

60W Thulium Fiber Laser for Industrial and Medical Applications

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Institute of Photonics and Electronics of the CAS

COST MP1401 Annual Conference

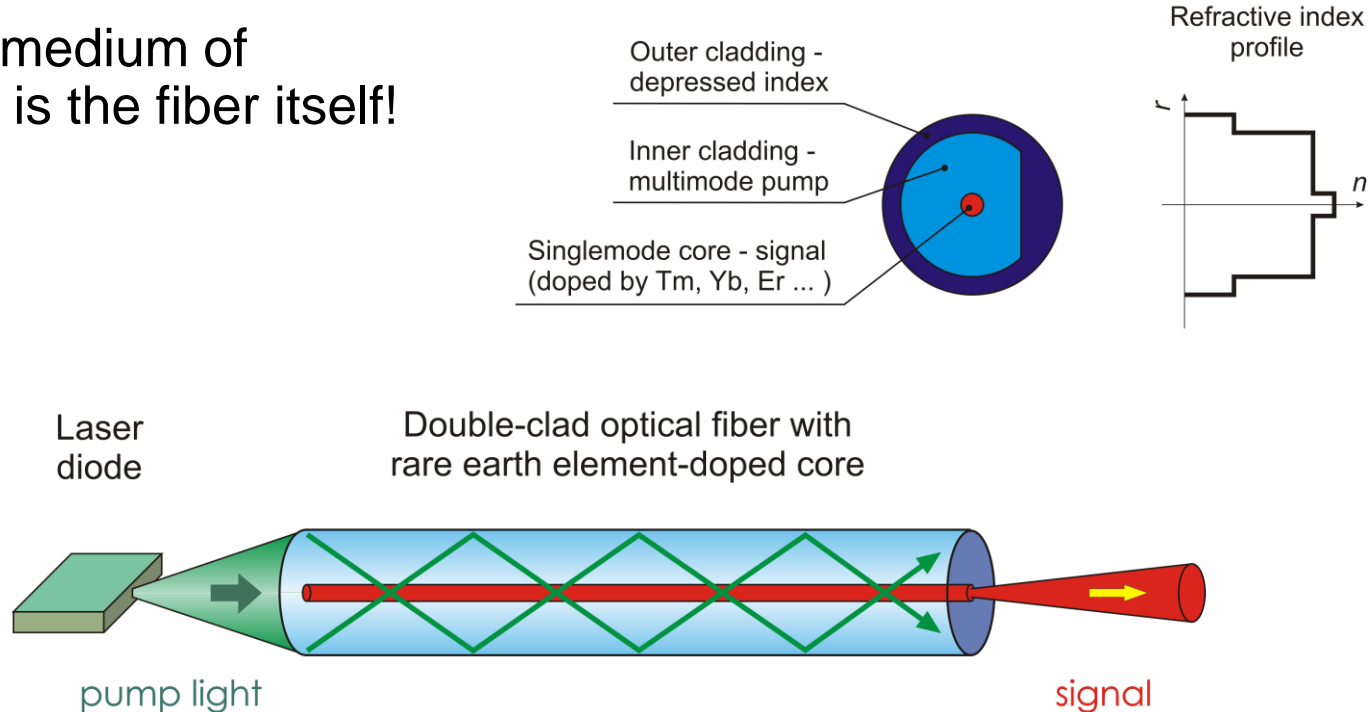
April 12-14, 2016, Zadar, Croatia

Outline

- **Thulium fiber lasers**
- **Applications of thulium fiber lasers**
- **60W CW thulium fiber laser at ÚFE**
- **Technique for improvement of the pump absorption in double-clad fibers by their simultaneous coiling and twisting**
- **Conclusions**

Thulium Fiber Lasers

The active medium of fiber lasers is the fiber itself!

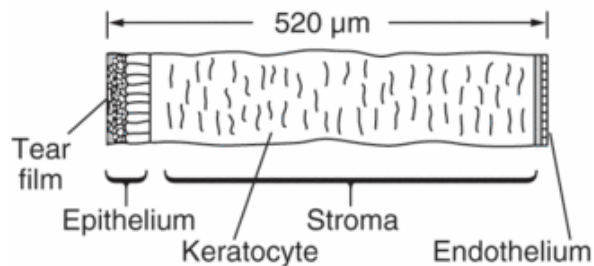
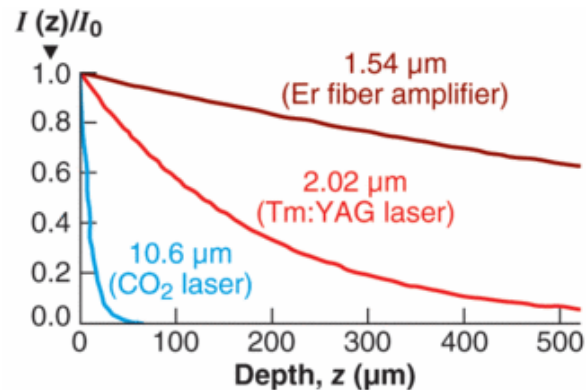


Main benefits of Tm-doped lasers ($2\ \mu\text{m}$) against Yb-doped lasers ($1\ \mu\text{m}$):

- safer for the human eye (lower retina damage by $2\ \mu\text{m}$ light),
- lower security demands for the laser workplace (safer and cheaper),
- new technological approaches (processing of polymeric materials...)

Thulium Fiber Lasers

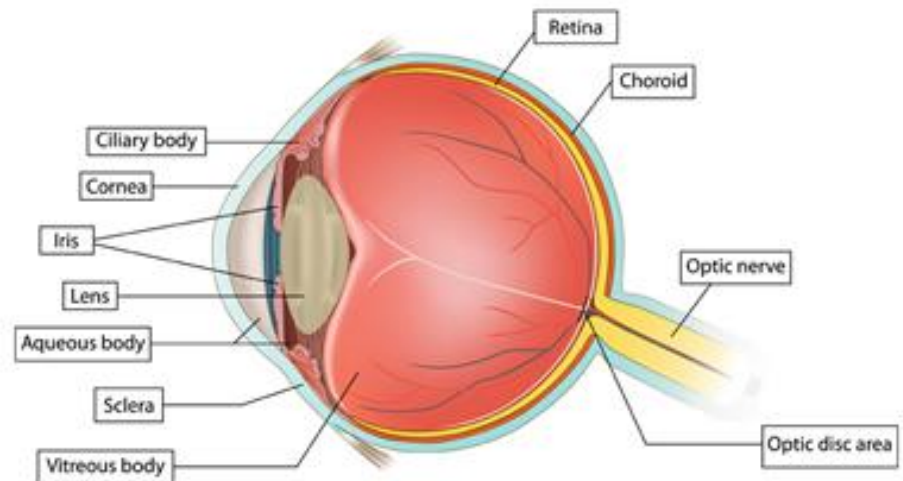
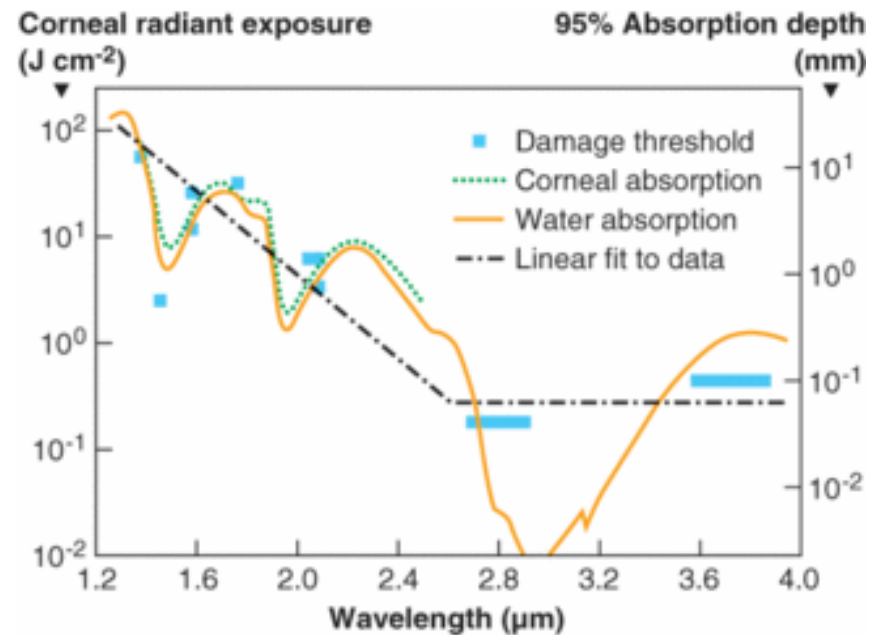
Absorption of the laser light in human eye:



Thulium lasers: Safer for retina, dangerous for cornea.

CO₂ lasers: Damage of epithelium.

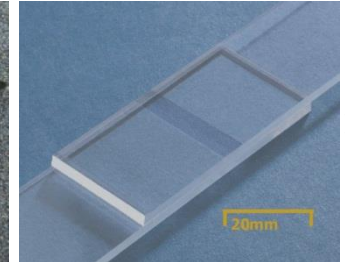
EDFL, TDFL: non curable damage of human endothelium.



Applications of Thulium Fiber Lasers

1 Industry

Welding, cutting, marking of polymeric materials.



www.jpktusa.com/lq/technology.htm

2 Medicine

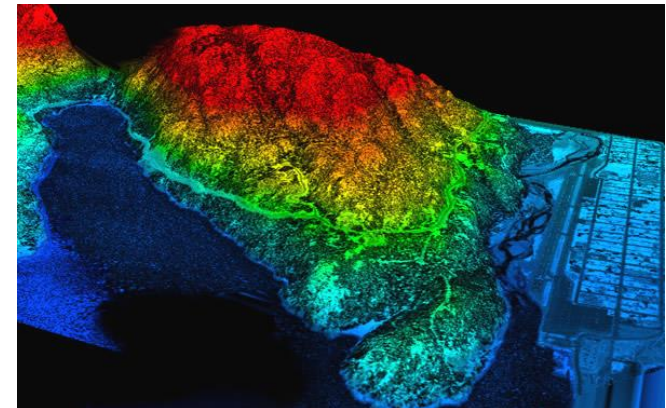
Minimal invasive surgery, treatment of benign prostatic hyperplasia, fragmentation of kidney stones.



www.urologielaser.it

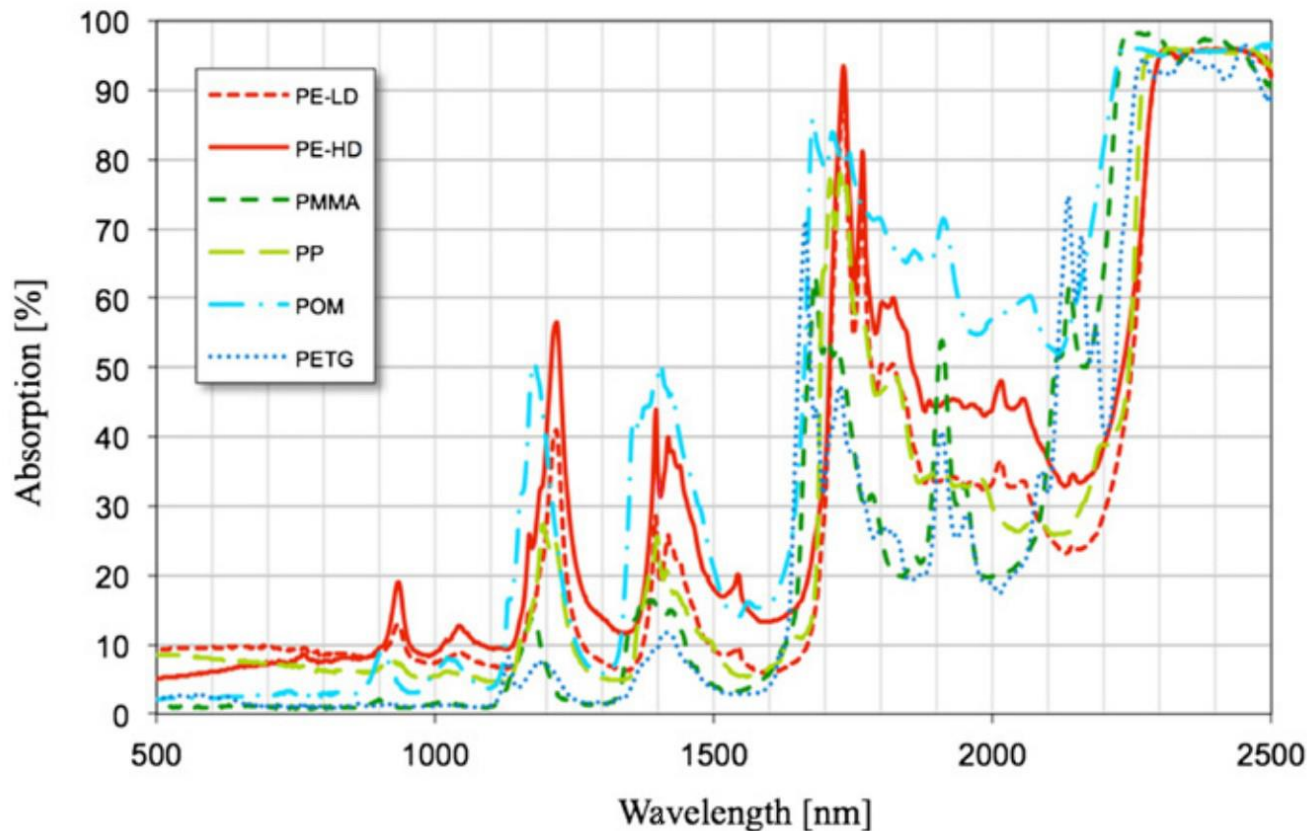
3 Sensors

LIDAR systems for air pollution monitoring (H_2O , CO_2 , N_2O ...), weather forecasting and topography.



Thulium Fiber Lasers: Processing of Polymeric Materials

Absorption spectra of different polymer samples (thickness 1.6 mm)



PE
Polyethylene,

PMMA
Polymethyl
methacrylate,

PP
Polypropylene,

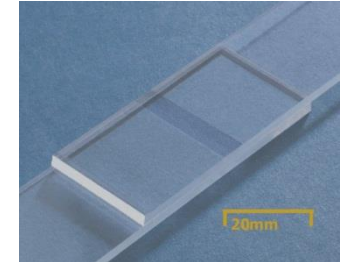
POM
Polyoxymethylene,

PETG
Polyethylene
terephthalate glycol-
modified

Mingareev I. et.al., Optics & Laser Technology, 44 (2012), 2095–2099

Thulium Fiber Lasers: Processing of Polymeric Materials

Sufficient absorption of $\sim 2\text{ }\mu\text{m}$ light in transparent polymeric materials **without additives** (important for medical products).



One-step processing of different polymeric materials (with/without additives) – cutting of runners of an injection moulded piece (car reflector).



www.lpkfusa.com/lq/technology.htm

Laser working regimes and usual applications of Tm fiber lasers :

- **CW for welding.**
High output power \rightarrow fusion penetration.
- **Pulsed for cutting and marking.**
Short high energy pulses \rightarrow low carbonization of the polymeric material (low temperature penetration).

Medical applications of Tm fiber lasers

Strong absorption of ~2 um light in water and soft tissue.

- minimal invasive surgery (precise tissue cutting with stopped bleeding, cutting or elimination of parts or whole organs by evaporation),
- treatment of benign prostatic hyperplasia,
- fragmentation of kidney stones (ablation and shock waves).

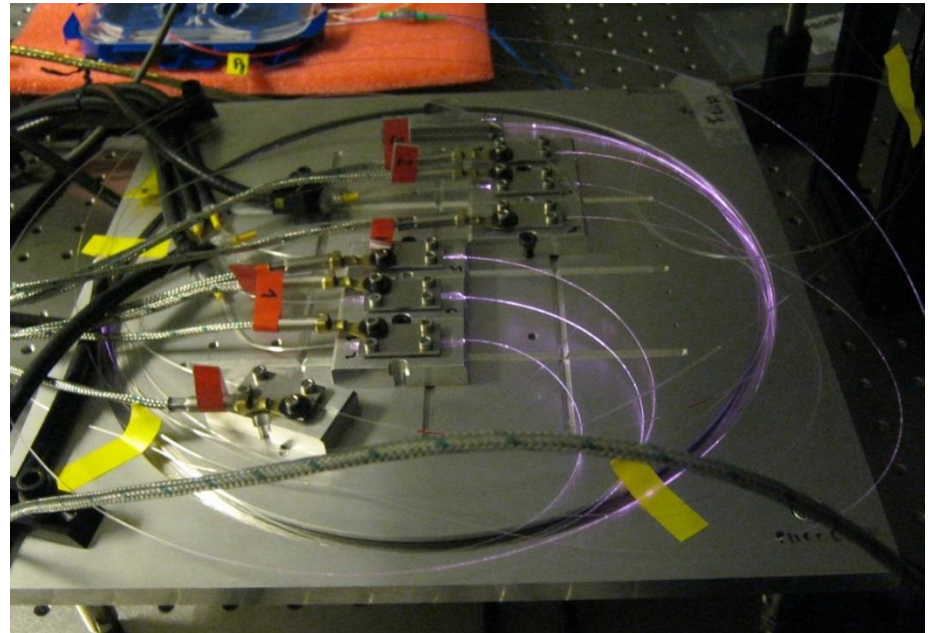
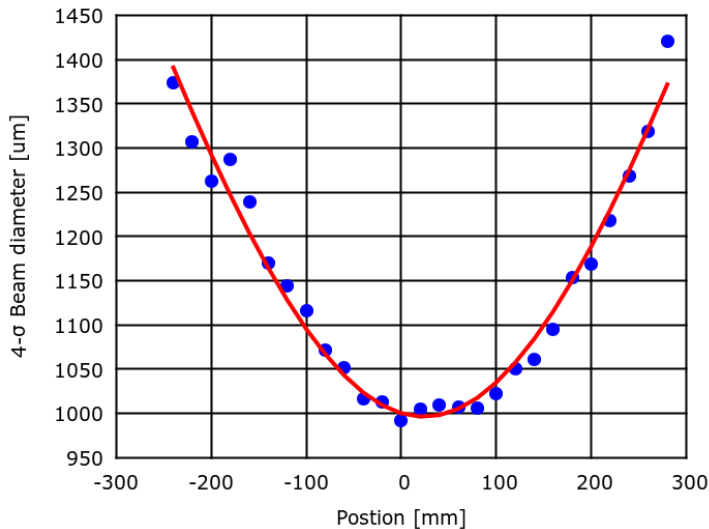
Thulium fiber lasers bring fast evaporation of the soft tissue with excellent hemostasis (process which causes bleeding to stop, meaning to keep blood within a damaged blood vessel).

- both regimes, CW and pulsed, are used,
- Tm fiber lasers instead of Ho:YAG solid state lasers,
- Penetration depth only 0.2 mm – minimal thermal damage of the surrounding tissue.

60W CW Thulium Fiber Laser at ÚFE

There was developed a **60W CW Thulium Fiber Laser** in the Institute of Photonics and Electronics of the CAS with parameters:

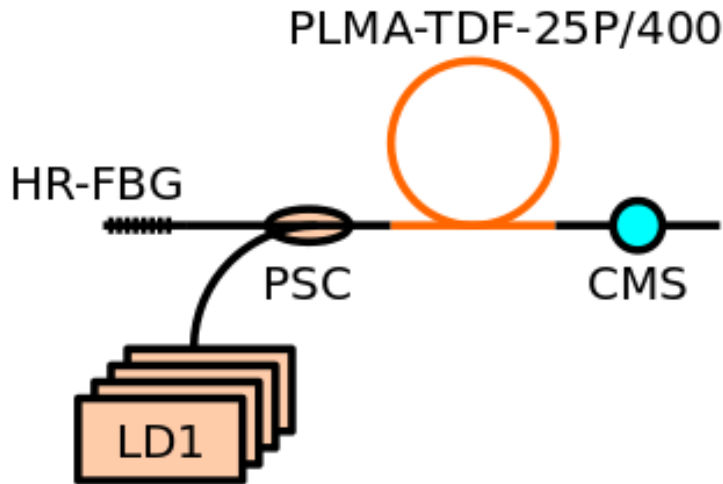
- **CW output power 60 W**
- **central wavelength 2039 nm**
- **beam quality $M^2 \leq 1,4$**



Our set-up still allows to increase the laser output power by ~11 W (5A).

60W CW Thulium Fiber Laser at ÚFE

Scheme of the fiber laser:



HR-FBG – high reflectivity fiber Bragg grating,

LD1 – Laser Diodes

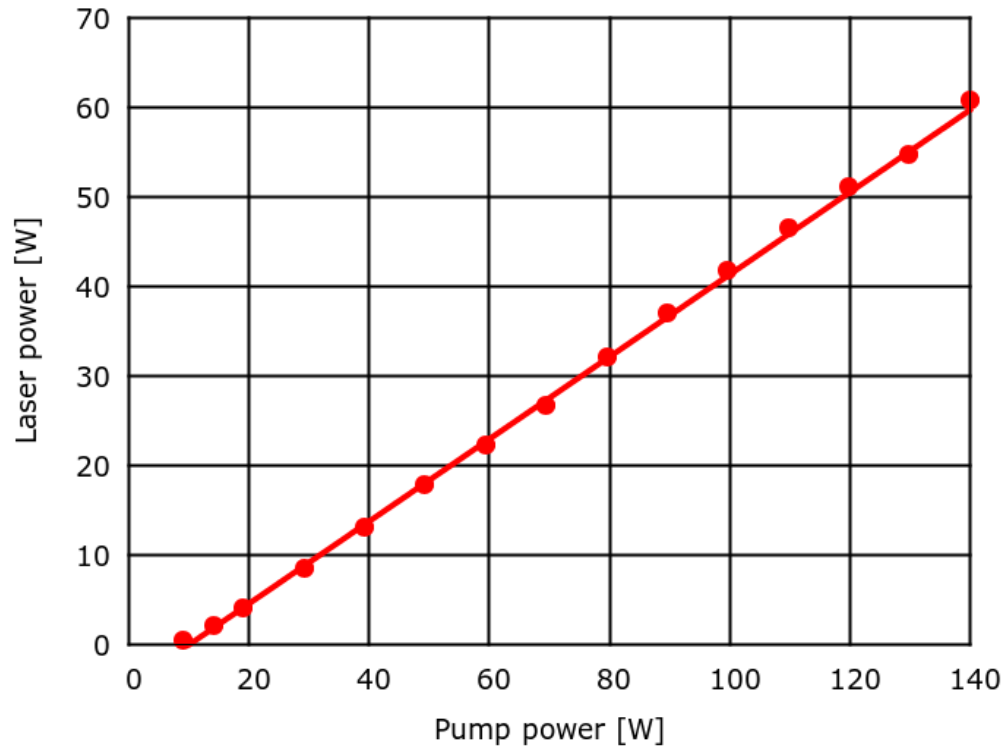
PSC - pump signal combiner,

PLMA-TDF-25P/400 – type of an optical fiber which was used,

CMS - cladding mode stripper.

60W CW Thulium Fiber Laser at ÚFE

Output power dependence on the pump power:

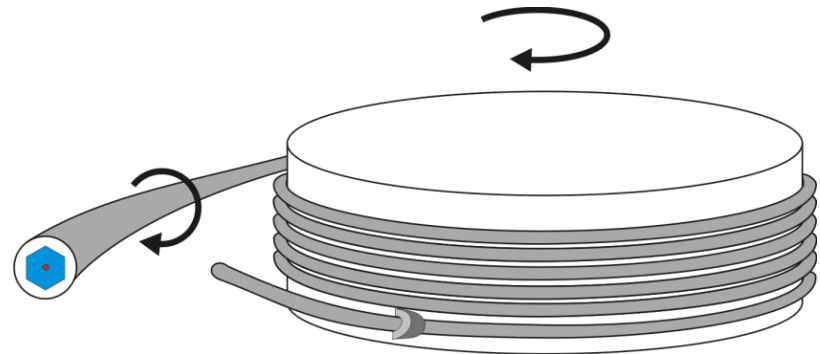
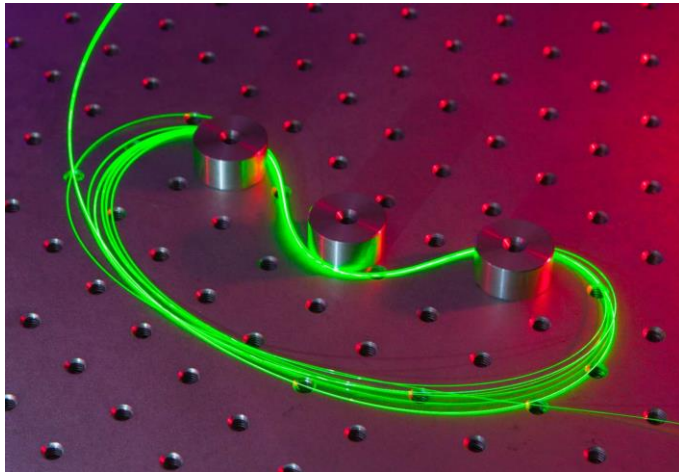
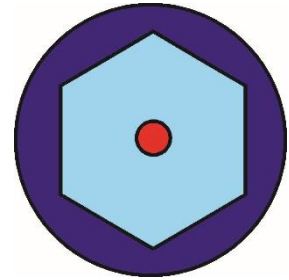


*A linear function $L_p = 0.46 \cdot (P_p - 10.2)$ was used.
(L_p -Laser output power, P_p -pump power)*

Technique for improvement of the pump absorption in double-clad fibers by their simultaneous coiling and twisting

What helps to absorb pump in double-clad fibers ?

1. **Cross sections with broken circular symmetry**
2. **Mode-scrambling by non-conventional coiling**
3. Squeezing of the effective area of the pump



First experimental observations:

J. Nilsson et al., IEEE J. Quant. Electronics 39:987 (2003)

First rigorous theoretical description:

Y. Li, S. D. Jackson, and S. Fleming, IEEE Photonics Technol. Lett., 16:2502 (2004)

P. Koška, P. Peterka, I. Kašík, V. Matějčec, O. Podrazký, SPIE 87750V (2013)

P. Peterka, P. Honzátka, P. Koška, O. Podrazký, and I. Kašík, SPIE 934423 (2015)

P. Koška, P. Peterka, Optical and Quantum Electronics , 47:3181 (2015)

P. Koška, P. Peterka, V. Doya, IEEE J. Sel. Top. Quantum Electron. 22(2), 2016

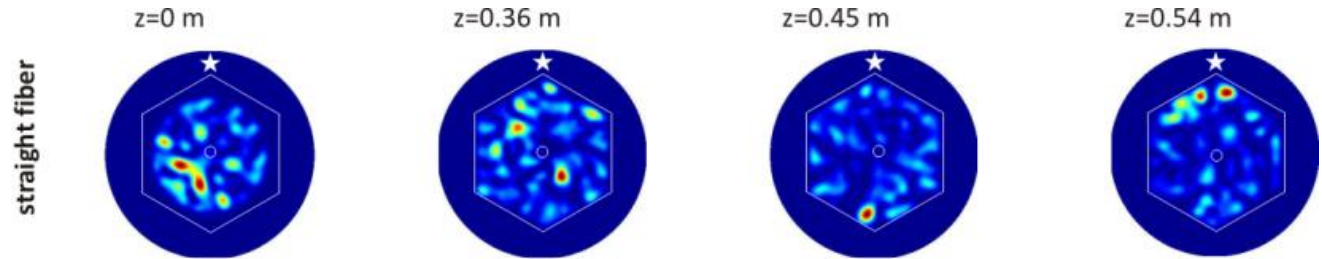
Patent pending:

P. Peterka, et.al., PV2015-72, filled 5 Feb 2015.

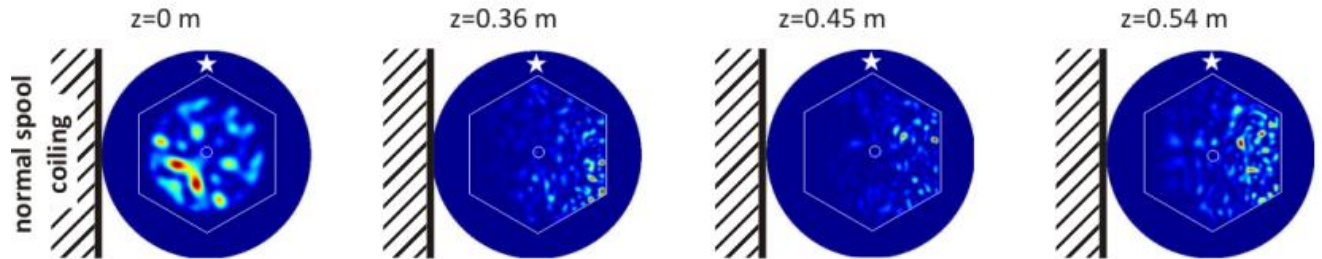
Technique for improvement of the pump absorption in double-clad fibers by their simultaneous coiling and twisting

1. Cross sections with broken circular symmetry
2. Mode-scrambling by non-conventional coiling
3. **Squeezing of the effective area of the pump**

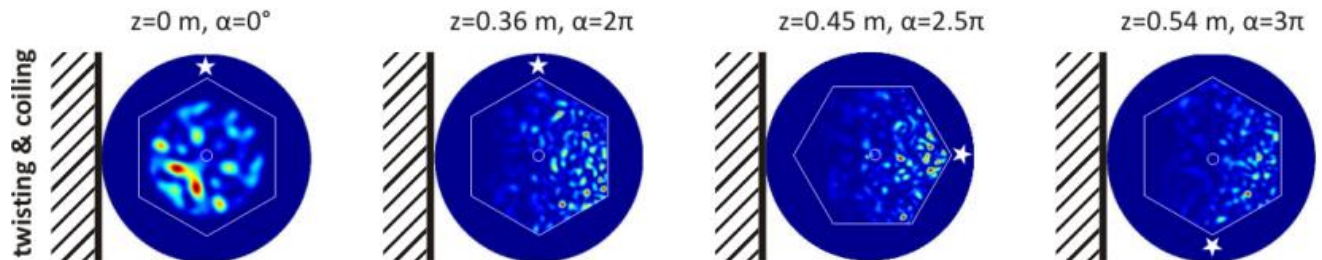
Only the effect of broken circular symmetry:



Effects of broken circular symmetry and pump area squeezing:



All three effects involved: broken circular symmetry, pump area squeezing and mode scrambling



Conclusions

Thulium fiber lasers working at $\sim 2 \mu\text{m}$ have a great potential for industry and medical applications.

CW thulium fiber laser with an output power of 60 W was demonstrated.

Technique for improvement of the pump absorption in double-clad fibers by their simultaneous coiling and twisting was presented.

Further work will focus on:

- increase of the laser output power,
- laser housing,
- testing of the laser for industrial (medical) applications.

Thank you for your attention!

Acknowledgements:

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COST MP1401 Training School on Fiber Lasers & Optical Fiber Technology

Aug 30 - Sep 1, 2016
Prague, Czech Republic

Pre-register at: **ITS.UFE.CZ**

Hands-on lab tutorials!

- Spectroscopy of rare-earth-doped optical fibers
- Preform preparation – MCVD technology
- Repusil preform preparation, fiber drawing
- RE- doped non-silica materials
- IR- transparent materials and fibers for lasers
- Components of fiber lasers
- Ultrafast fiber lasers

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