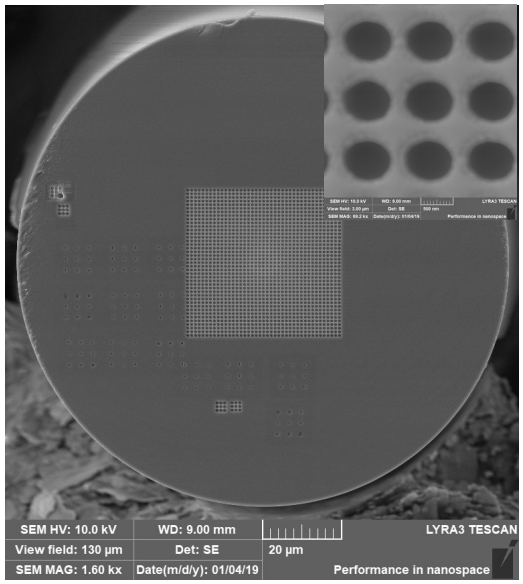


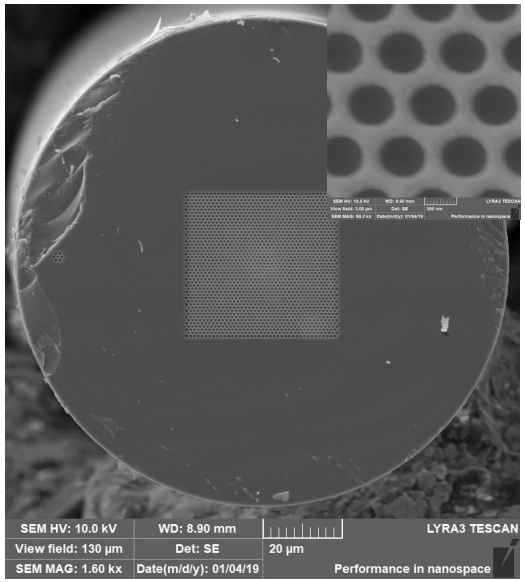
M. Vanek, J. Ctyroky, P. Honzatko, Opt. Quant. Electronics 50:50 (2018).
Martin Vanek, Jan Vanis, Yauhen Baravets, Filip Todorov, Jiri Ctyroky, and Pavel Honzatko, Opt. Express 24, 30225-30233 (2016)

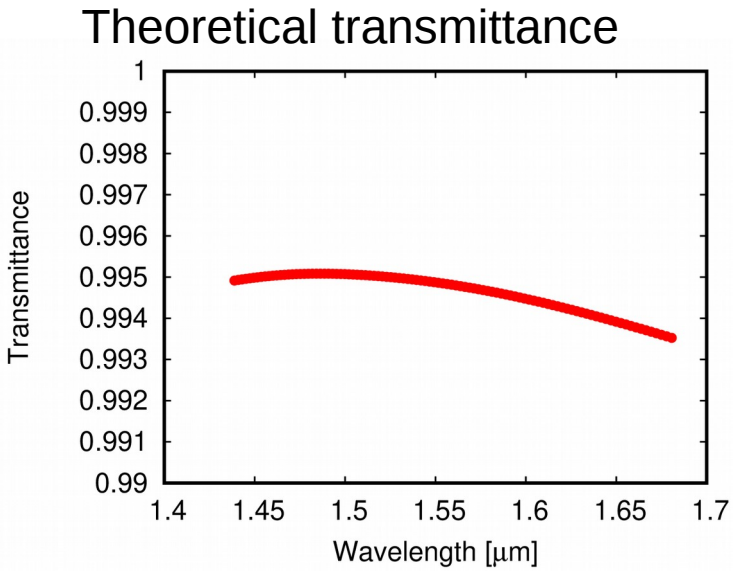
NANOSTRUCTURED FIBRE FACETS

Antireflection structures

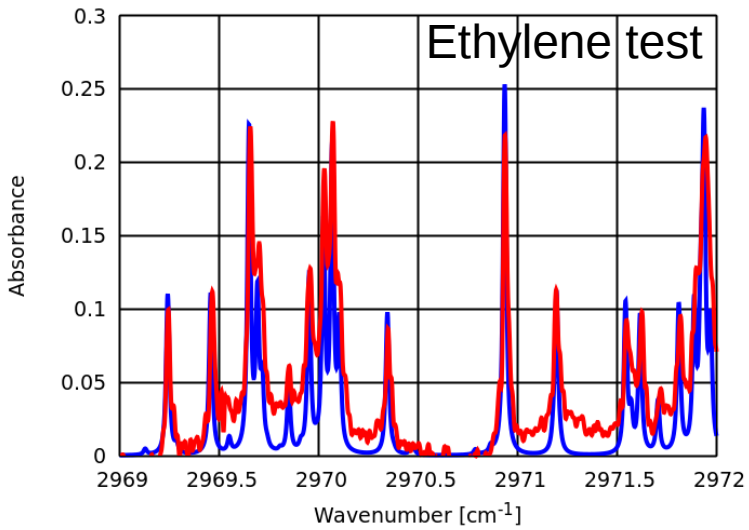
Utilisation in output connectors of fibre lasers







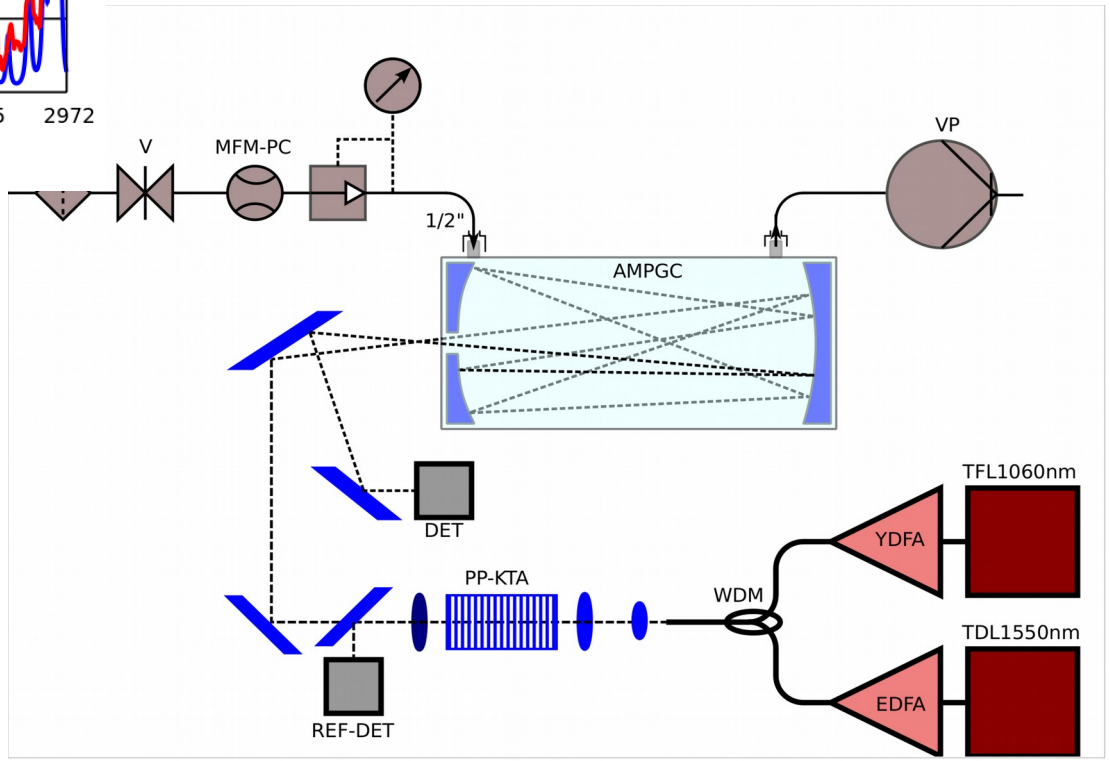
MIR LASERS ABSORPTION SPECTROSCOPY



Tuning range:
3200-3500 nm PP-KTP
3000-3700 nm KTA

Applications:

- **Agriculture – detection of phytohormones: ethylene, ..**
- **Environmetal monitoring: toluene, ethylene, ..**



Thank you.