# Multicolour emission in RE - doped fibers

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## Photonic Materials and Optical Fiber Technology

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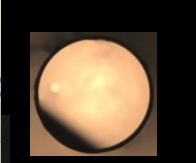
## RE - doped optical fibres, photonics materials

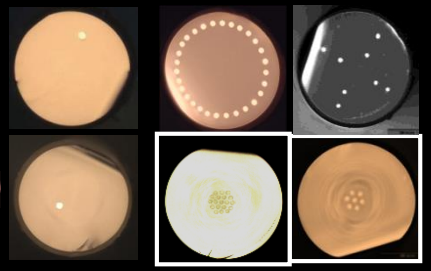

**Dominik Dorosz,** PhD, DSc, Assoc. Prof.

- **Marcin Kochanowicz**, PhD – optical fiber technology
- **Jacek Żmojda**, PhD – active optical glasses
- **Piotr Miluski**, PhD – active glasses and polymers in sensors
- PhD students


*Helical core optical fibres*

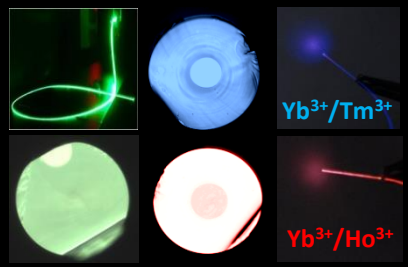


*1,8-21 μm ASE fibres*

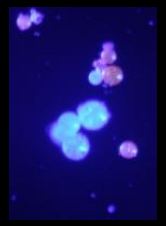


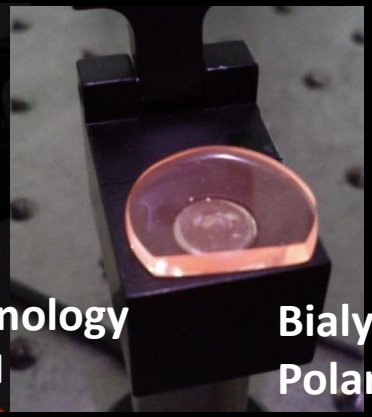
*Multicore supermode optical fibers*

*Upconversion optical fibre sources*




*Polymer microbeads*



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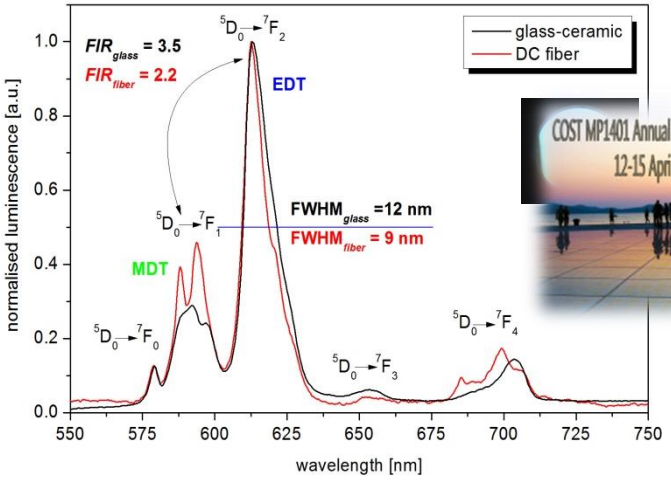
**Poland**

Action MP1401

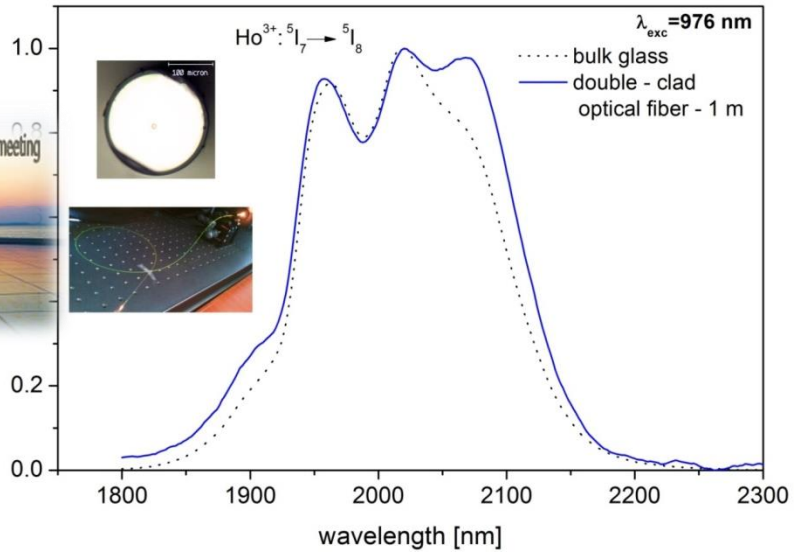
# Outline

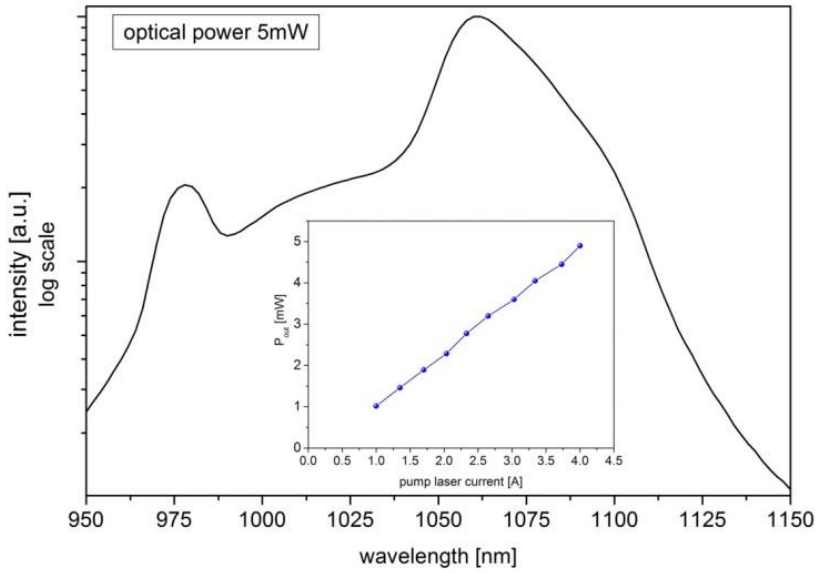
- Motivation –multicomponent optical fibers – ASE multicolour upconversion emission ( *bio-analysis, medical therapy (LLLT) therapeutic window, display technologies)*
- Constructions of co-doped antimony - germanate optical fibers –
  - Triply doped
  - Double –core
- luminescent properties, possibility of tuning CIE coordinates
- Conclusions and perspectives

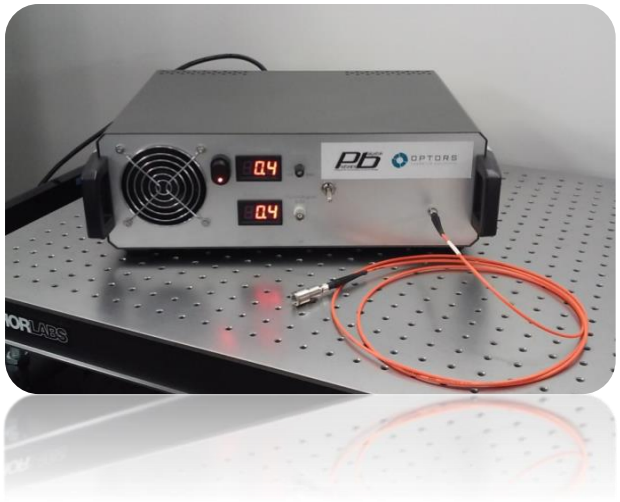
# Previous results





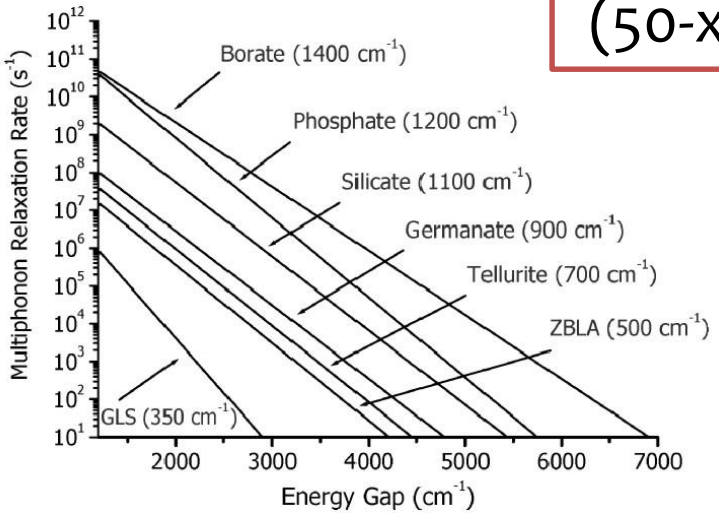


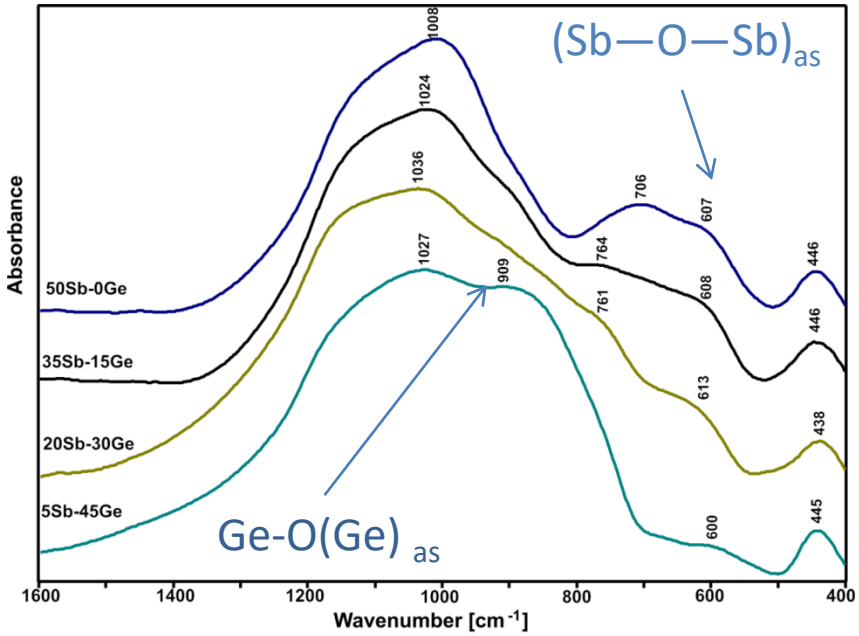



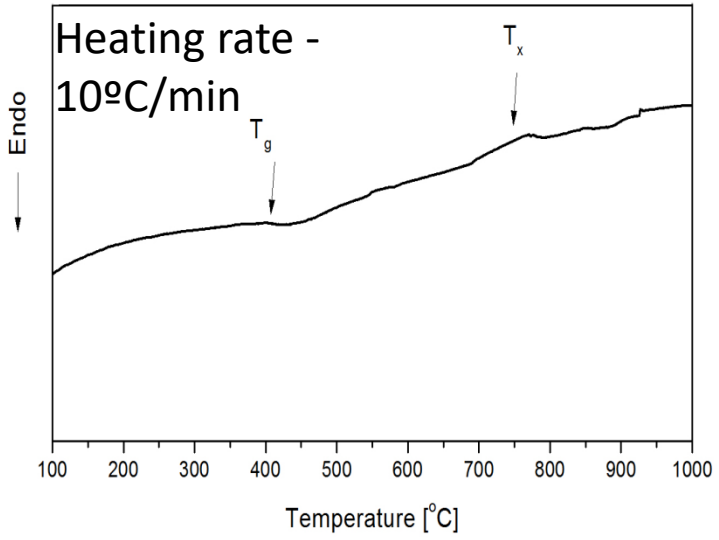
# Antimony - germanate glass host

$(50\text{-}x)Sb_2O_3 - xGeO_2 - 50SiO_2$



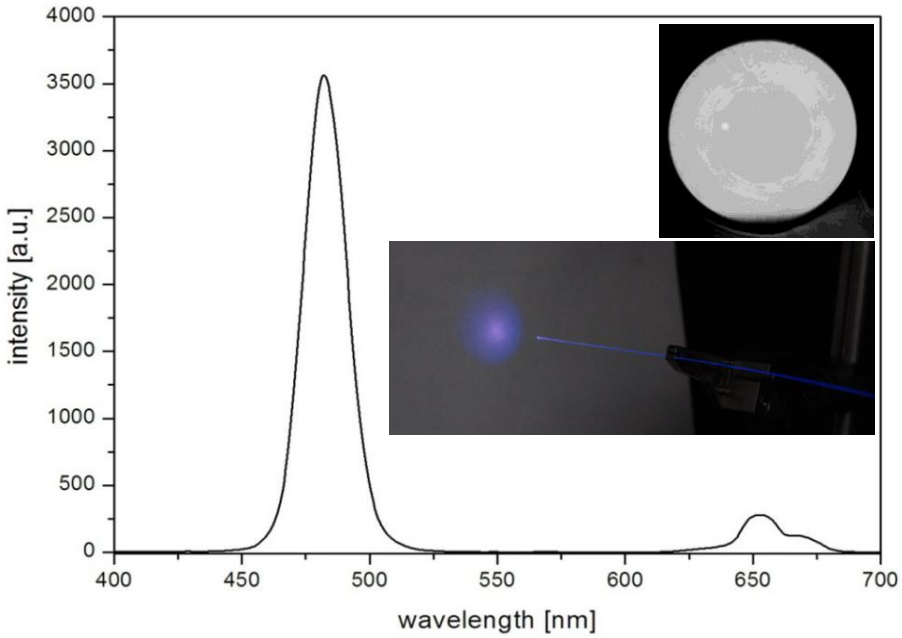

| PARAMETER | value |
|---|---|
| Refractive index $n$ (@632.8nm) | 1.73 |
| Density $\rho$ [g/cm$^3$] | 3.7 |
| Thermal expansion coefficient [$10^{-7}$ 1/K] | 56 |
| Transformation temperature $T_g$ [°C] (DSC) | 430 |



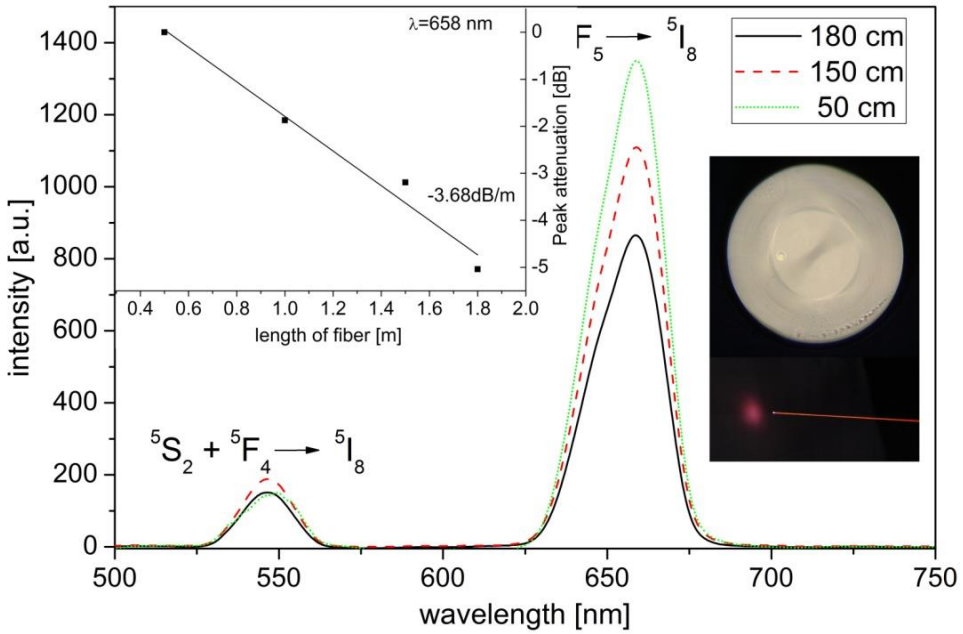



# $Sb_2O_3$-$GeO_2$ fibers – Upconversion

## $Yb^{3+}/Tm^{3+}$




## $Yb^{3+}/Ho^{3+}$




Optical Materials 41 (2015) 108–111
Contents lists available at ScienceDirect
Optical Materials
journal homepage: www.elsevier.com/locate/optmat

Upconversion emission in antimony–germanate double-clad optical fiber co-doped with $Yb^{3+}/Tm^{3+}$ ions

M. Kochanowicz [a], D. Dorosz [a,*], J. Zmojda [a], P. Miluski [a], J. Dorosz [a], J. Pisarska [b], W.A. Pisarski [b]

**NIR to visible upconversion in double – clad optical fiber co-doped with $Yb^{3+}/Ho^{3+}$**

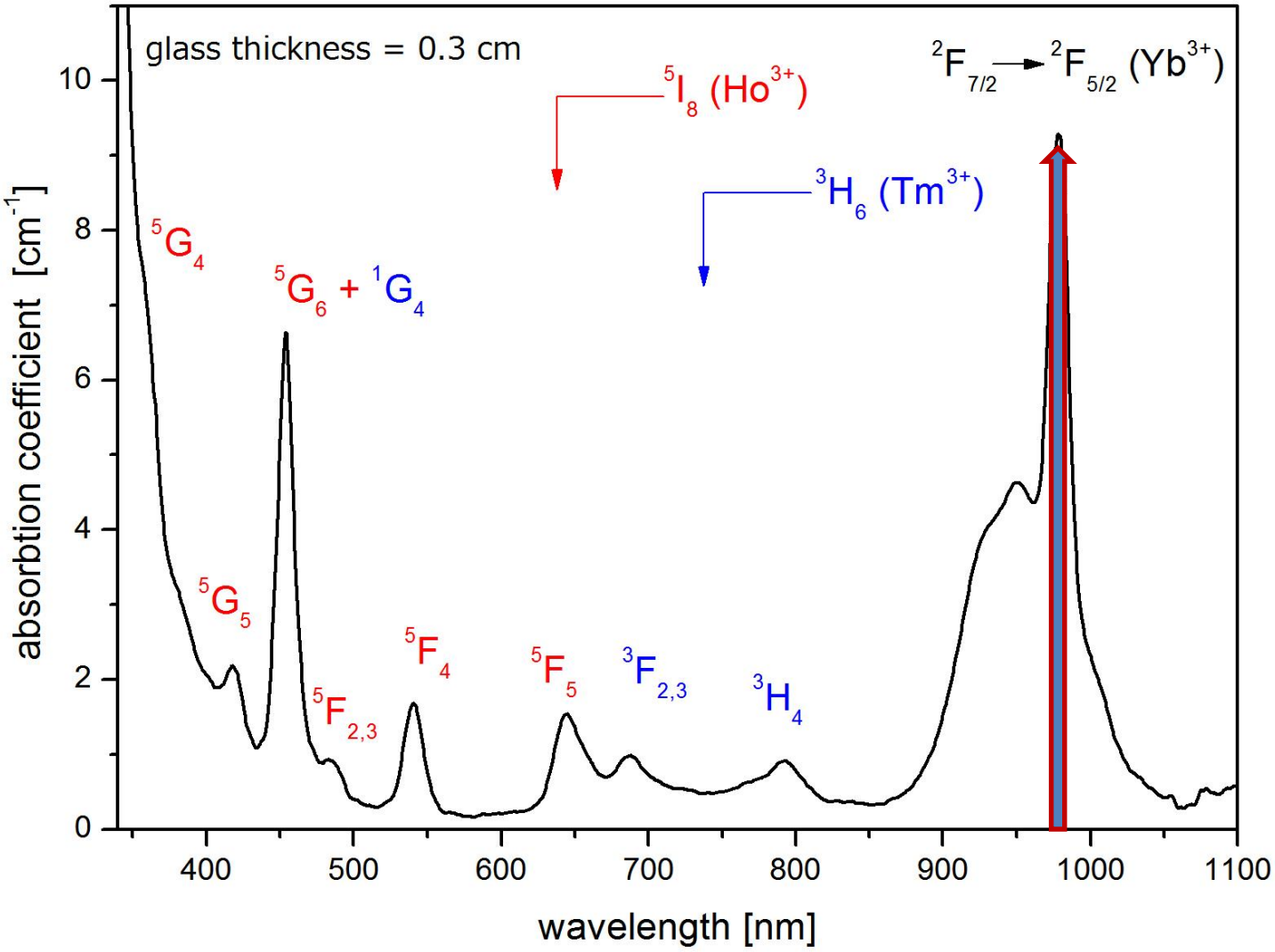
Marcin Kochanowicz,[1] Jacek Zmojda,[1] Piotr Miluski,[1] Joanna Pisarska,[2] Wojciech A. Pisarski,[2] and Dominik Dorosz[1,*]

#240414 - $15.00 USD Received 14 May 2015; accepted 21 May 2015; published 3 Jun 2015

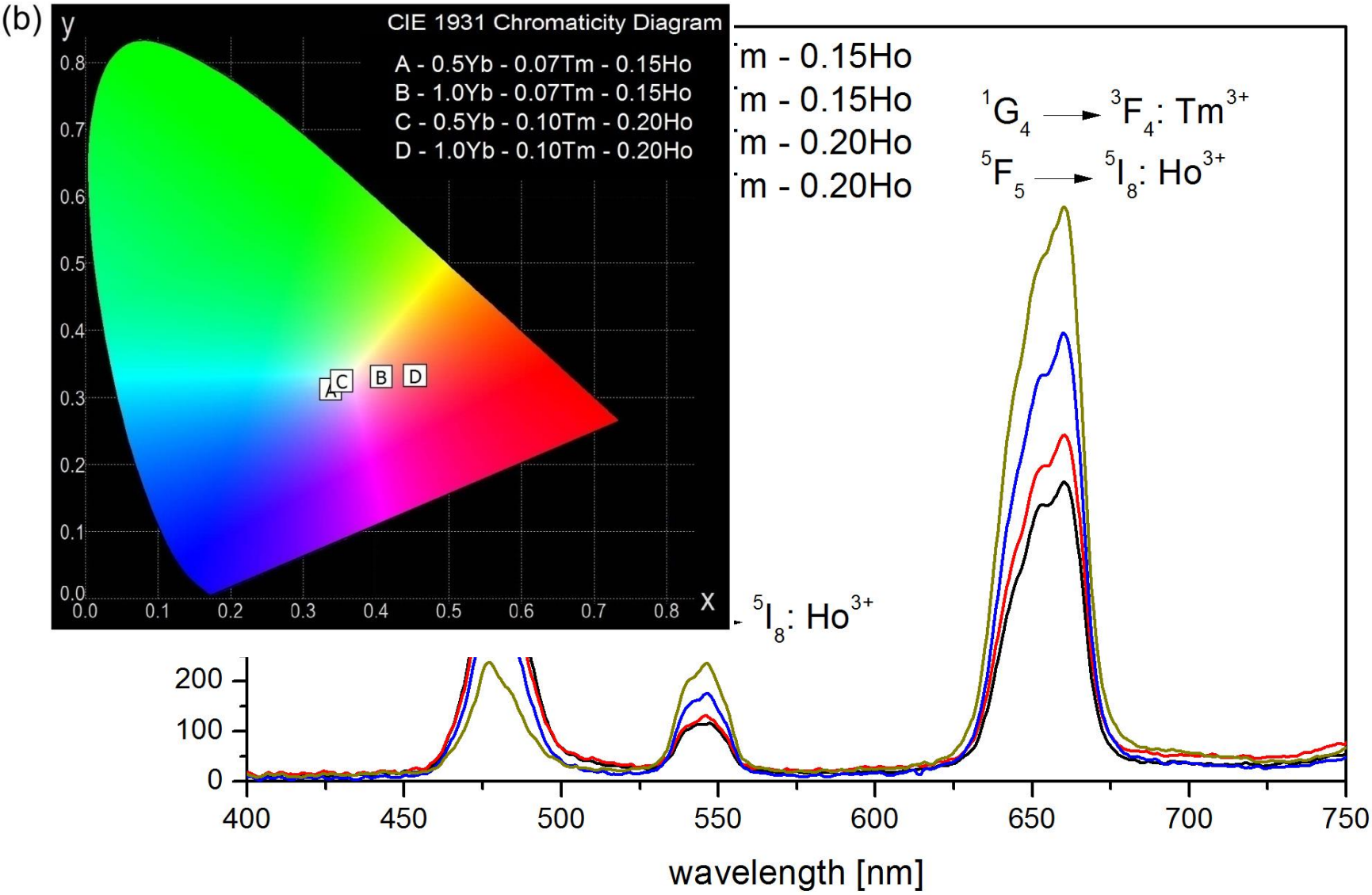
# Triply doped $Sb_2O_3$-$GeO_2$ fiber

# $Yb^{3+}/Tm^{3+}/Ho^{3+}$

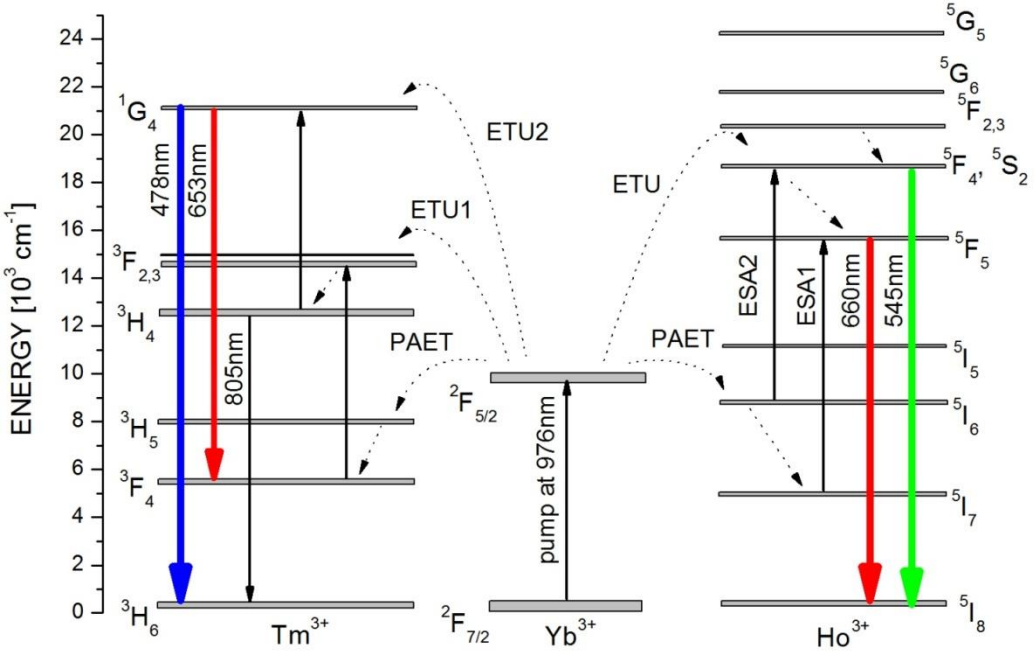
# Triply $Yb^{3+}/Tm^{3+}/Ho^{3+}$ doped glass

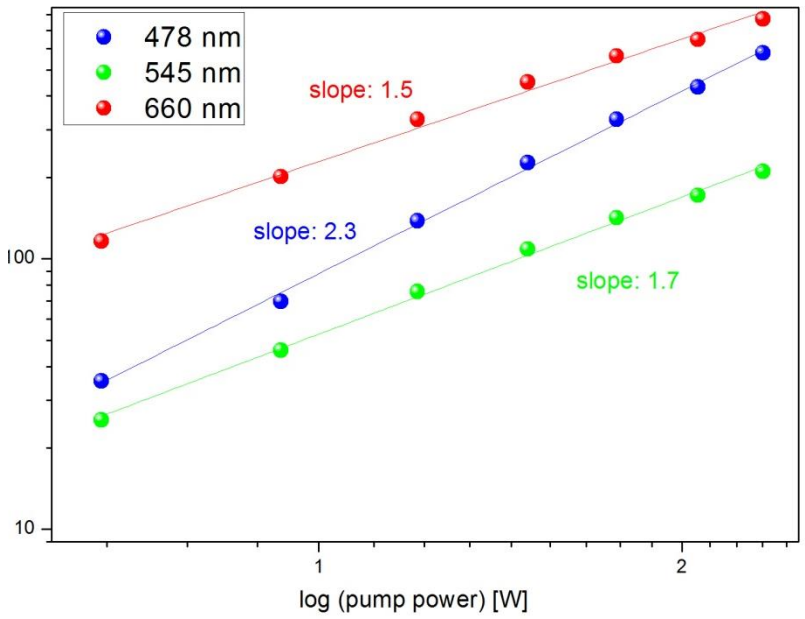


# Triply doped $Sb_2O_3$-$GeO_2$ glass - core

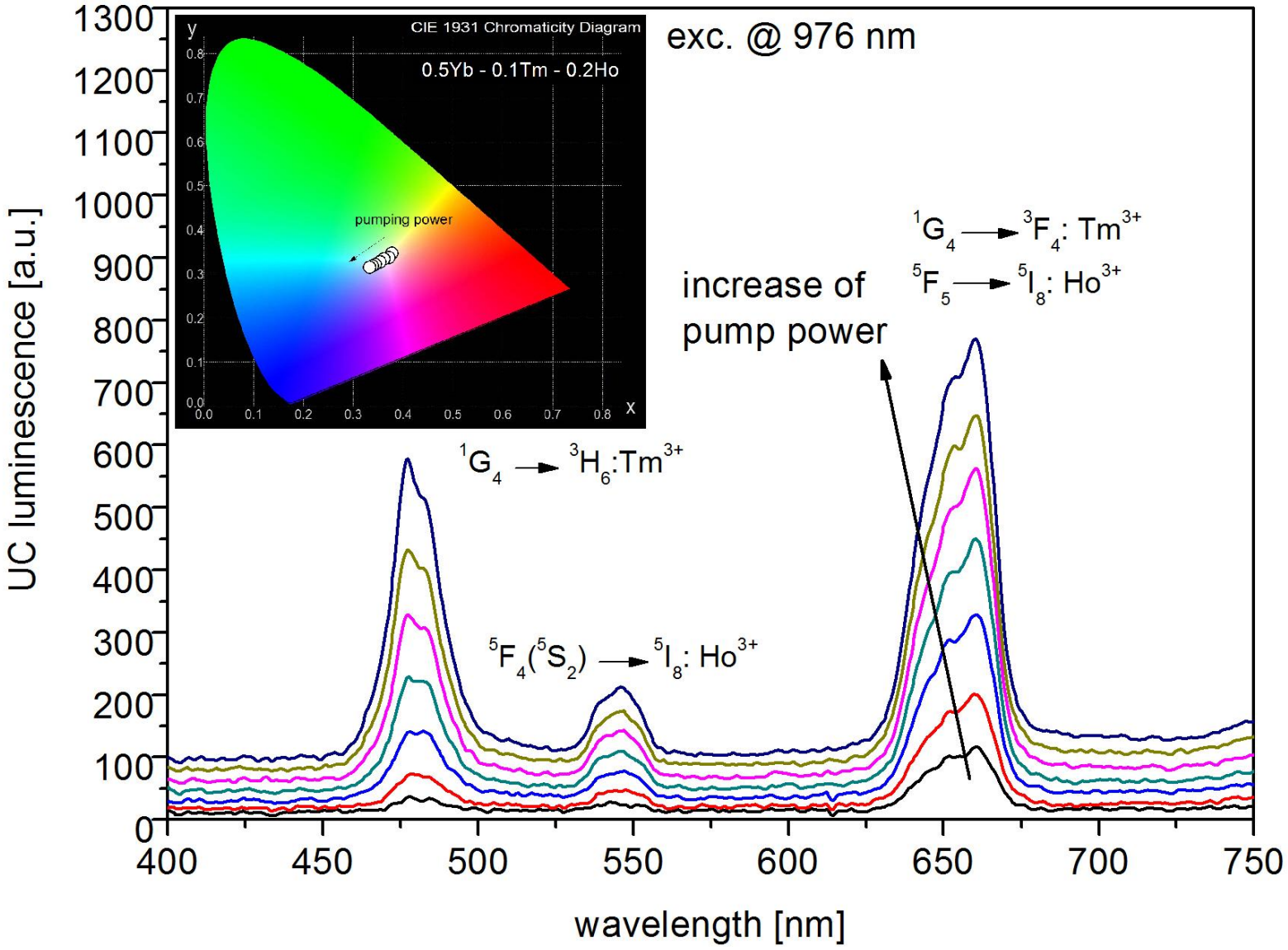


# Triply doped $Sb_2O_3$-$GeO_2$ glass - core

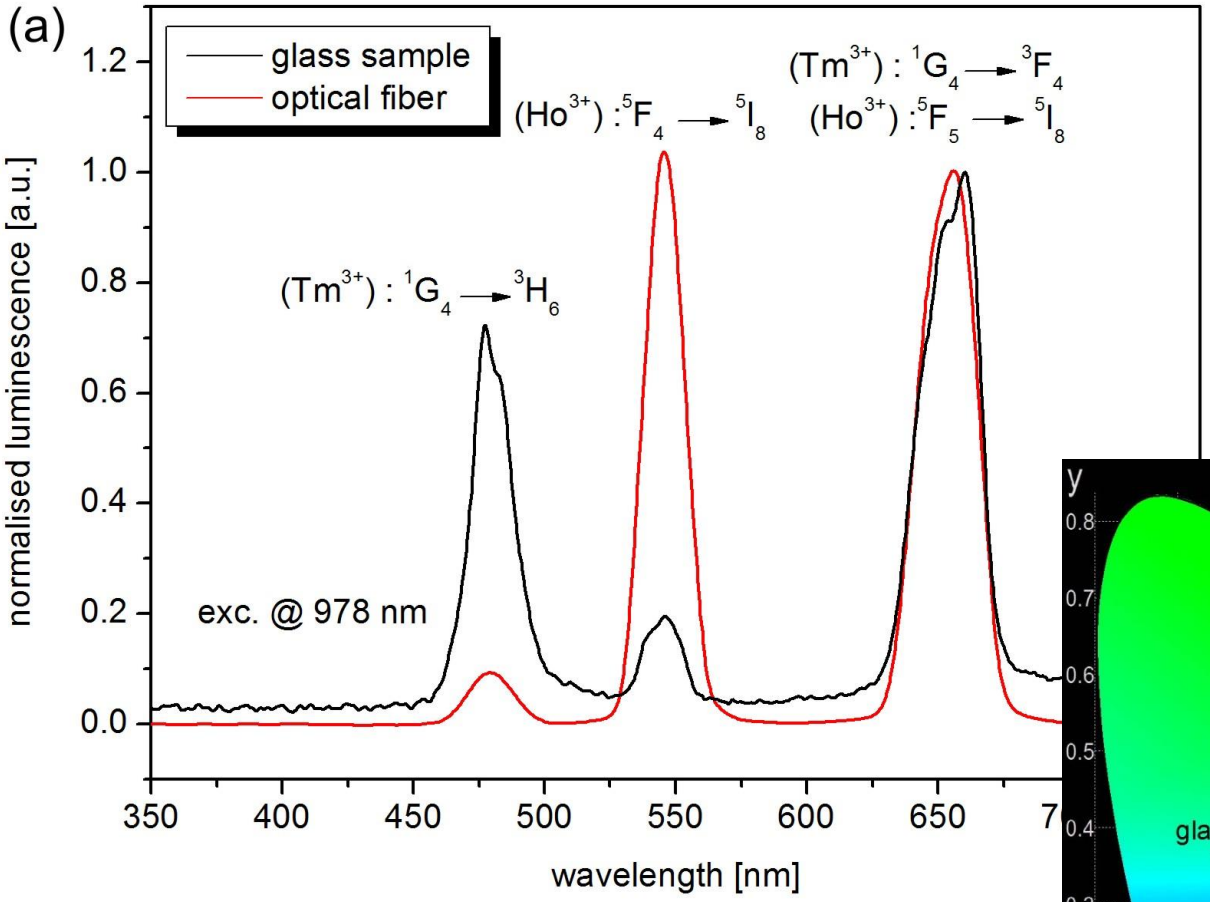


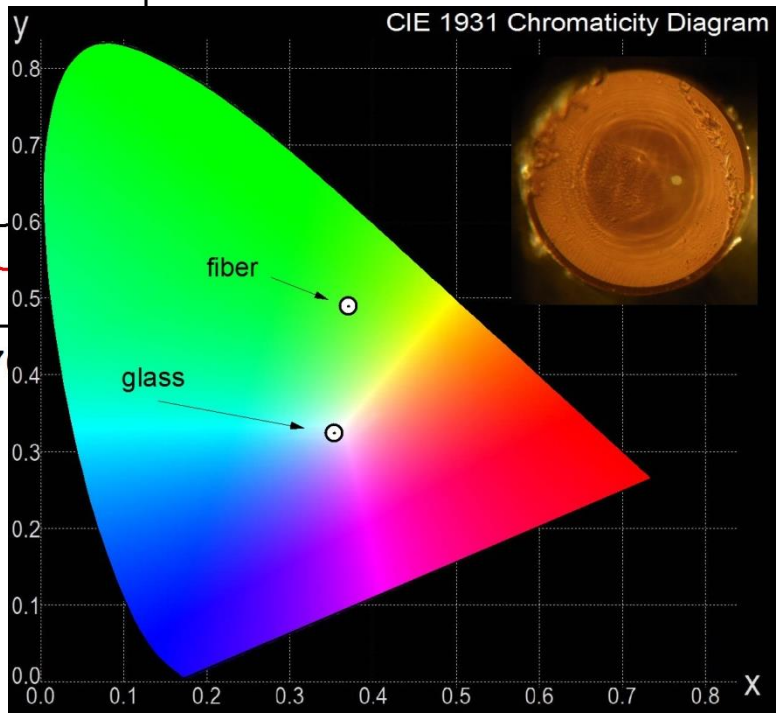
# Triply doped $Sb_2O_3$-$GeO_2$ glass - core



# Triply doped $Sb_2O_3$-$GeO_2$ fiber




Outer diameter = 370 µm
Core diameter = 10 µm
$NA_{cladding}$=0.58
$NA_{core}$=0.4




Optical Materials 58 (2016) 279–284
Contents lists available at ScienceDirect
Optical Materials
journal homepage: www.elsevier.com/locate/optmat

Investigation of upconversion luminescence in $Yb^{3+}/Tm^{3+}/Ho^{3+}$ triply doped antimony-germanate glass and double-clad optical fiber

Jacek Zmojda [a,*], Marcin Kochanowicz [a], Piotr Miluski [a], Giancarlo C. Righini [c], Maurizio Ferrari [b,c], Dominik Dorosz [a]

Atten. =3dB/m
@600 nm

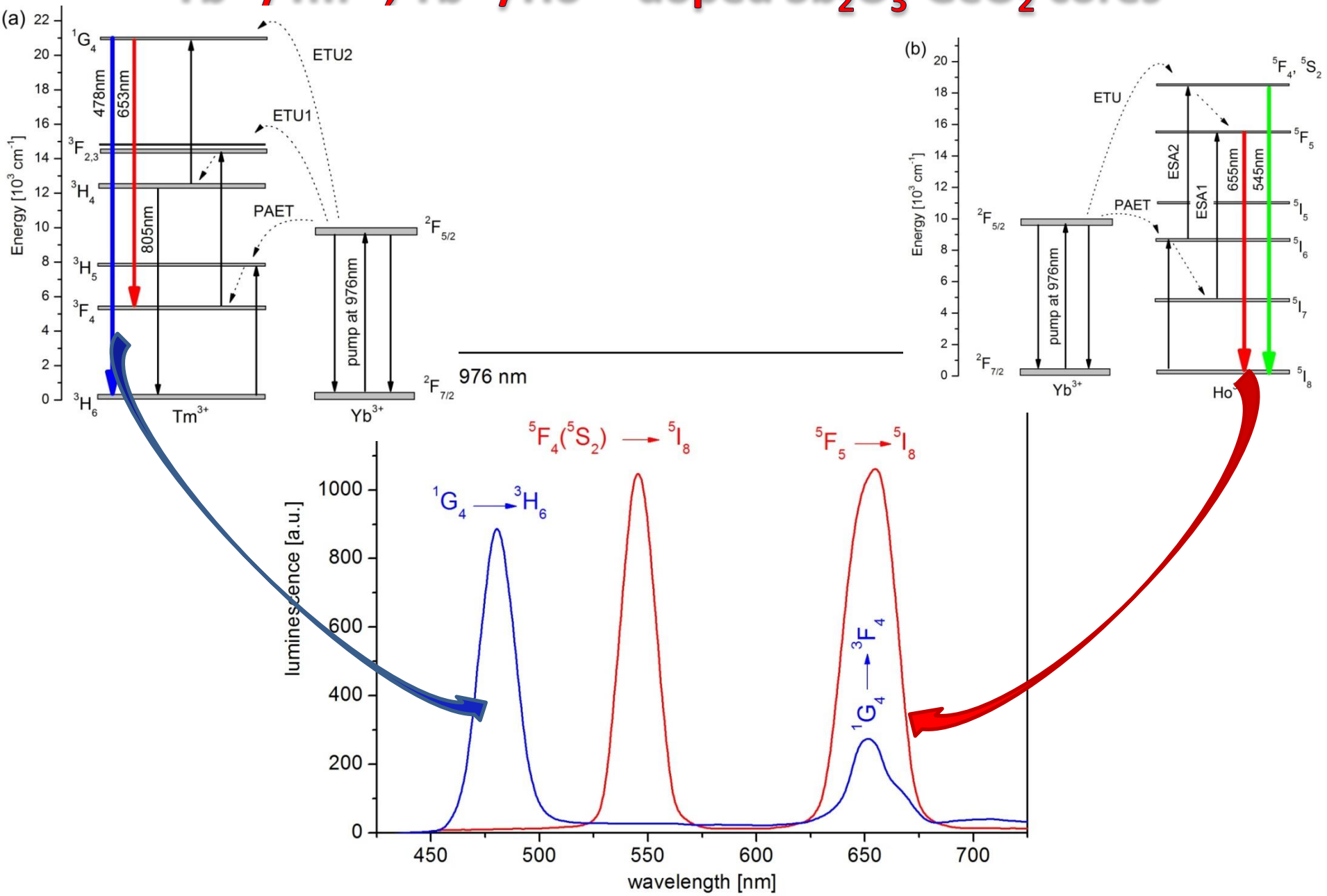
# Double – core $Yb^{3+}/Tm^{3+}$, $Yb^{3+}/Ho^{3+}$ doped $Sb_2O_3$-$GeO_2$ fiber

Yb/Tm

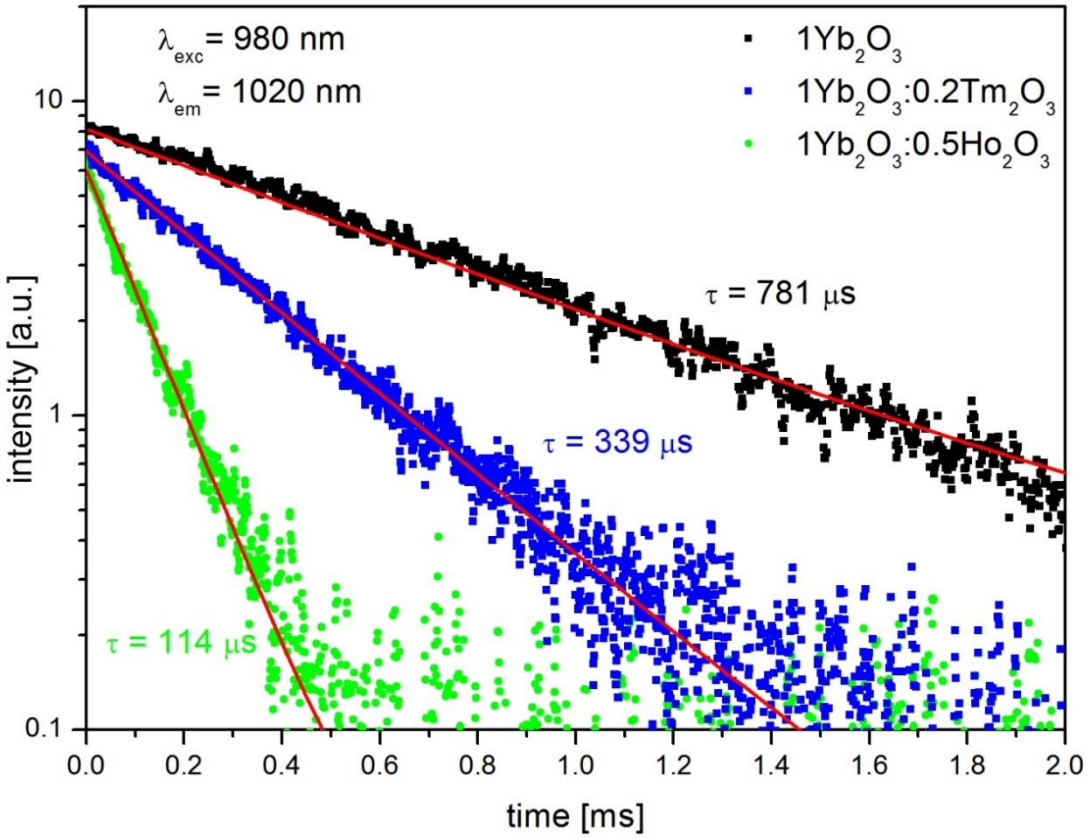
Yb/Ho

**Yb/Tm+Ho**

# $Yb^{3+}/Tm^{3+}$, $Yb^{3+}/Ho^{3+}$ doped $Sb_2O_3$-$GeO_2$ cores



# $Yb^{3+}/Tm^{3+}$, $Yb^{3+}/Ho^{3+}$ doped $Sb_2O_3$-$GeO_2$ core glass



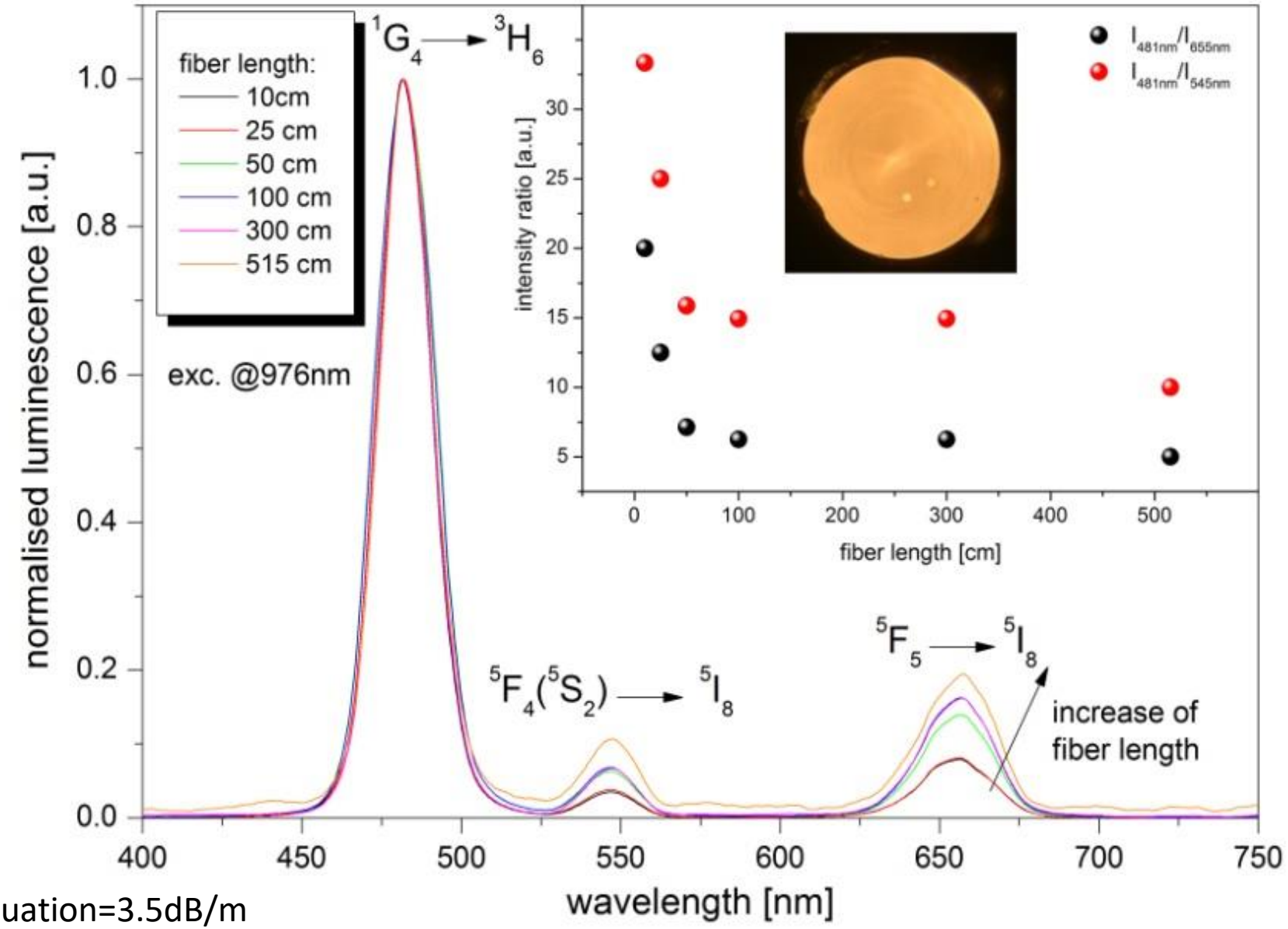

## Energy transfer efficiency

$$\eta_{ET} = 1 - \tau_{Yb}^{DA} / \tau_{Yb}^{D}$$

$\eta_{Tm}$ = 56%

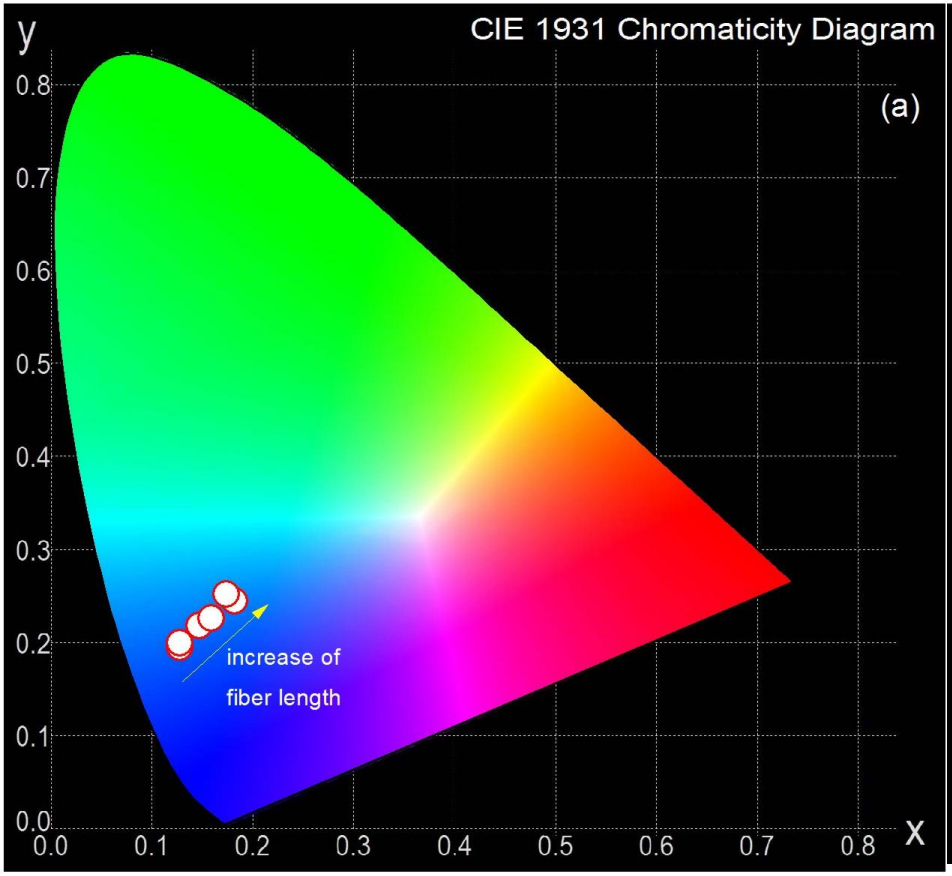
$\eta_{Ho}$ = 85%

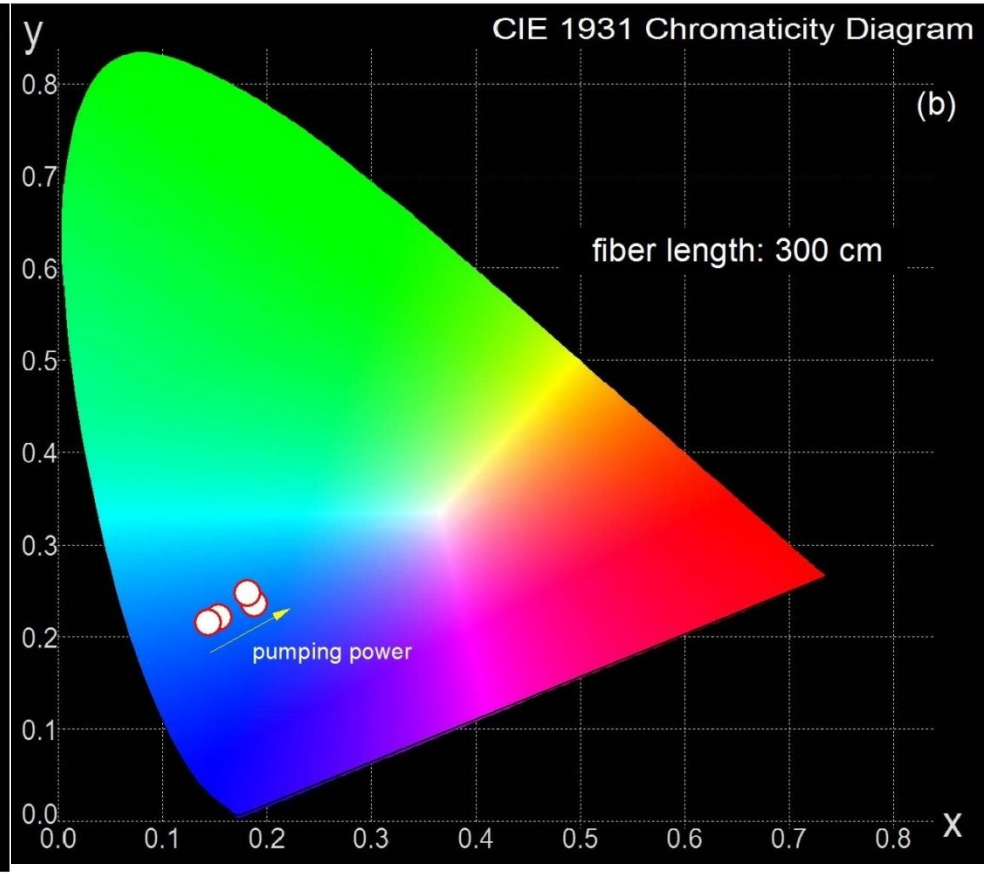
# Double – core $Yb^{3+}/Tm^{3+}$, $Yb^{3+}/Ho^{3+}$ doped $Sb_2O_3$-$GeO_2$ fiber




Attenuation=3.5dB/m
@600 nm

# Double – core $Yb^{3+}/Tm^{3+}$, $Yb^{3+}/Ho^{3+}$ doped $Sb_2O_3$-$GeO_2$ fiber




Journal of Luminescence 170 (2016) 795–800
Contents lists available at ScienceDirect
Journal of Luminescence
journal homepage: www.elsevier.com/locate/jlumin

Investigation of upconversion luminescence in antimony–germanate double-clad two cores optical fiber co-doped with $Yb^{3+}/Tm^{3+}$ and $Yb^{3+}/Ho^{3+}$ ions

J. Zmojda [a], M. Kochanowicz [a], P. Miluski [a], J. Dorosz [a], J. Pisarska [b], W.A. Pisarski [b], D. Dorosz [a,*]

# Summary

**Conclusions:**

- **Developement of antimony – germanate core double – clad optical fibers.**
- **Fabricated** optical fibers enable to achieve:
  - **Triply doped $Yb^{3+}/Tm^{3+}/Ho^{3+}$** and **dual – core $Yb^{3+}/Tm^{3+}$ and $Yb^{3+}/Ho^{3+}$ – UC multicolour emission –** upconversion ($\lambda_p$=976 nm)
  - **Possibility of tunning** of CIE coordinates (pump power, fiber length)

**Perspectives:**

- **Construction of optical fibers characterised by multicolour emission for tunable radiation sources (VIS)**
- **Optimization of construction (dopant concentration, cores number) for particular CIE range of values**

# ACKNOWLEDGMENTS


- ***National Science Centre (Poland)*** *„Mechanisms influencing differences in luminescent properties of glasses and optical fibers doped with lanthanides”* ***No. DEC-2013/09/D/ST8/03987*** (2014-2017).
- **National Science Centre (Poland)** *„New antimony glasses with mixed low, high – phonon energy for the construction of active optical fibers”* **No. DEC-2012/07/B/ST8/04019,** (2013-2016).
- **The COST Action MP1401** *“Advanced fibre laser and coherent source as tools for society, manufacturing and life science”* is also acknowledged.


# THANK YOU