CNR IFN Istituto di Fotonica e Nanotecnologie

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Dy^{3+}-doped ZBLAN fiber for efficient laser emission at 3 μm

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EAGLES
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Rare-Earth Doped Glass Materials and Fibre Lasers
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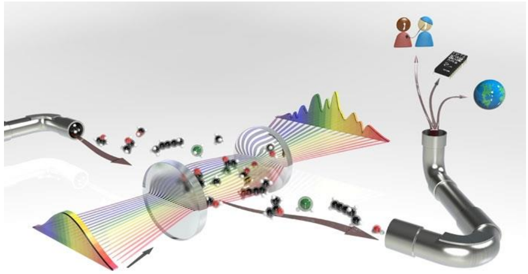
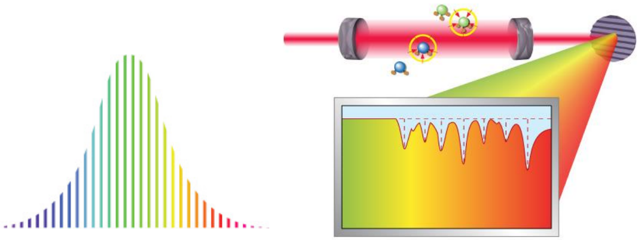
Aim of the work

Development of widely tunable (broadband) mid-IR laser sources at around 3 μm (molecular fingerprint region) based on fiber technology

- High-resolution molecular spectroscopy
  - Isotope ratios (^{13}C, ^{18}O)
  - Fundamental constants
  - Test of fundamental theories



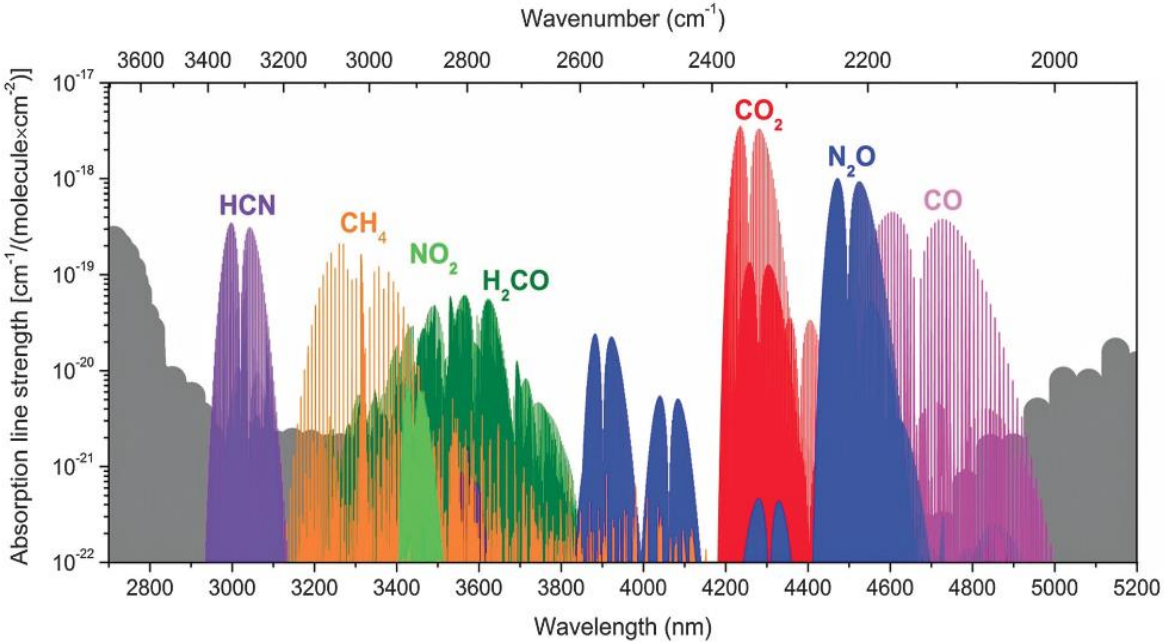
- Trace gas broadband measurements
  - Air quality and environment monitoring (greenhouse gases and pollutants)
  - Human breath analisys (identification and detection of molecular biomarkers)
  - Detection of biological hazardous or explosive materials
- Frequency metrology
  - Measurements and synthesis of optical frequencie
  - Optical clocks



Mid-IR molecular fingerprints

Why Mid-IR radiation for applications such as gas sensing and spectroscopy, safety and security, biology, and medicine?

In the spectral interval from 2 to 20 µm, the so called "fingerprint" region, inorganic and organic molecules show the strongest absorption features associated with fundamental ro-vibrational transitions



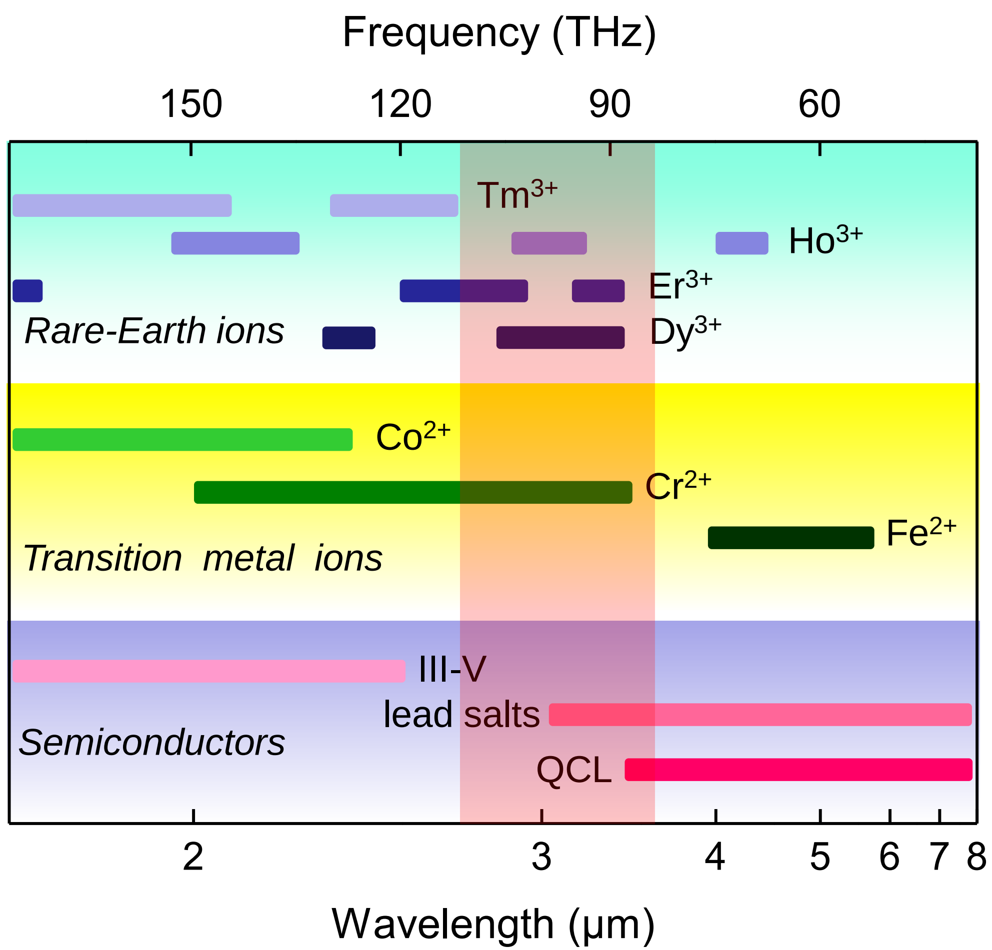
Absorption spectra of some important trace gases in the wavelength region between 3 and 5 µm.

Outline

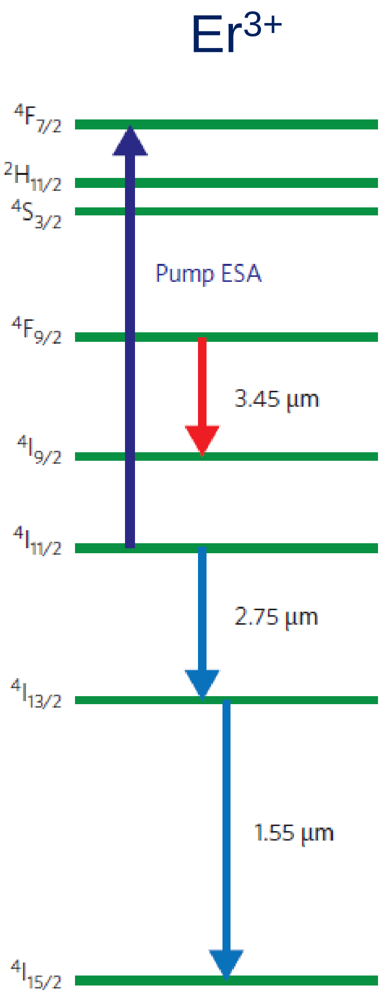
- Mid-infrared solid-state lasers
- Dy-doped ZBLAN fiber as active medium
- Dy-doped ZBLAN optical amplifier
- Conclusions

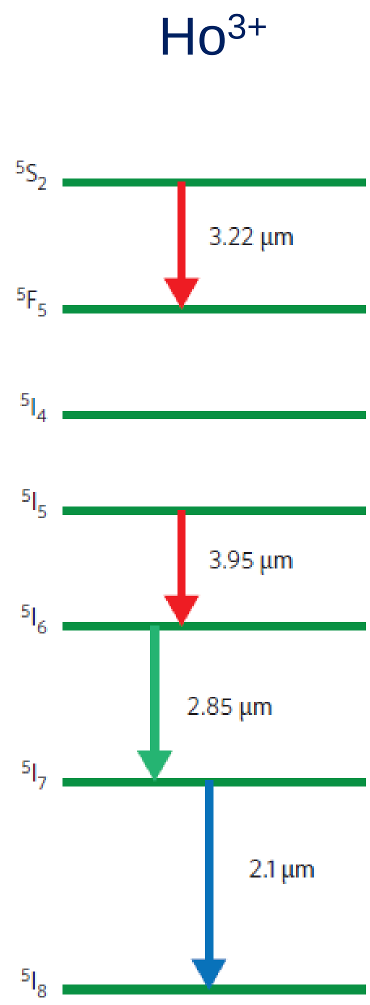
Mid-IR solid-state lasers

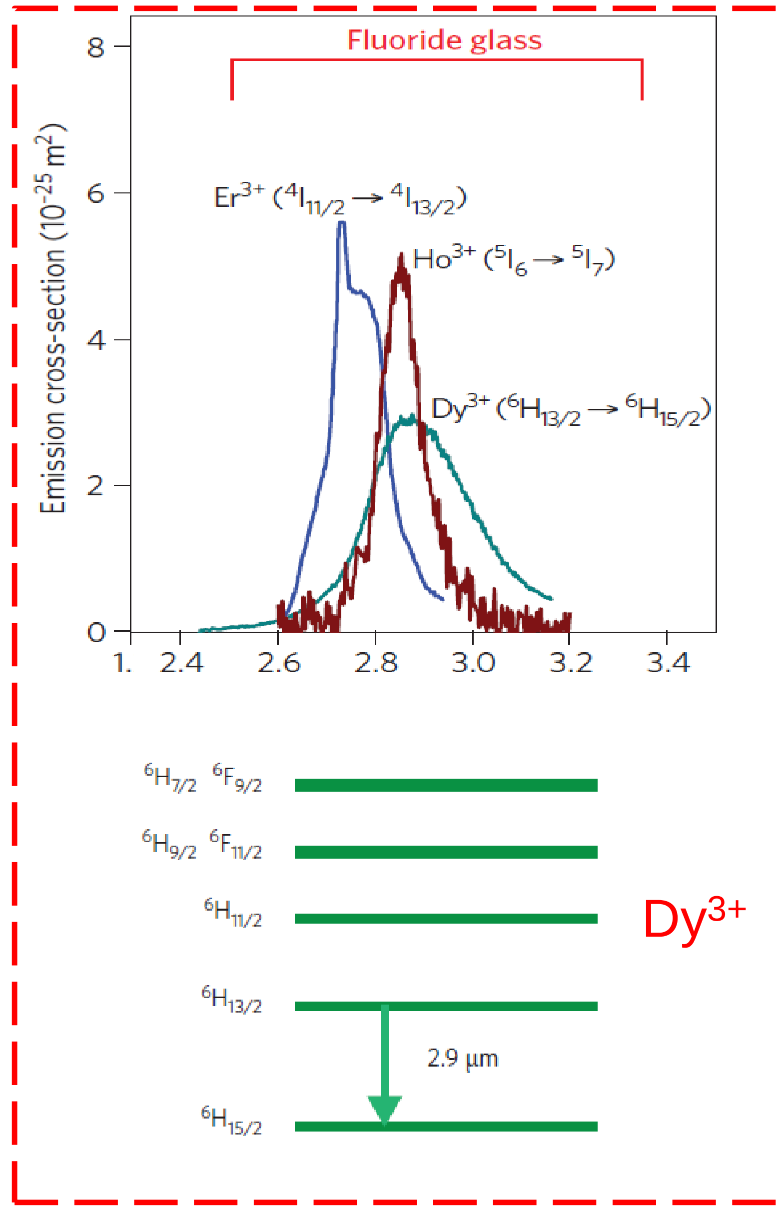
An increasing number of different solid-state laser technologies can be used to access the mid-infrared spectral region



Rare earth ions for mid-infrared laser emission

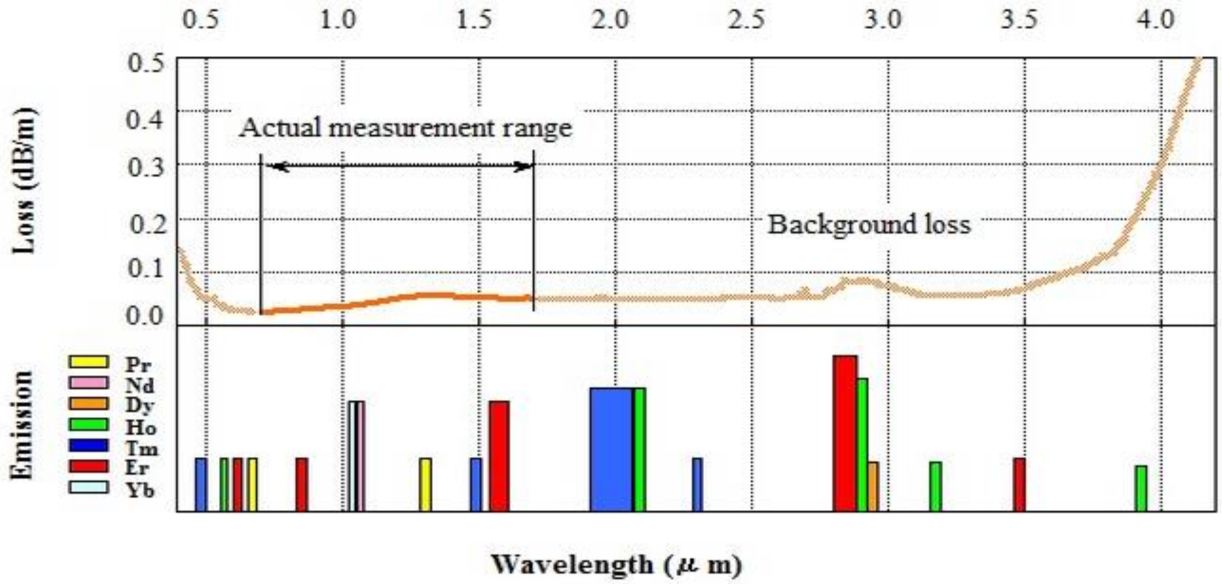




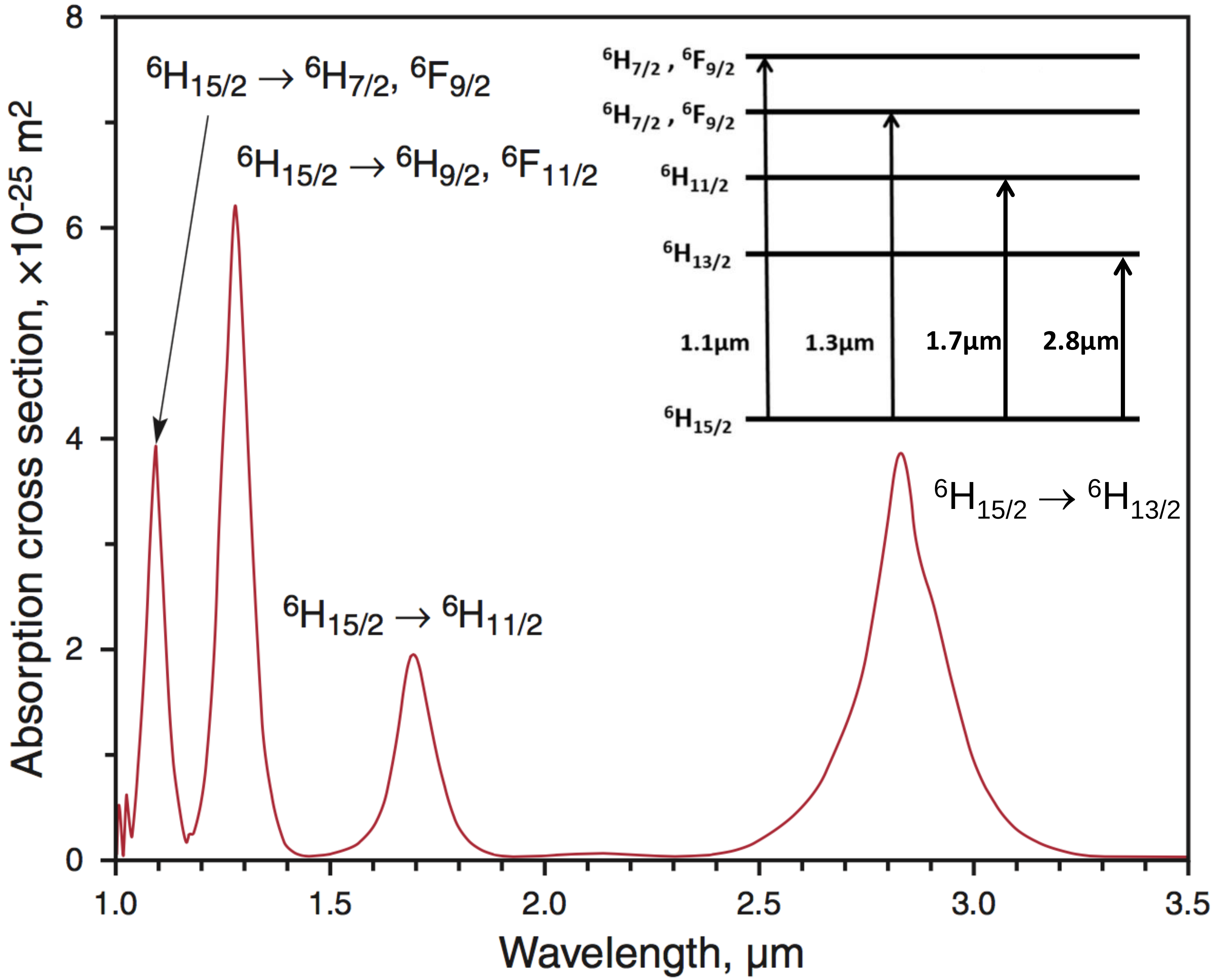


ZBLAN glass host

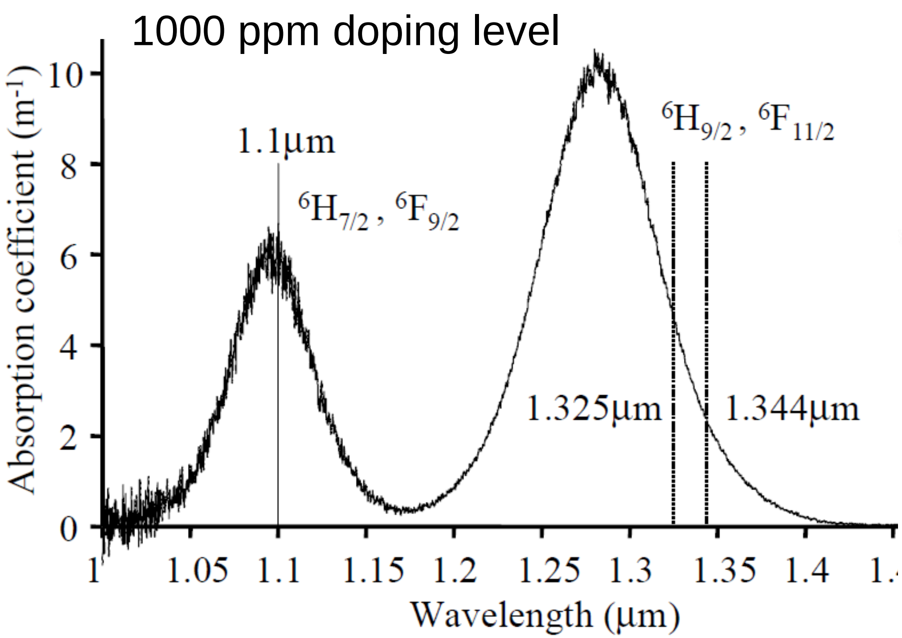
- ✓ Low phonon energy (565 cm^{-1})
- ✓ Low refractive index 1.5
- ✓ Transparency up to 6 µm
- ✓ Low propagation losses (<0.01 dB/km within wavelength region of 2 to 5 µm)
- ✓ Commercially available
- ▪ Linewidth of RE ions are narrow in Flourides
- ▪ Magnitude of stark splitting and its variation are much smaller compared to oxide glasses

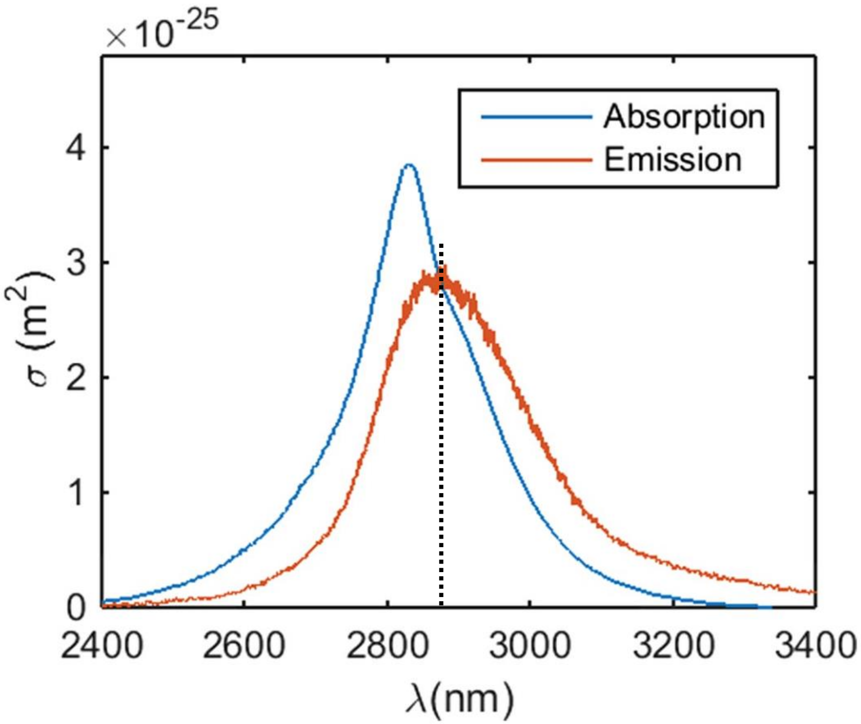


Dy-doped ZBLAN absorption spectroscopy



Dy-doped ZBLAN spectroscopy

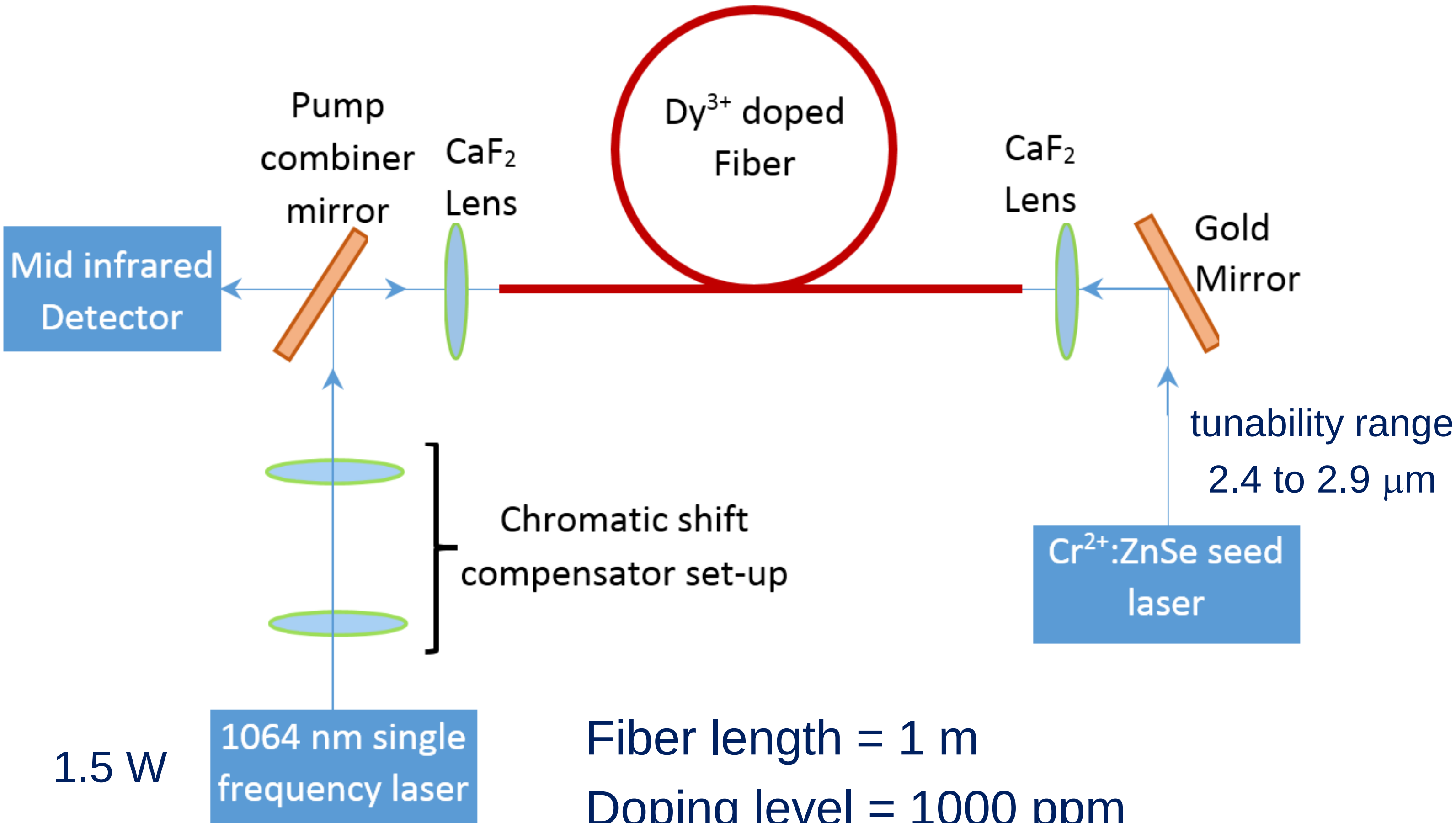




Wavelength (µm)	Absorption (dB/m)
1.098	27.2
1.280	42
1.7	14
2.8	31.5

σ_a (10^{-25} m^2) at λ_p (µm)	4 2.83
σ_e (10^{-25} m^2) at λ_p (µm)	2.9 2.87
lifetime (ms)	0.65
Gain bandwidth (THz) (µm)	15 2.9 to 3.4

Dy-doped ZBLAN amplifier: optical layout



Fiber length = 1 m

Doping level = 1000 ppm

Core / cladding diameters = 15 / 125 μm

Cutoff-wavelength = 2.55 μm; NA = 0.13

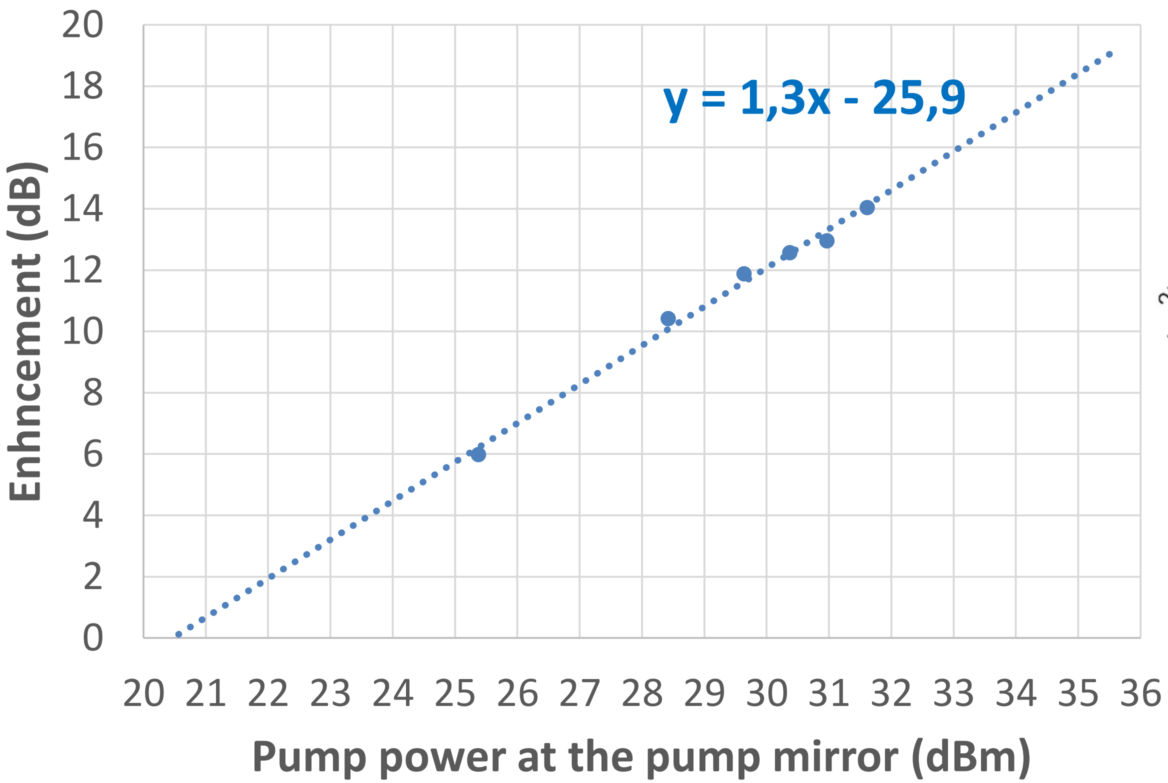
Dy-doped ZBLAN amplifier: characterization

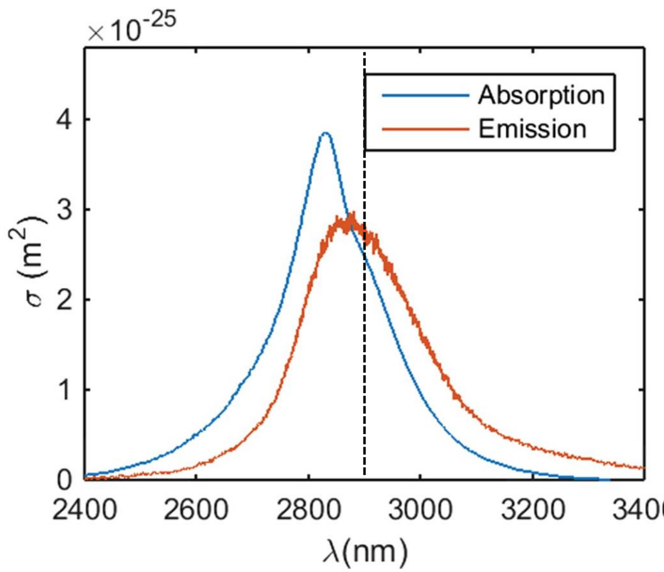
Wavelength (μm)	Coupling (%)	Measured Absorption (dB/m)	Predicted Absorption (dB/m)
1.06	76	8.2	13.0
2.6	28	1	0.02
2.9	30	14.6 ± 1	18.8

ZBLAN background absorption (OH^{-1} absorption?)

M. R. Majewski and S. D. Jackson, Opt. Lett. 41, 10, 2173-2176 (2016)

Dy-doped ZBLAN amplifier: enhancement at 2.9 μm





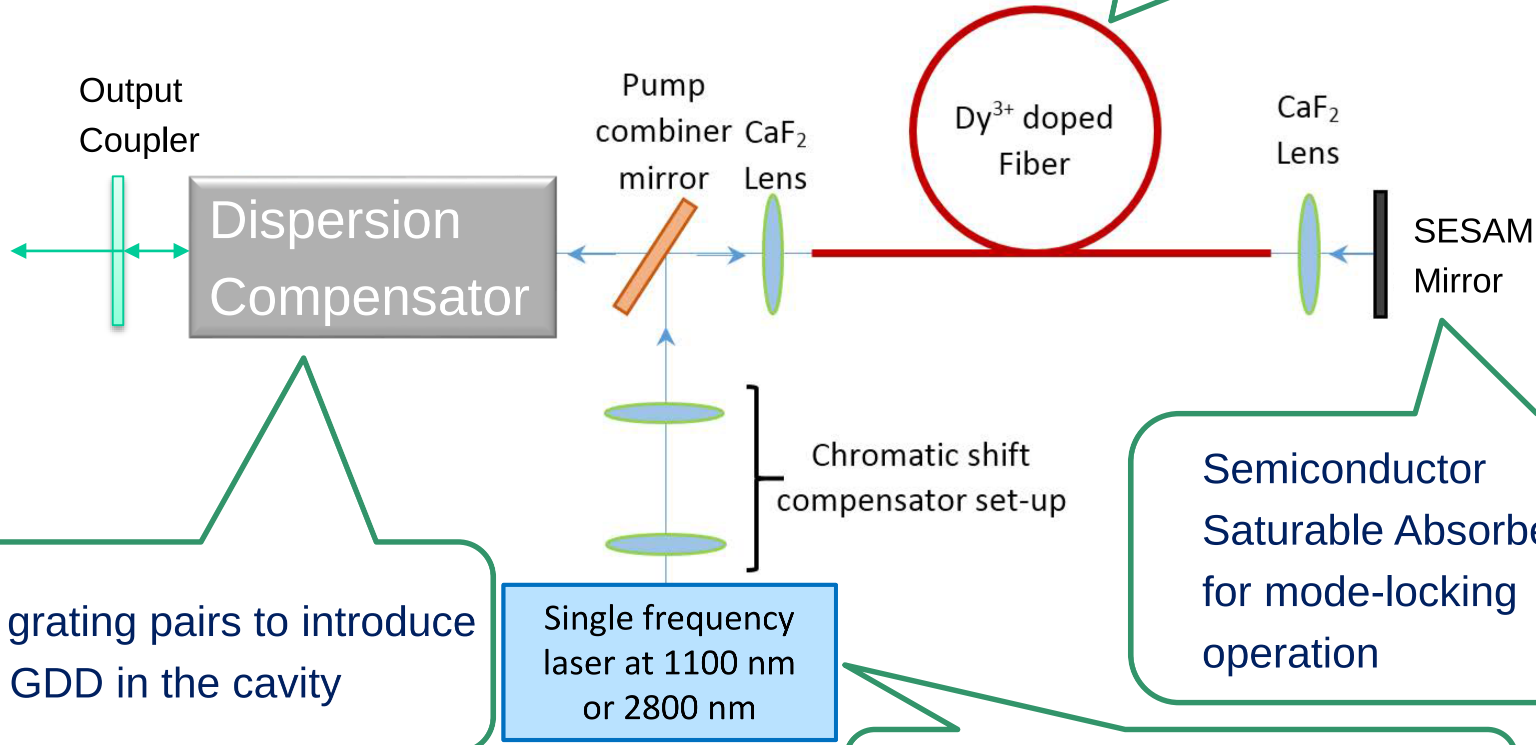
14 dB enhancement at 1.4 W (31.5 dBm) pump power

1.3 dB estimated optical gain at 2.9 μm

Estimated inversion >80%

Toward femtosecond pulse generation

New Dy-ZBLAN fiber design
2000 ppm doping level
12.5 µm core; NA=0.16



Semiconductor Saturable Absorber for mode-locking operation

Prism or grating pairs to introduce negative GDD in the cavity

Low noise pump source for high coherence laser emission

Acknowledgement

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