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Optical Fiber Sources Design in OptiSystem Software

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OUTLINE

- Introduction
- Optical Fiber Lasers Review
- Cascaded Fiber Laser for Pumping Holmium-Doped Fiber Amplifier
  - Enable the use of commercial 980nm and 1480nm laser pumps
- Modeling and Simulation using OptiSystem Software
- Results and Discussions
- Live Demonstration
- Q&A

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Introduction

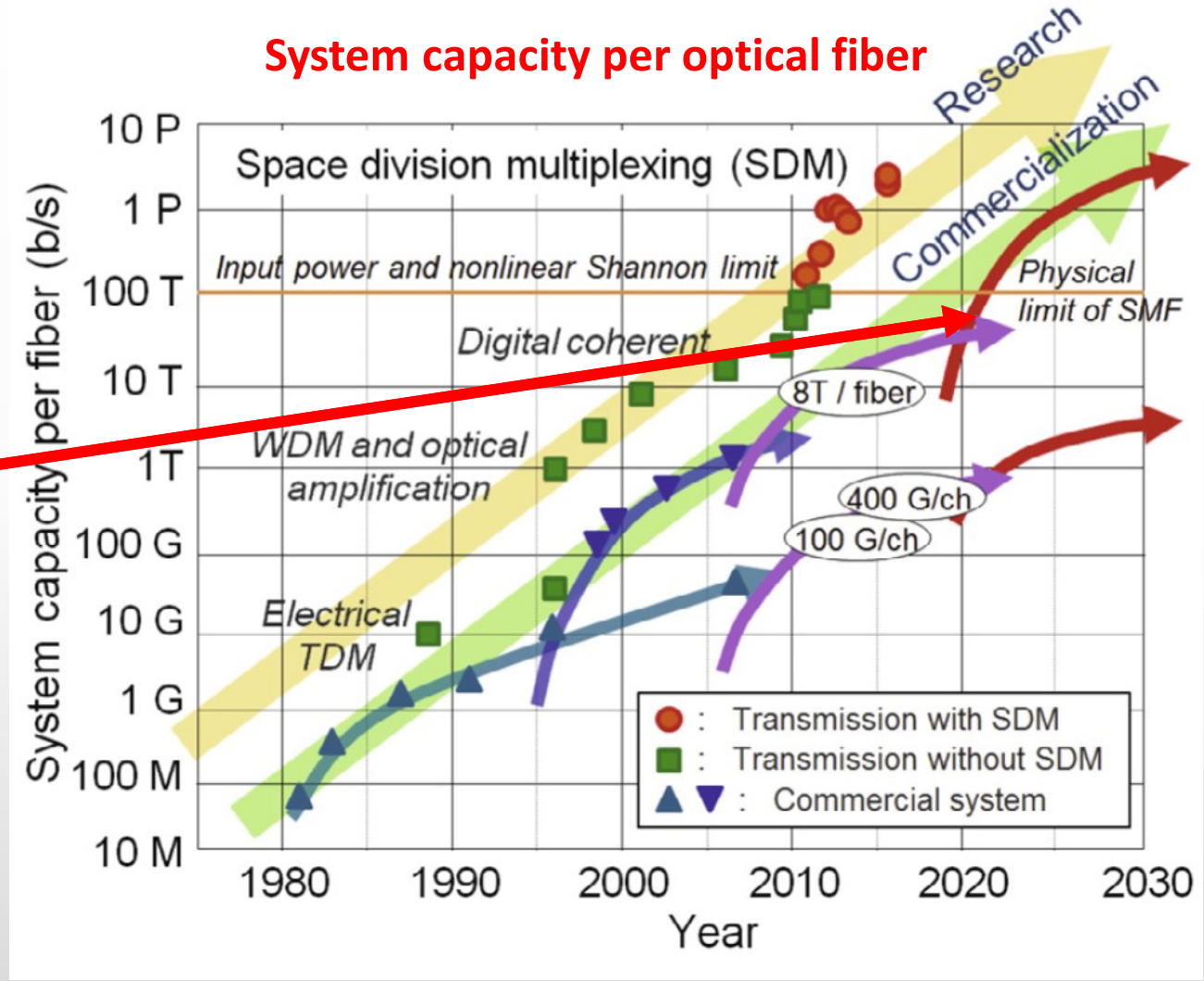
Bandwidth hungry services

- Voice-over-IP
- High-definition TV
- IP-TV
- Education-on-demand
- Video-on-demand
- Video conferencing
- Interactive video gaming
- Video surveillance

Transmission Systems Capacity Progress

- Available degrees of data transmission scaled to (λ, Pol. Mux. & digital coherent)
- Reached capacity limits in SMF
- SDM improves capacity with cost per bit economy

Exploring 2μm region



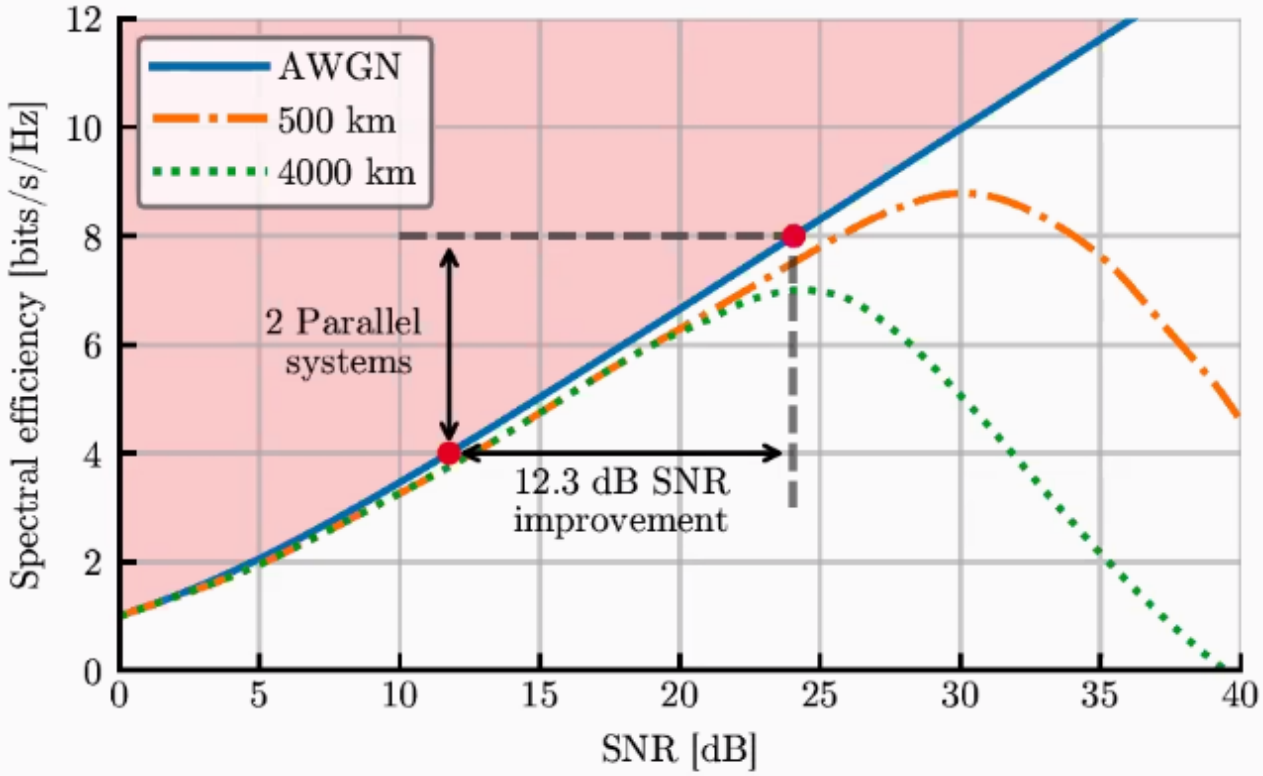
T. Mizuno, Y. Miyamoto, "High-capacity dense space division multiplexing transmission," Optical Fiber Technology, 35,108-117 (2017)

Optical Fiber Capacity Definition

Capacity scaling in optical fibers

$$C = \log_2(1 + \mathrm{SNR}) \times 2 \times B \times M$$

- **C** Capacity
- **SNR** Signal-to-noise ratio
- **×2** Polarization multiplexing
- **B** Number of wavelength channels (Bandwidth)
- **M** Number of spatial paths



Exploiting a new dimension: Space

C. Okonkwo “Maximising Capacity Through Space Division Multiplexing” CLEO2021

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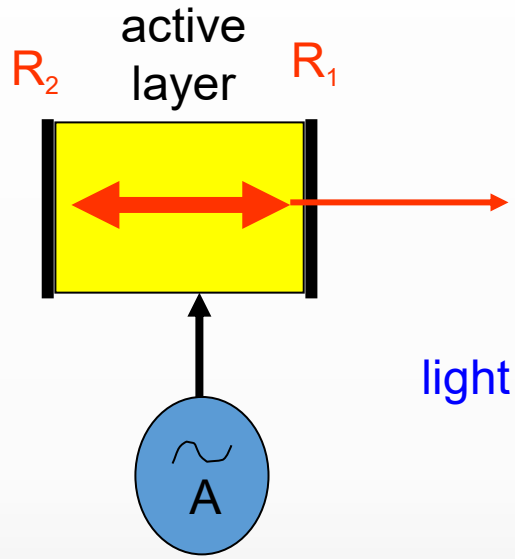
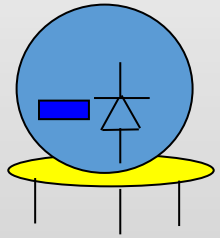
2 µm Region Enabling Technologies

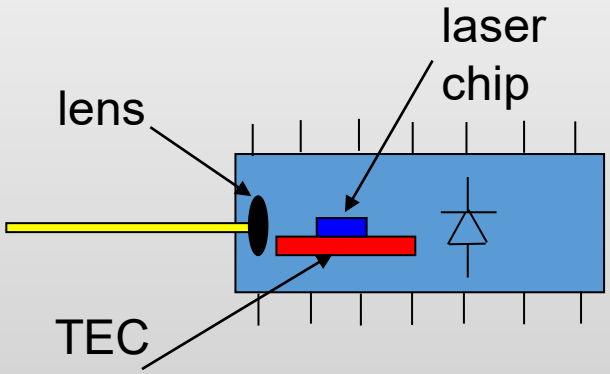
- Lasers (fiber lasers)
- Amplifiers – Holmium-doped fiber amplifier (HDFA)
- Passive components
- Modulators

Laser (light amplification with stimulated emission and radiation)

- Gain medium between two reflectors
  - When gain > loss = lasing
- Semiconductor Laser Packaging
  - 14 pins butterfly package
  - 3 pins TO can
  - TOSA (transmitter optical subassembly) - Transceivers







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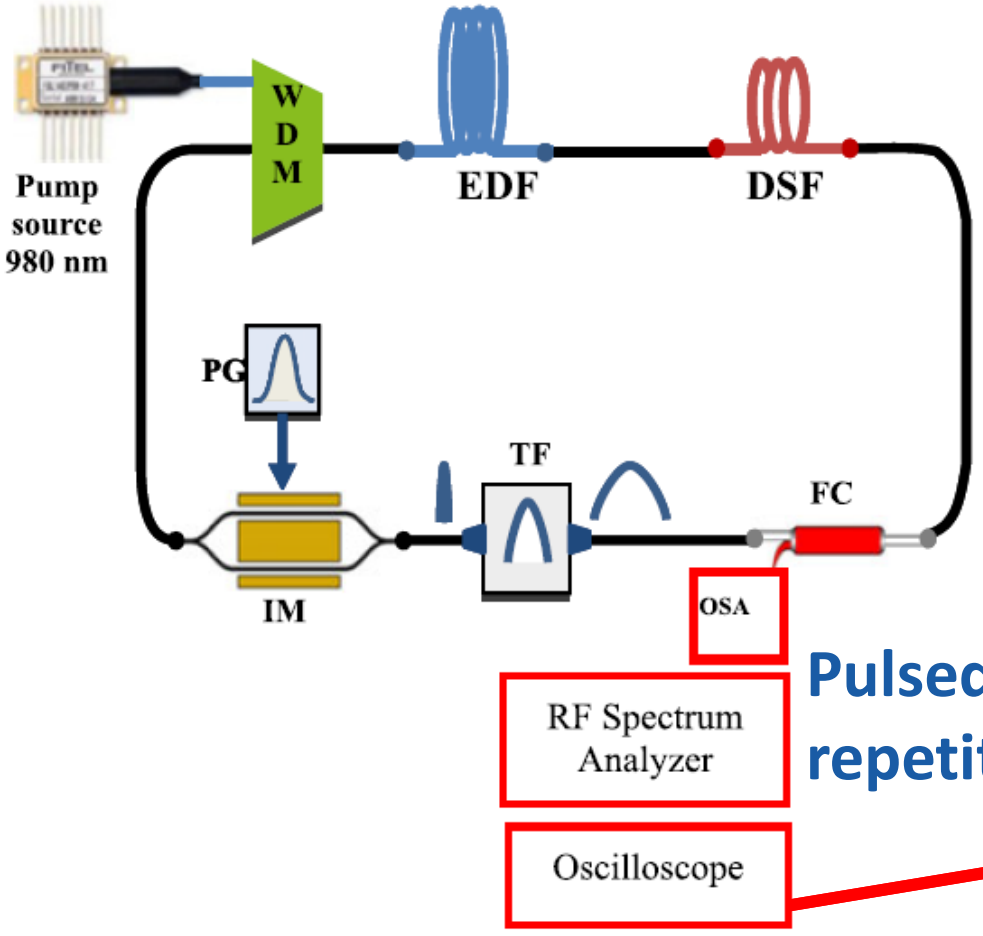
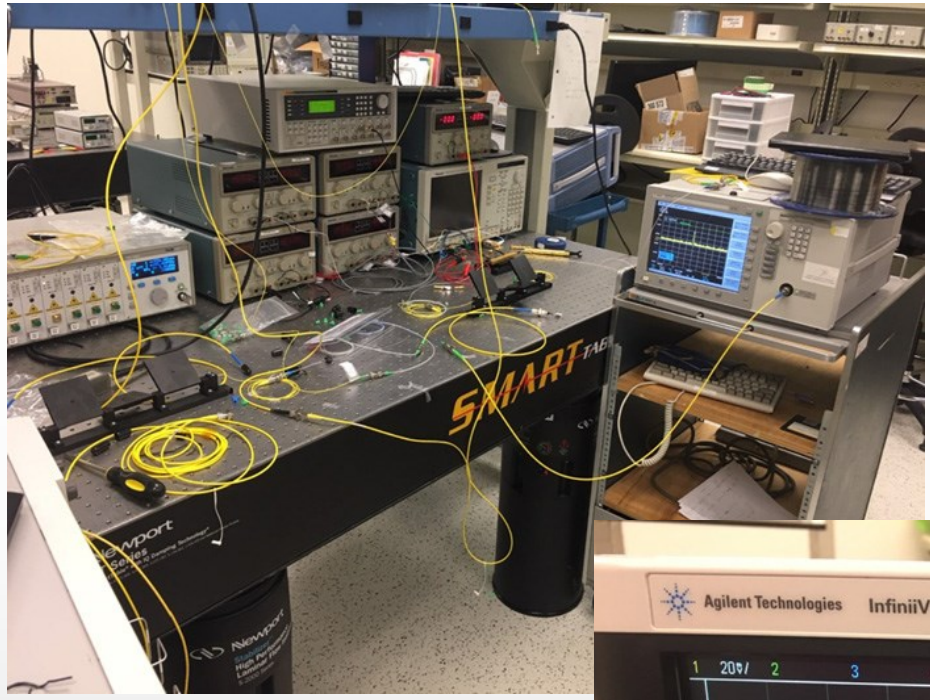
Fiber Lasers

- Ring lasers
- Figure-8 lasers
- Loop mirror lasers
- Cascaded fiber lasers for HDFA

Ring Lasers

Active Mode locking [1]

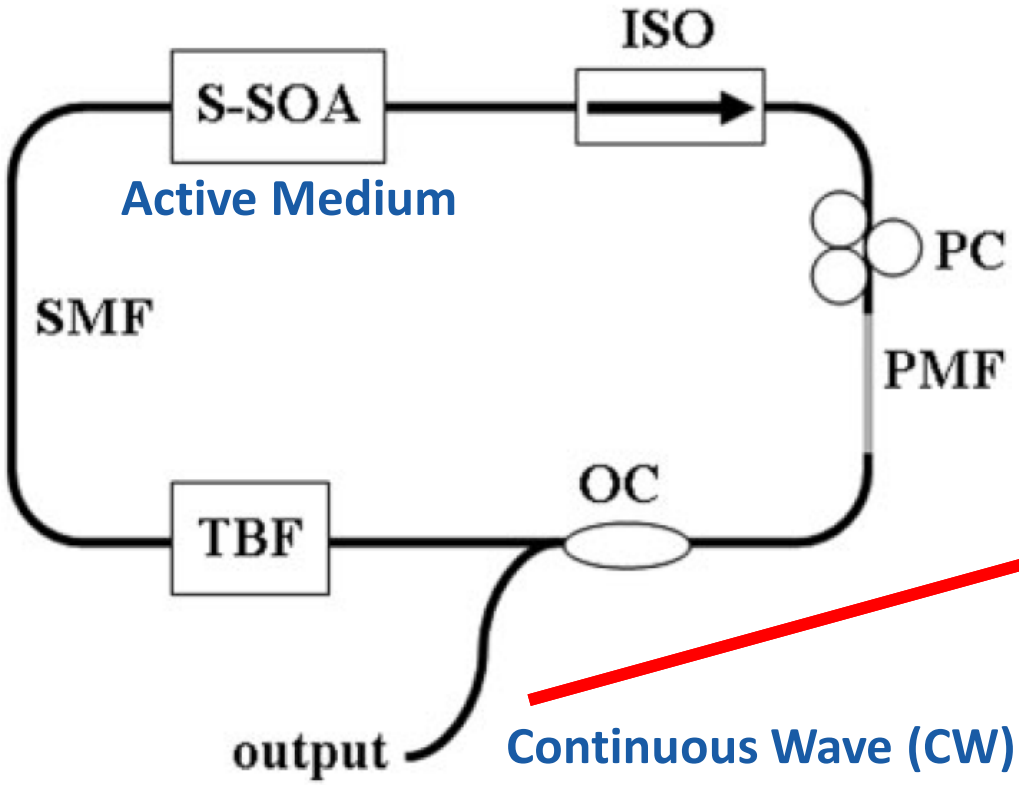




Pulsed Output @ 0.67 MHz repetition rate

Ring Lasers

Passive Mode locking [2,3]



Continuous Wave (CW) Light

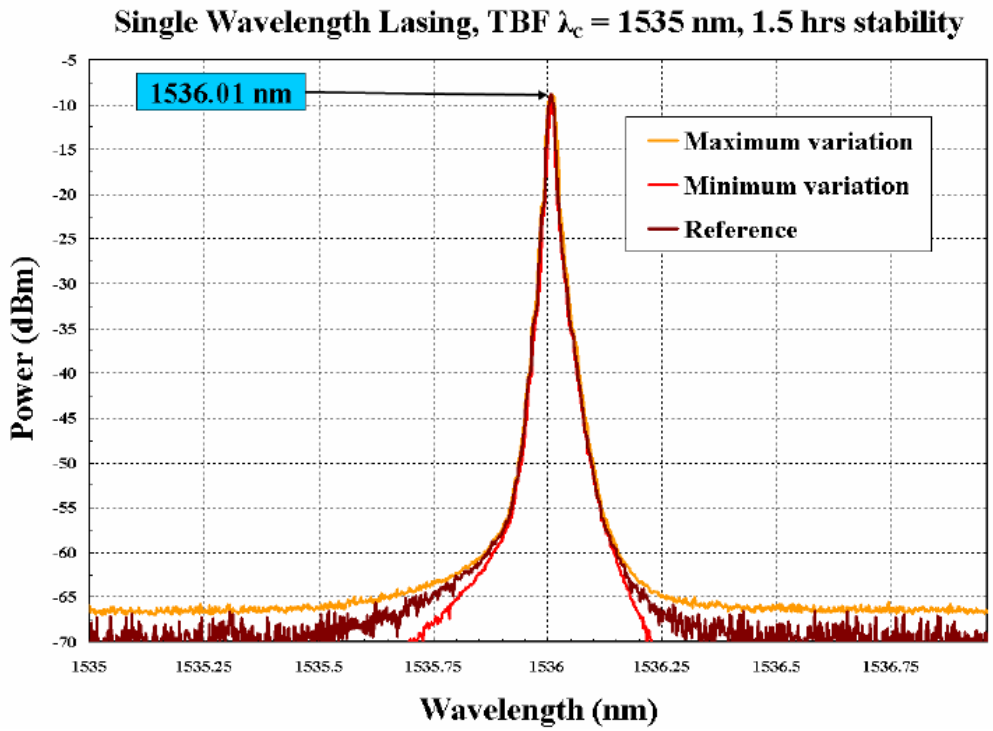
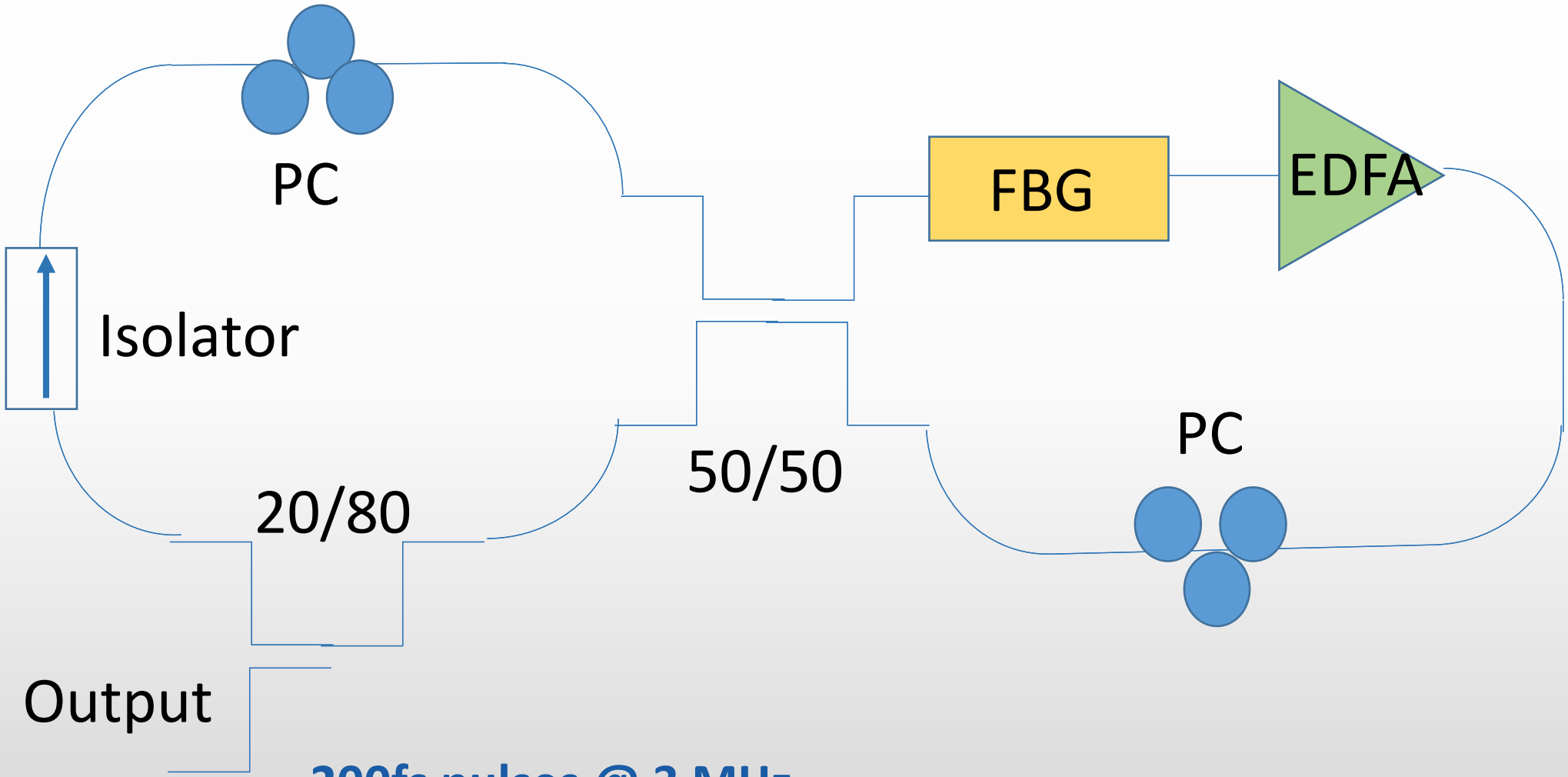


Fig. 6 HC-SFRL lasing spectrum for TBF λ_c = 1535 nm.

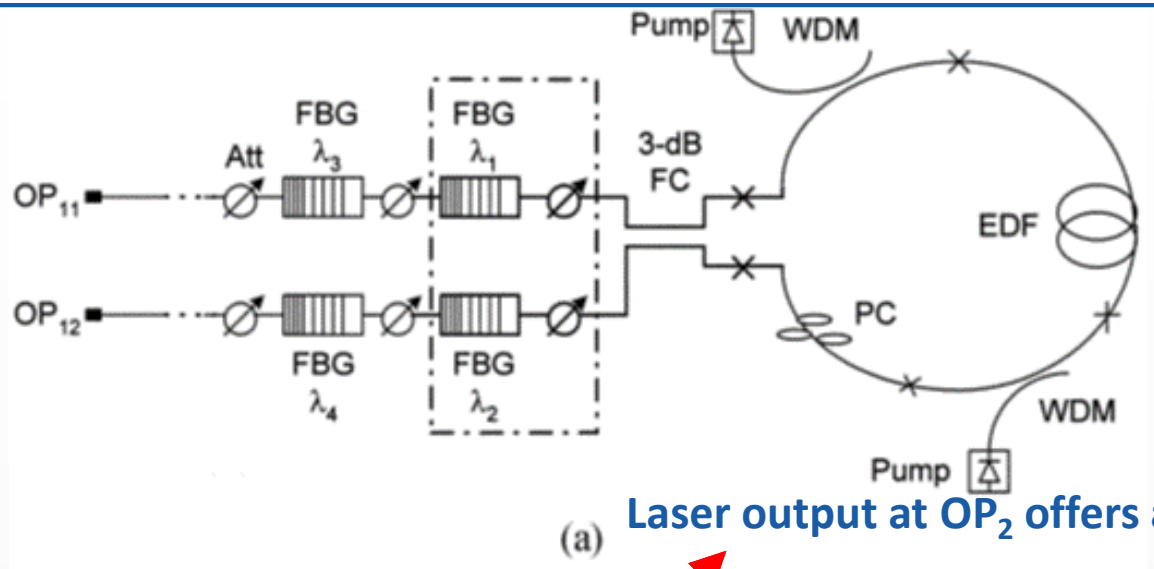
Figure 1 Diagram for semiconductor fiber ring laser (SFRL) incorporating S-band SOA (S-SOA), isolator (ISO), polarization controller (PC), single mode fiber (SMF), polarization maintaining fiber (PMF), 3-dB optical coupler (OC), and tuneable band-pass filter (TBF)

Figure-8 Lasers [4]

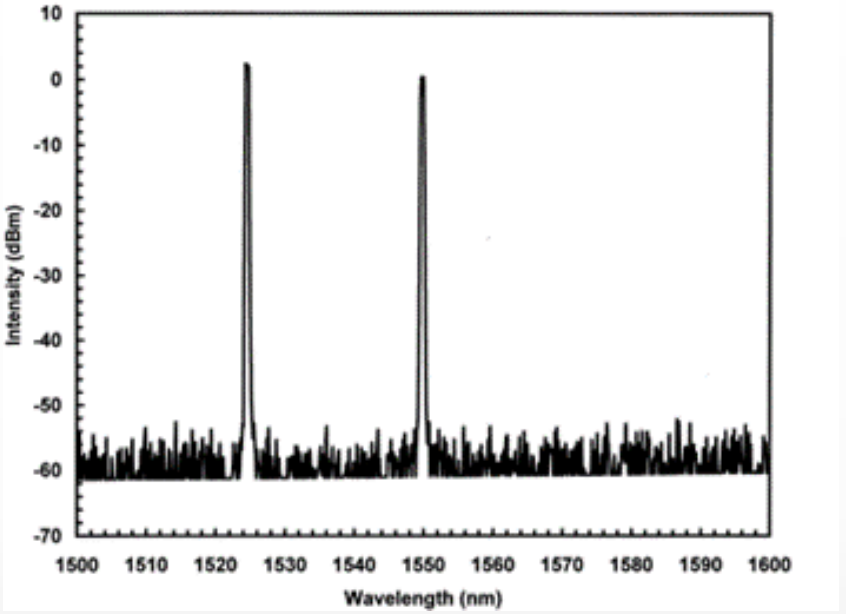


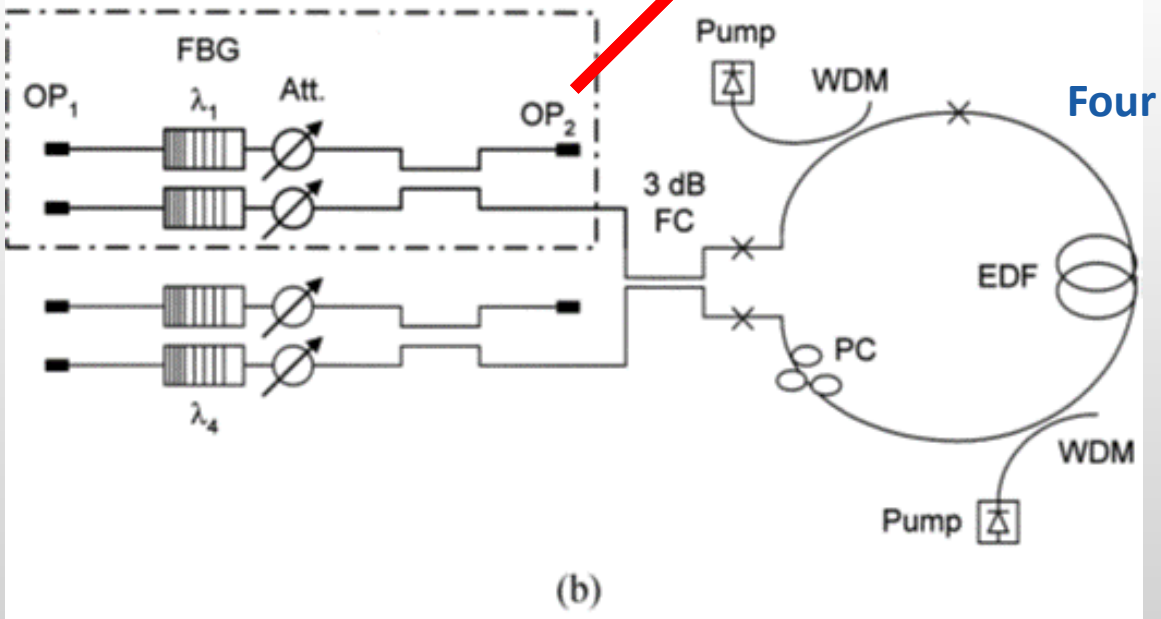
200fs pulses @ 3 MHz repetition rate

Loop mirror Lasers [5]

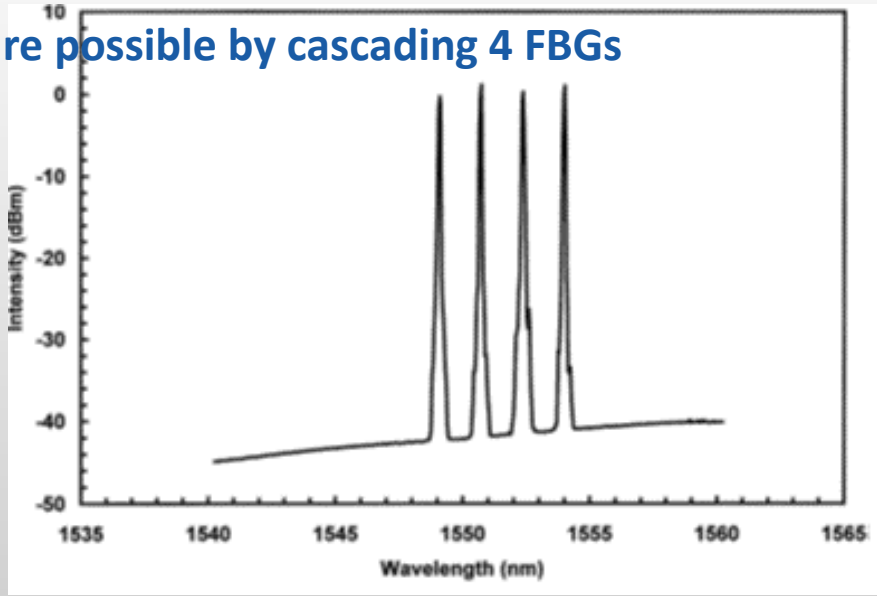


Laser output at OP_2 offers about 60dB OSNR





Four Laser lines at OP_{11} are possible by cascading 4 FBGs



Cascaded Fiber Lasers for HDFA [6]

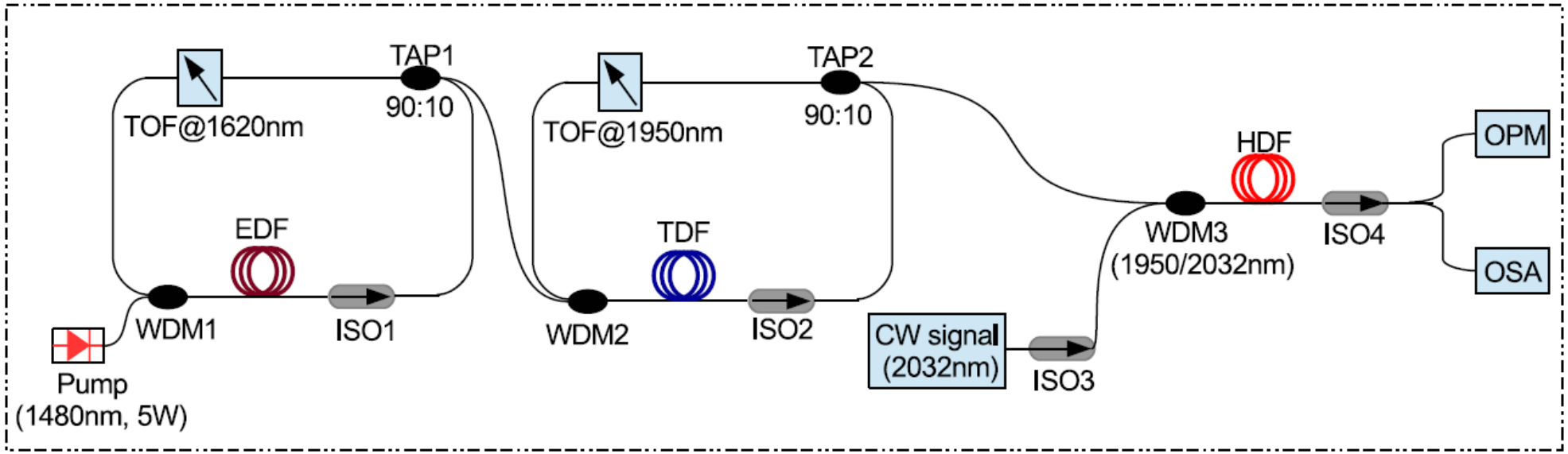


Fig. 4. Schematic of the proposed pumping scheme, **WDM**: Wavelength division multiplexer coupler, **EDF**: Erbium-doped fiber, **ISO**: Isolator, **TOF**: Tunable optical filter, **TDF**: Thulium-doped fiber, **HDF**: Holmium-doped fiber **OPM**: Optical power meter, **OSA**: Optical spectrum analyzer.

Pumps for HDF are expensive and not widely available

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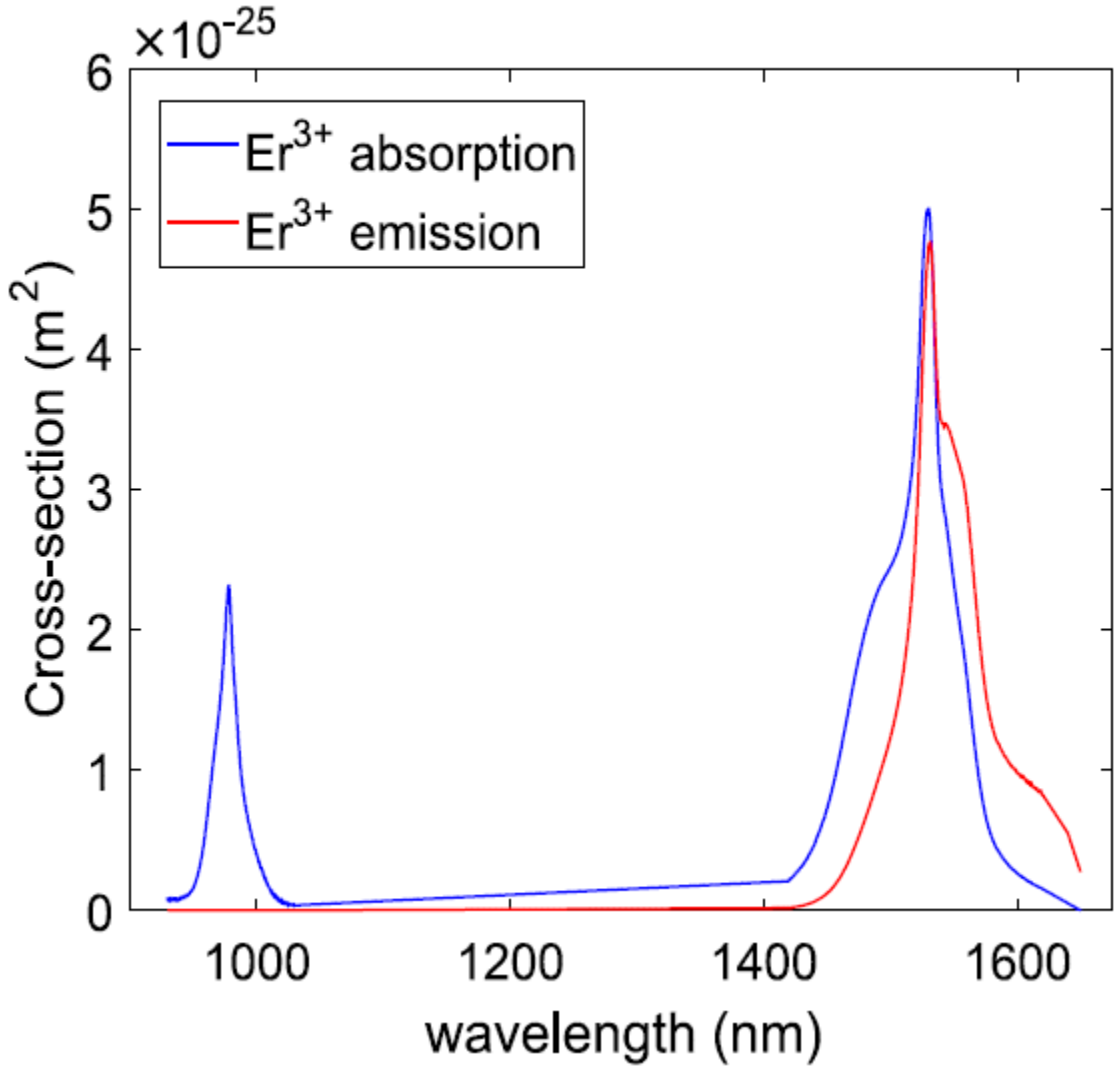
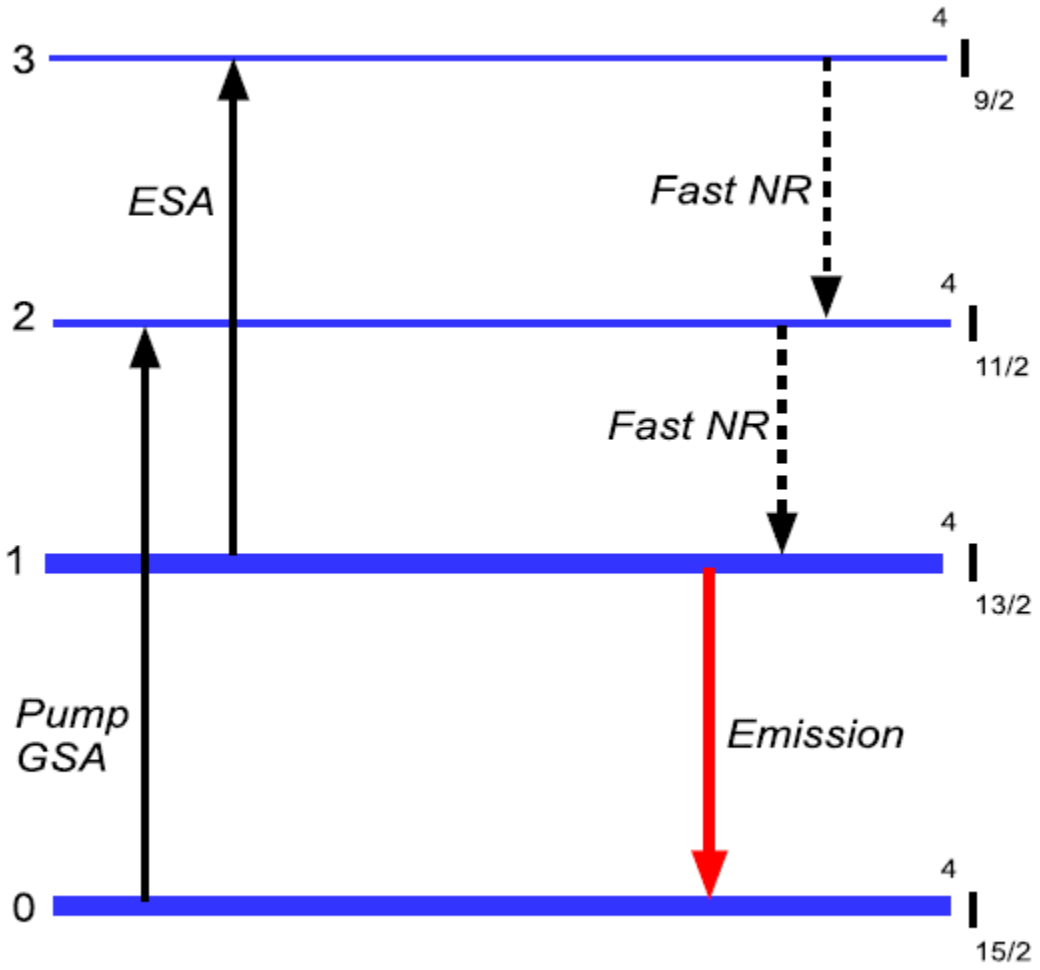
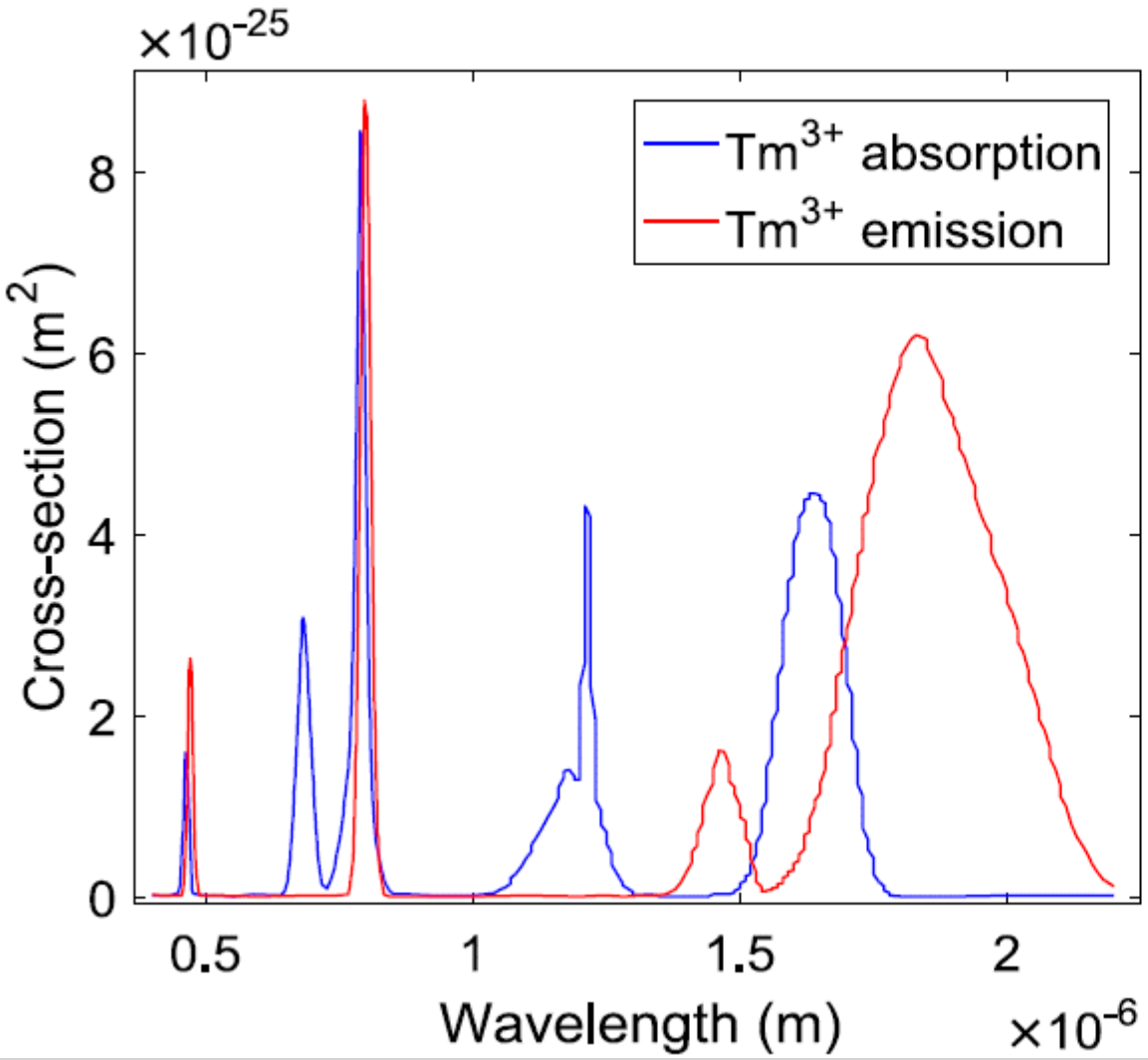
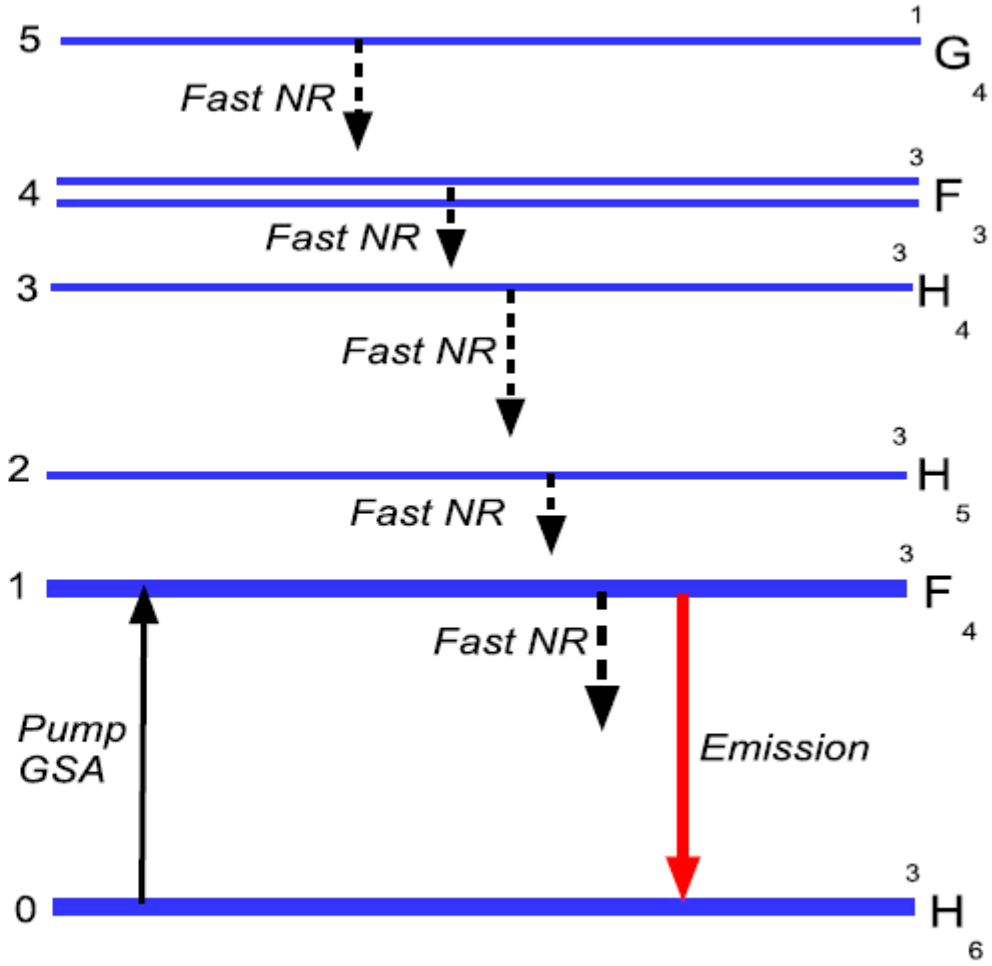
EDF Absorption & Emission Spectra and Energy Levels



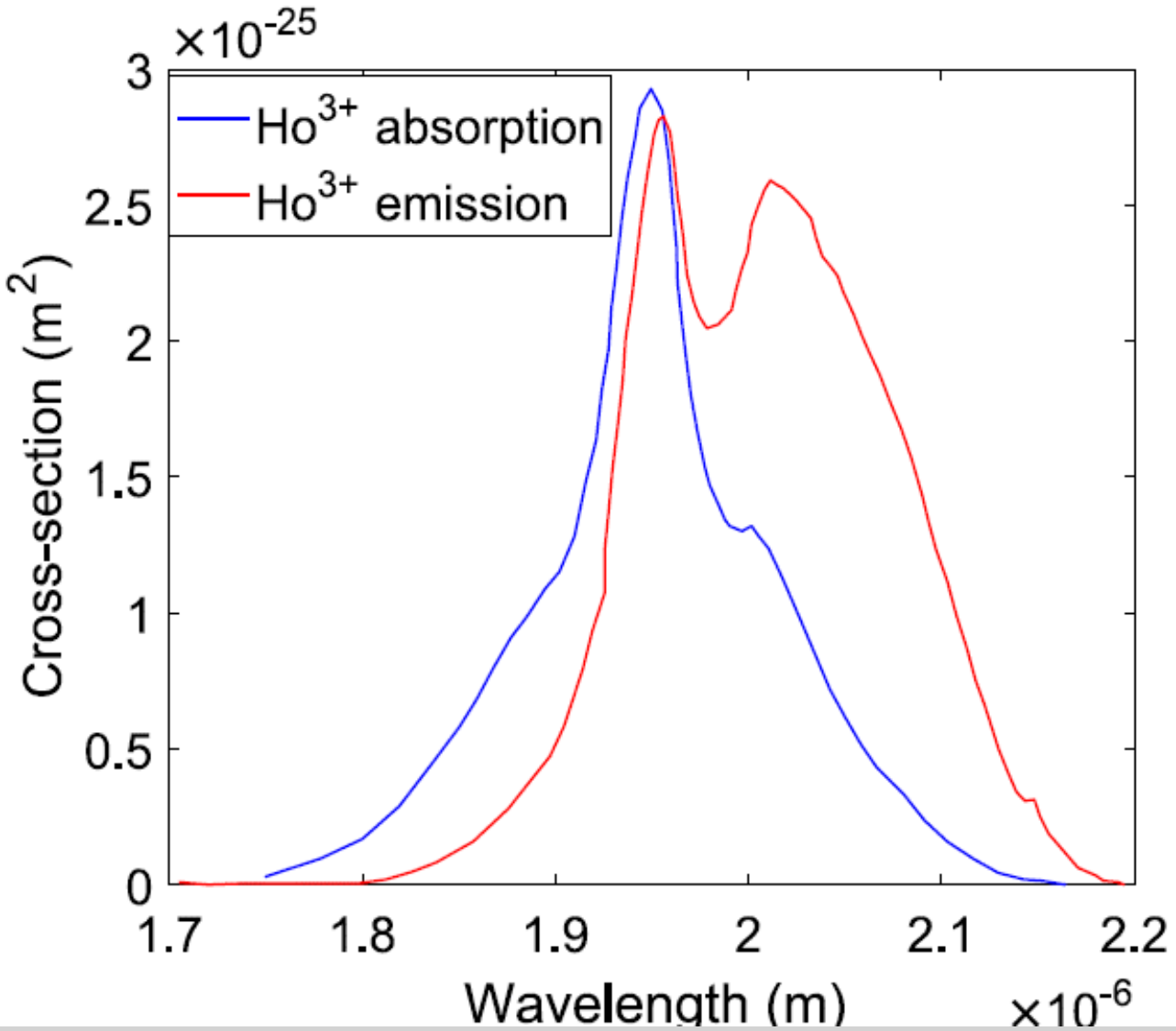


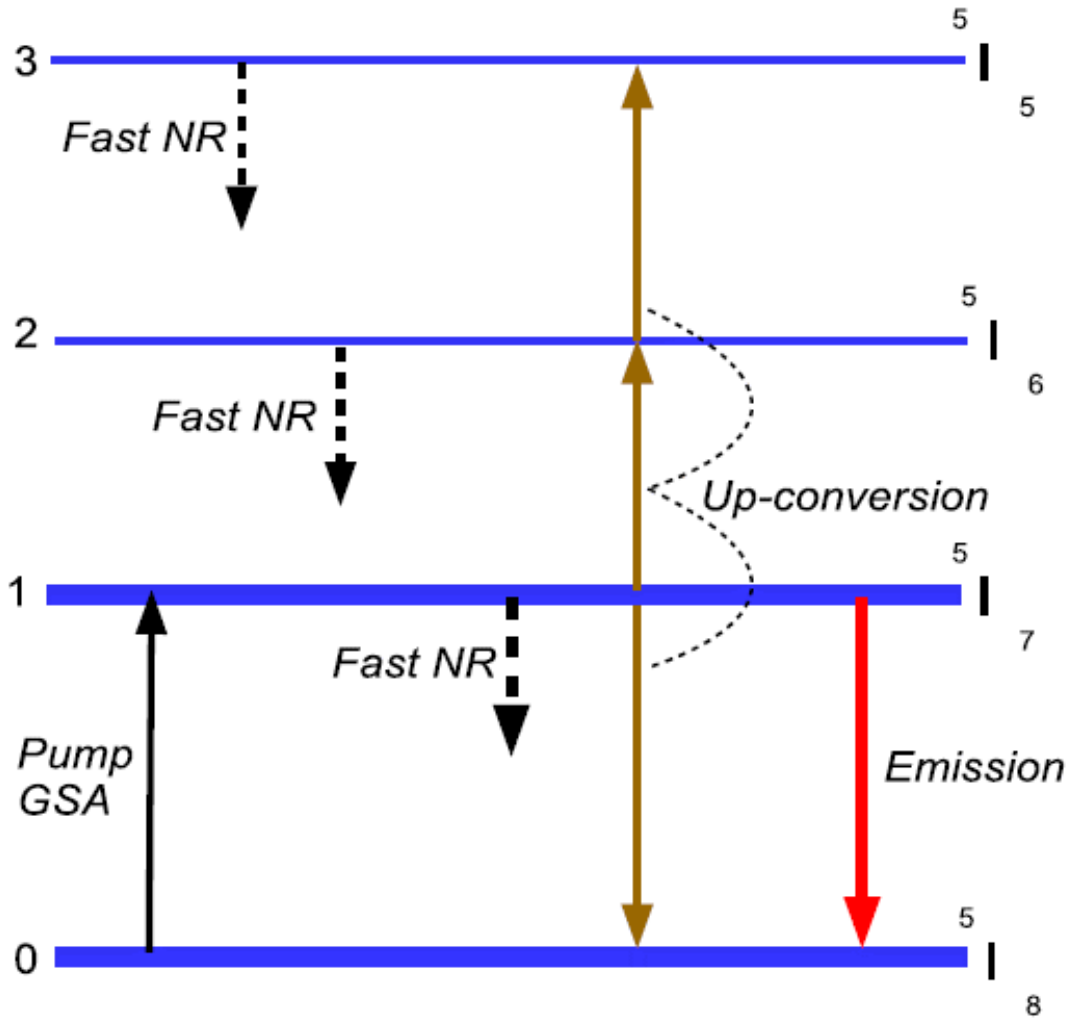
TDF Absorption & Emission Spectra and Energy Levels



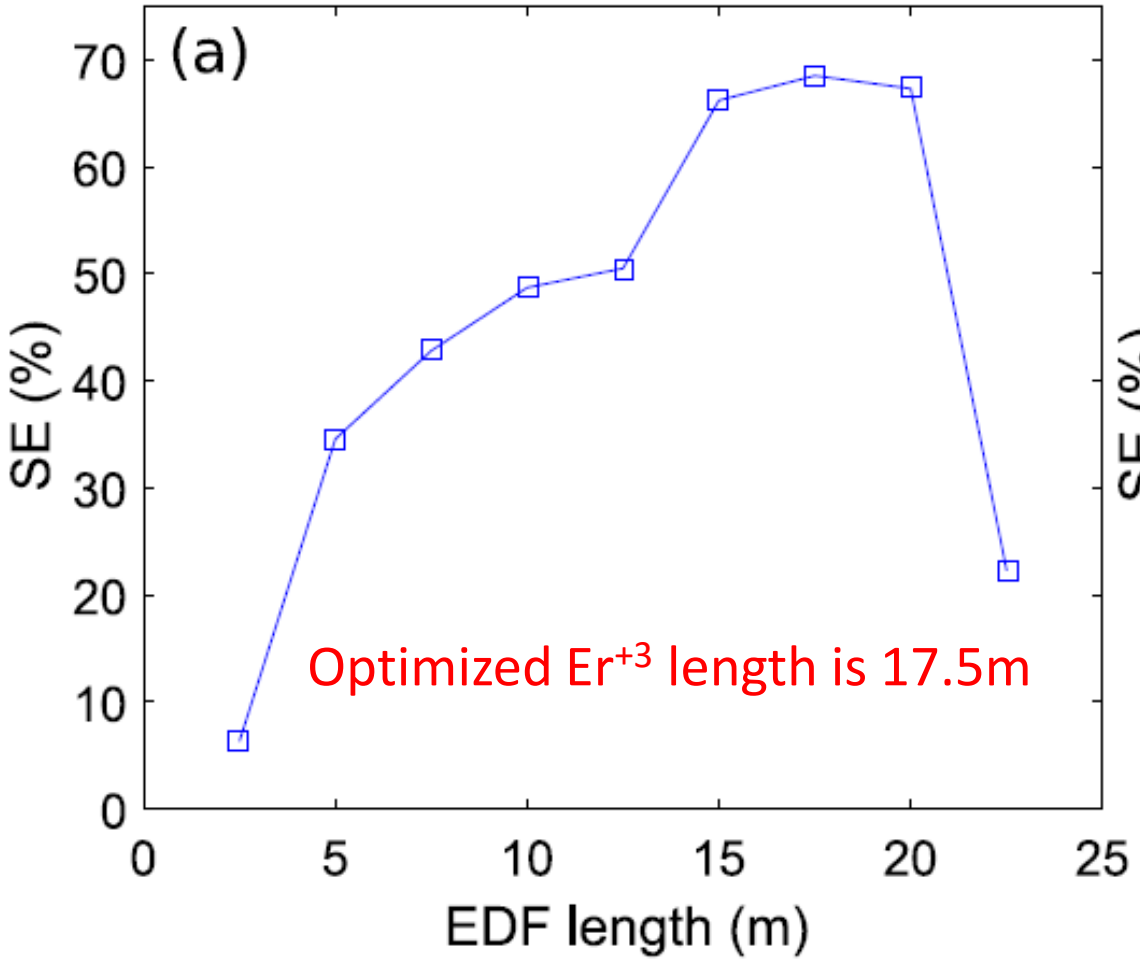


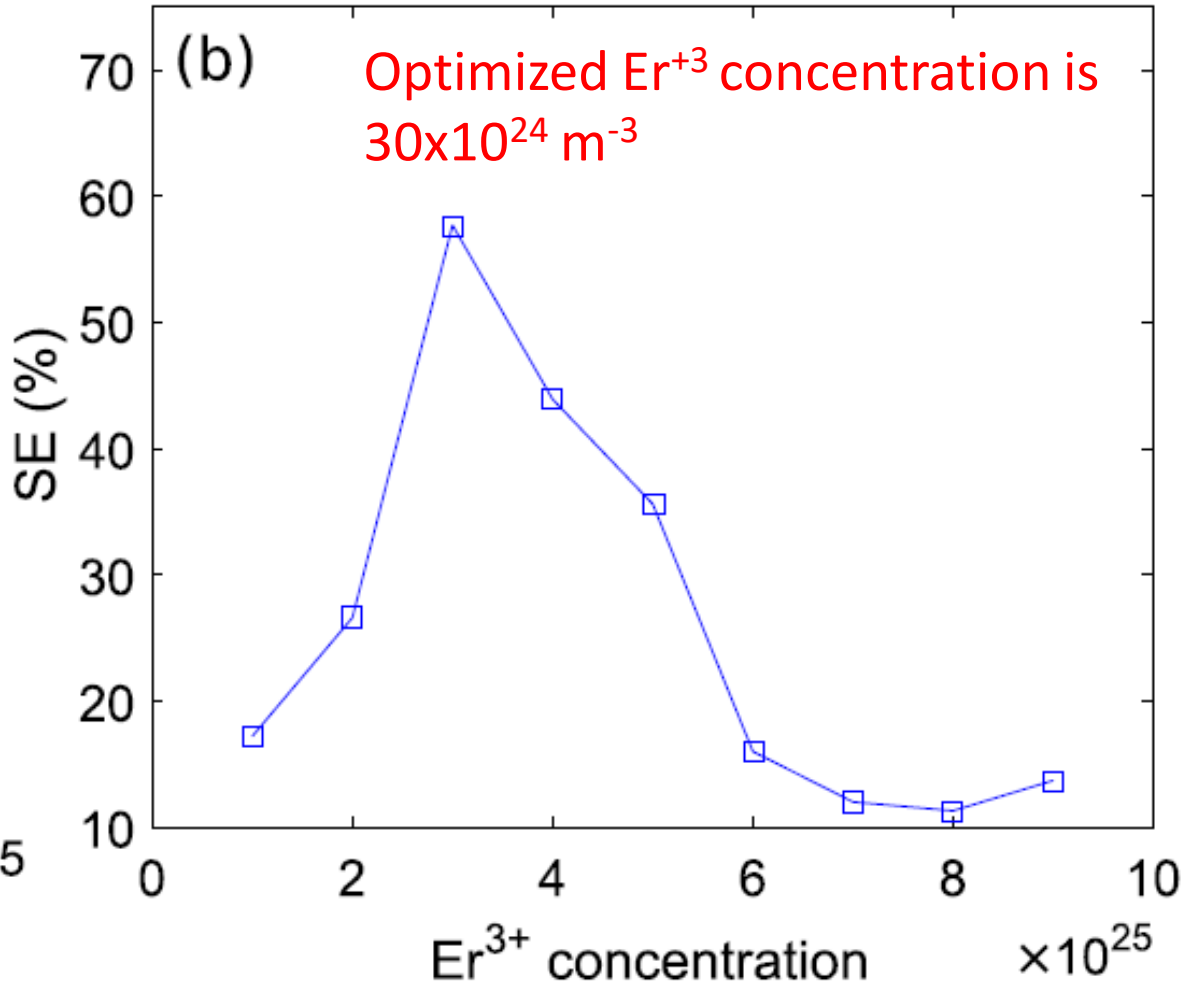
HDF Absorption & Emission Spectra and Energy Levels





EDF Optimization





SE: slope efficiency

Fig. 2. SE versus (a) EDF length plot (b) Er^{3+} concentration plot.

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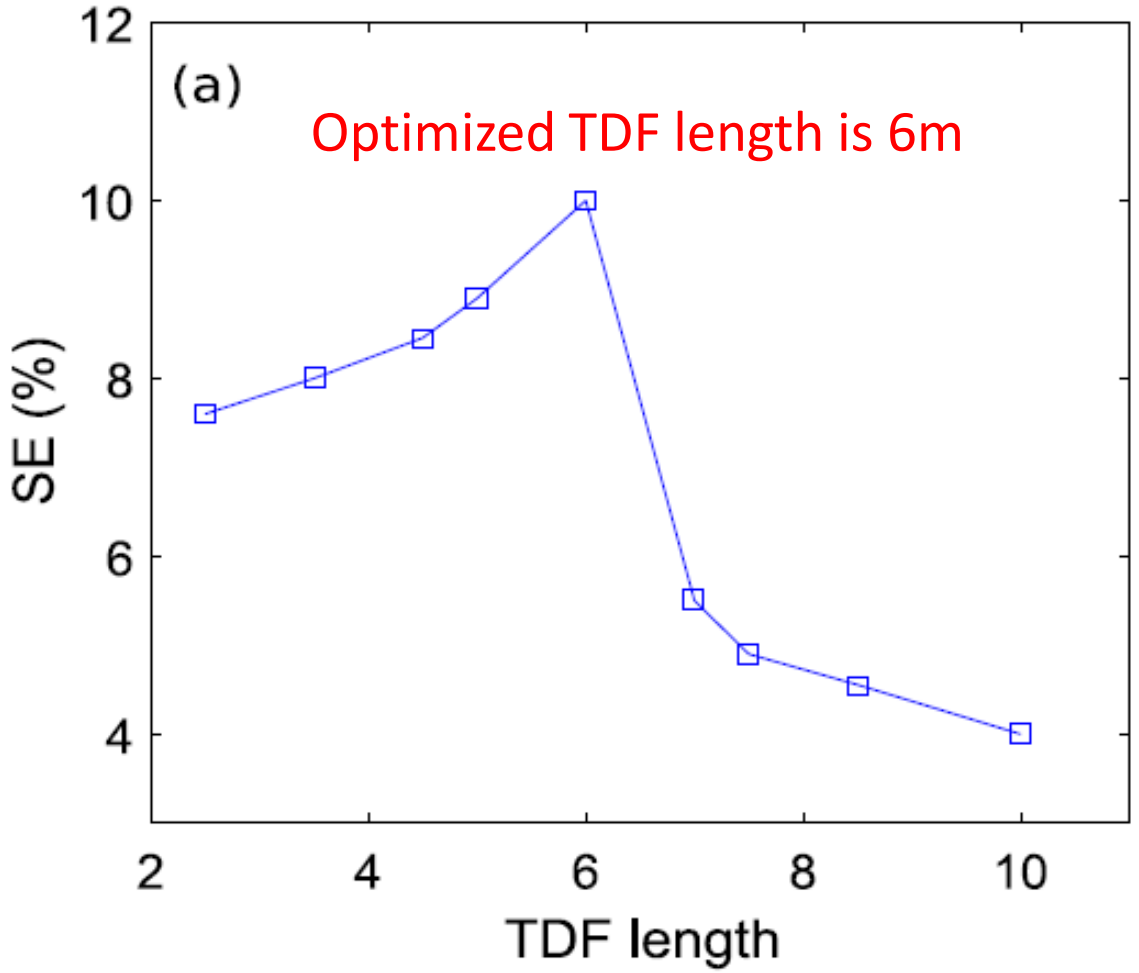
TDF Optimization



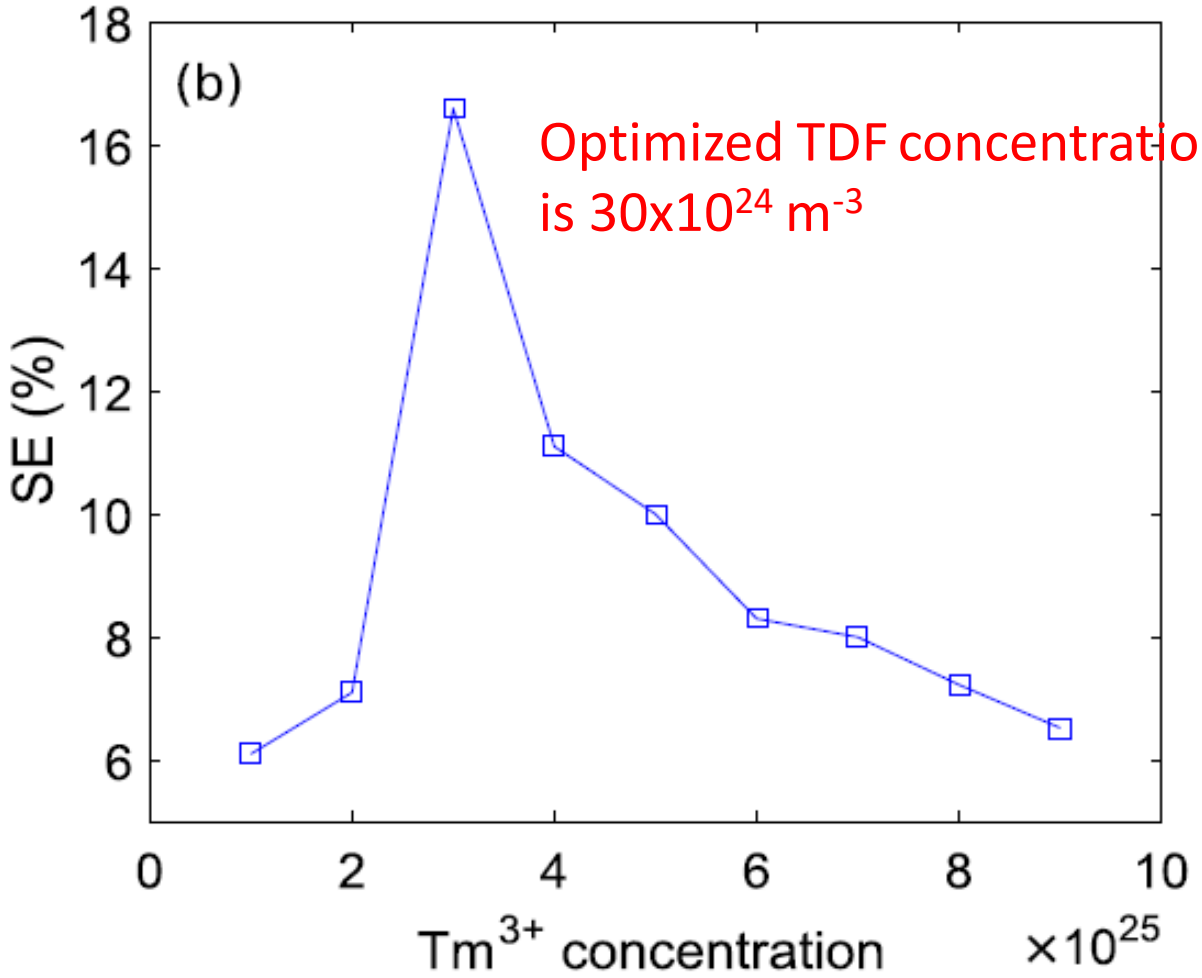


Fig. 3. SE versus (a) TDF length plot (b) Tm^{3+} concentration plot.

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Cascaded Lasers Output

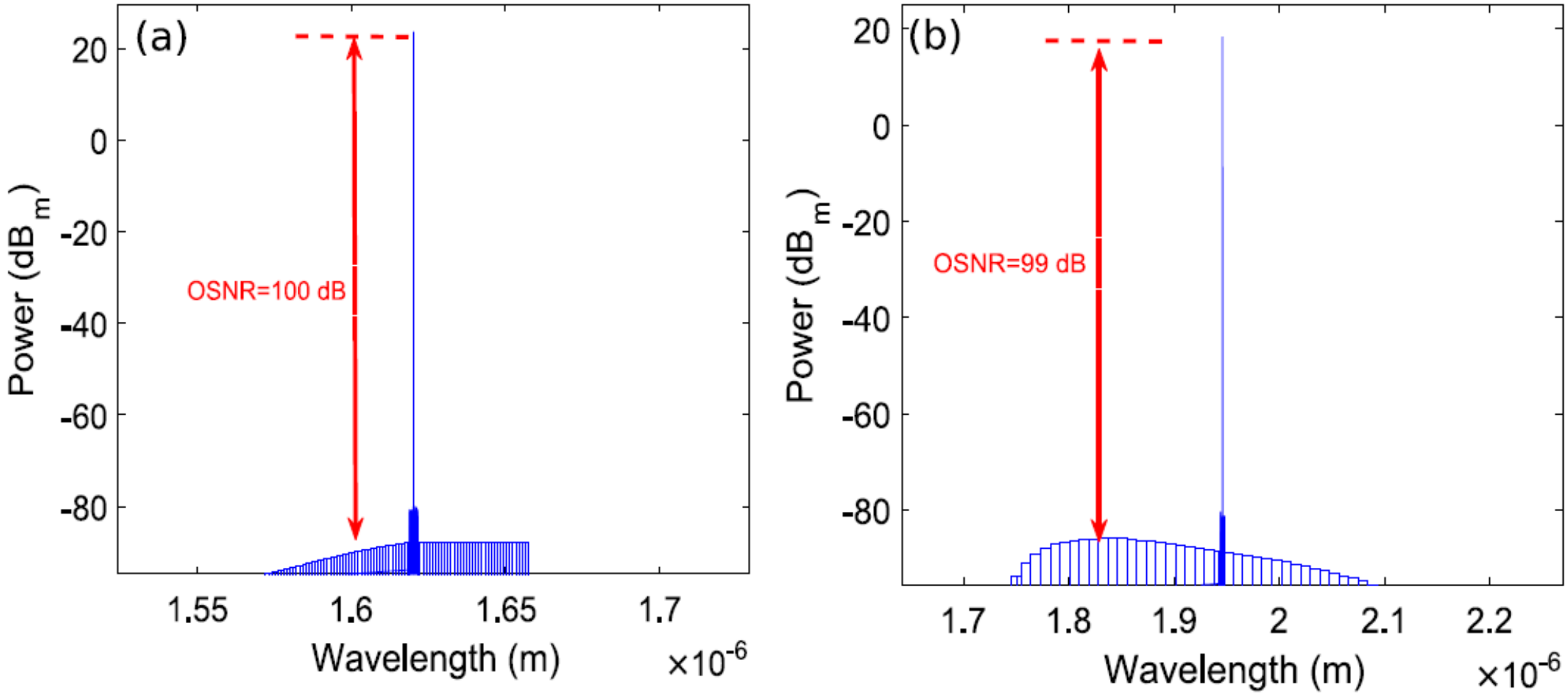

Fig. 6. Plots of lasing wavelengths at (a) 1.62 μm (b) 1.95 μm.

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HDF Optimization

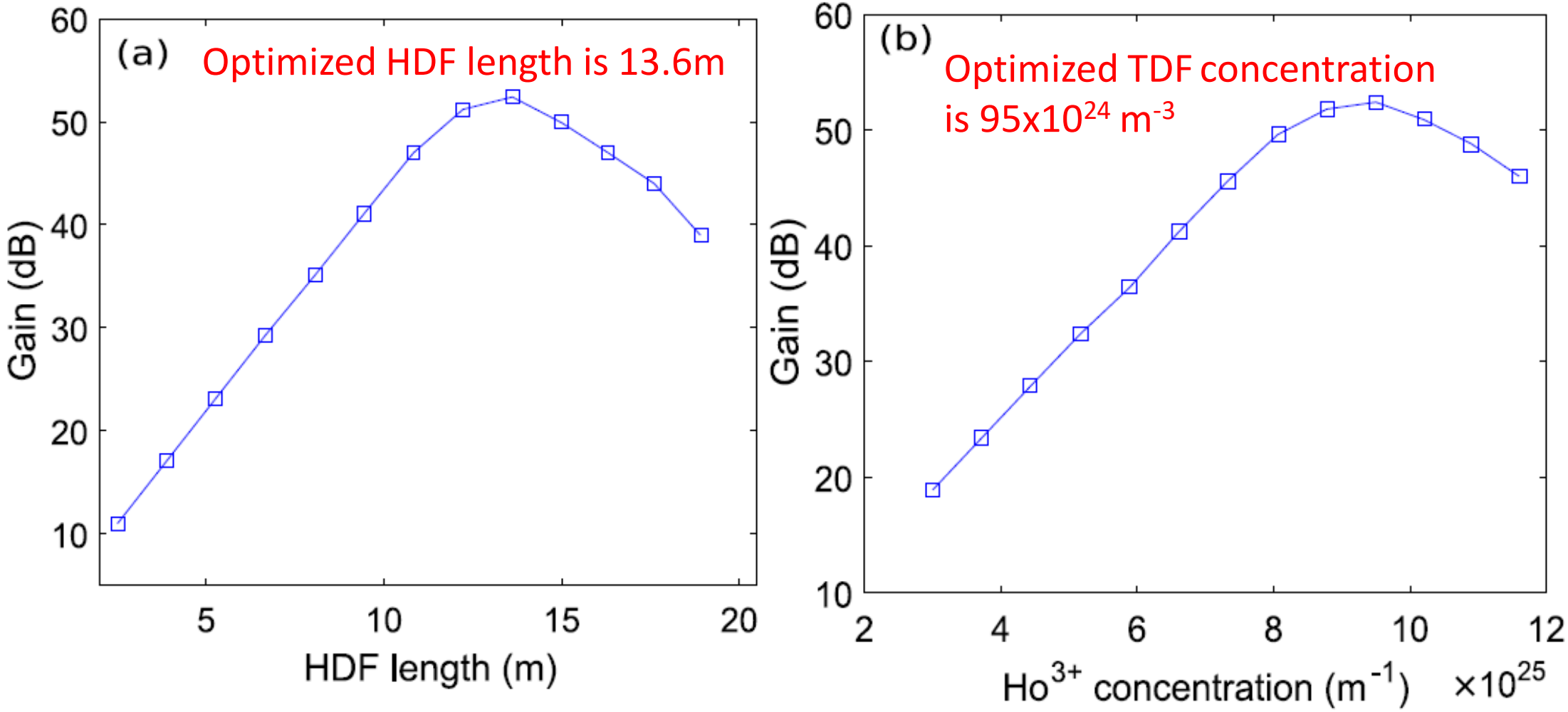

Fig. 7. Gain versus (a) HDF length (b) doping concentration of Ho^{3+}.

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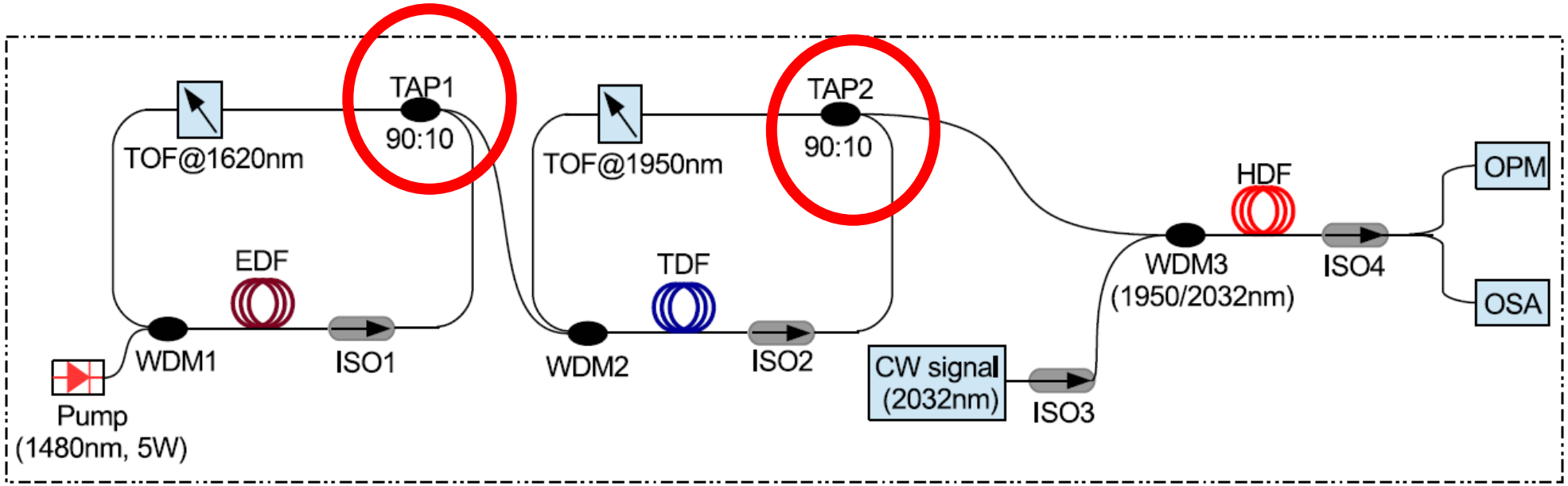
Simulation Parameters

Table 2
Important simulation parameters.

Parameter	Value
Pump power	5 W
Pump wavelength	1.48 μm
Core radius of EDF, TDF, HDF	2.25 μm, 2.25 μm, 1.3 μm
Doping radius of EDF, TDF, HDF	1.2 μm, 1.3 μm, 1.3 μm
Numerical aperture of EDF, TDF, HDF	0.26, 0.3, 0.3
Bandwidth of TOFs	0.01 nm
Insertion and return losses of TOFs	0 and 65 dB
Cross relaxation coefficient of HDF (K_{2101})	2×10^{-24} m^{-3} s^{-1}
Cross relaxation coefficient of HDF (K_{1012})	40×10^{-24} m^{-3} s^{-1}
Homogeneous upconversion coefficient of HDF (K_{3101})	0.78×10^{-21} m^{-3} s^{-1}
Homogeneous upconversion coefficient of HDF (K_{1013})	2.3×10^{-24} m^{-3} s^{-1}
Ions per cluster	2

Effect of Coupling ration on Lasers Output



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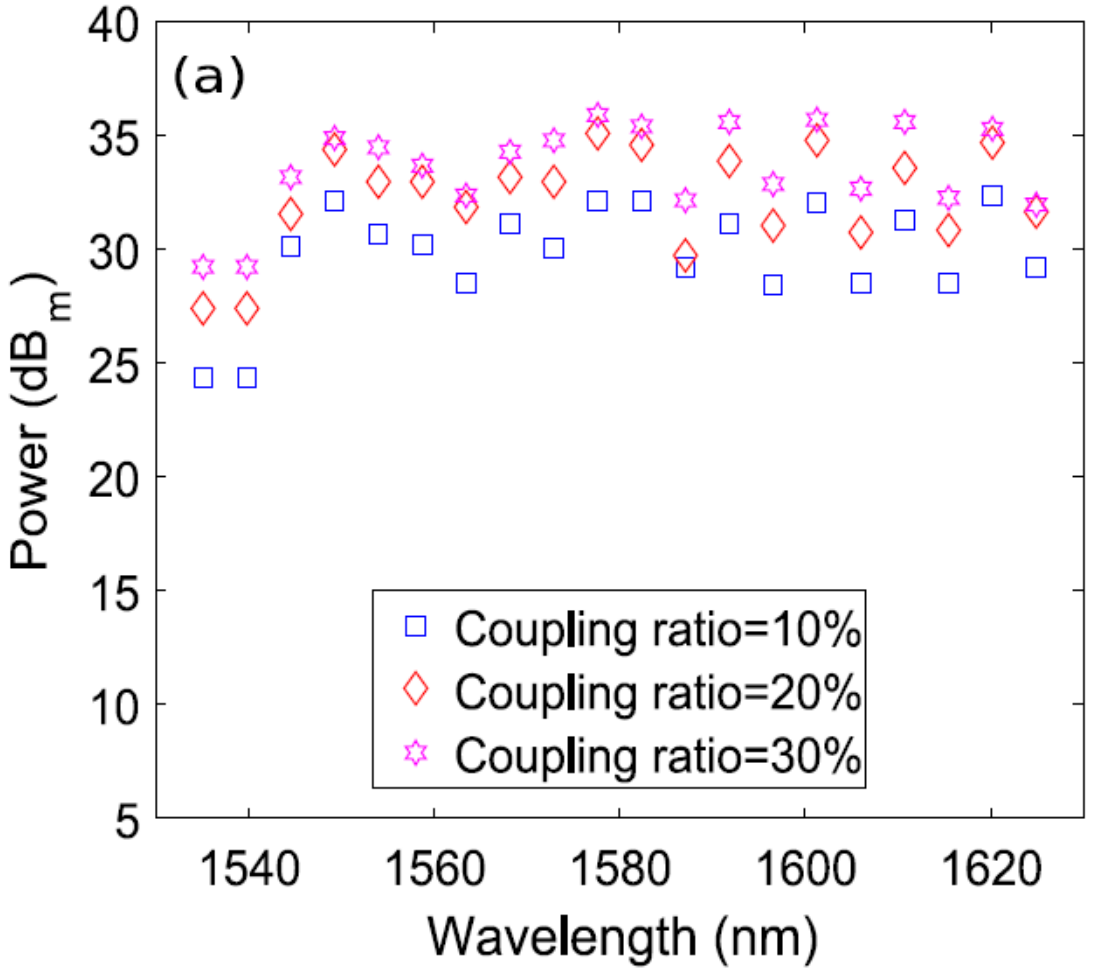
Effect of Coupling ration on Lasers Output

EDF



TDF

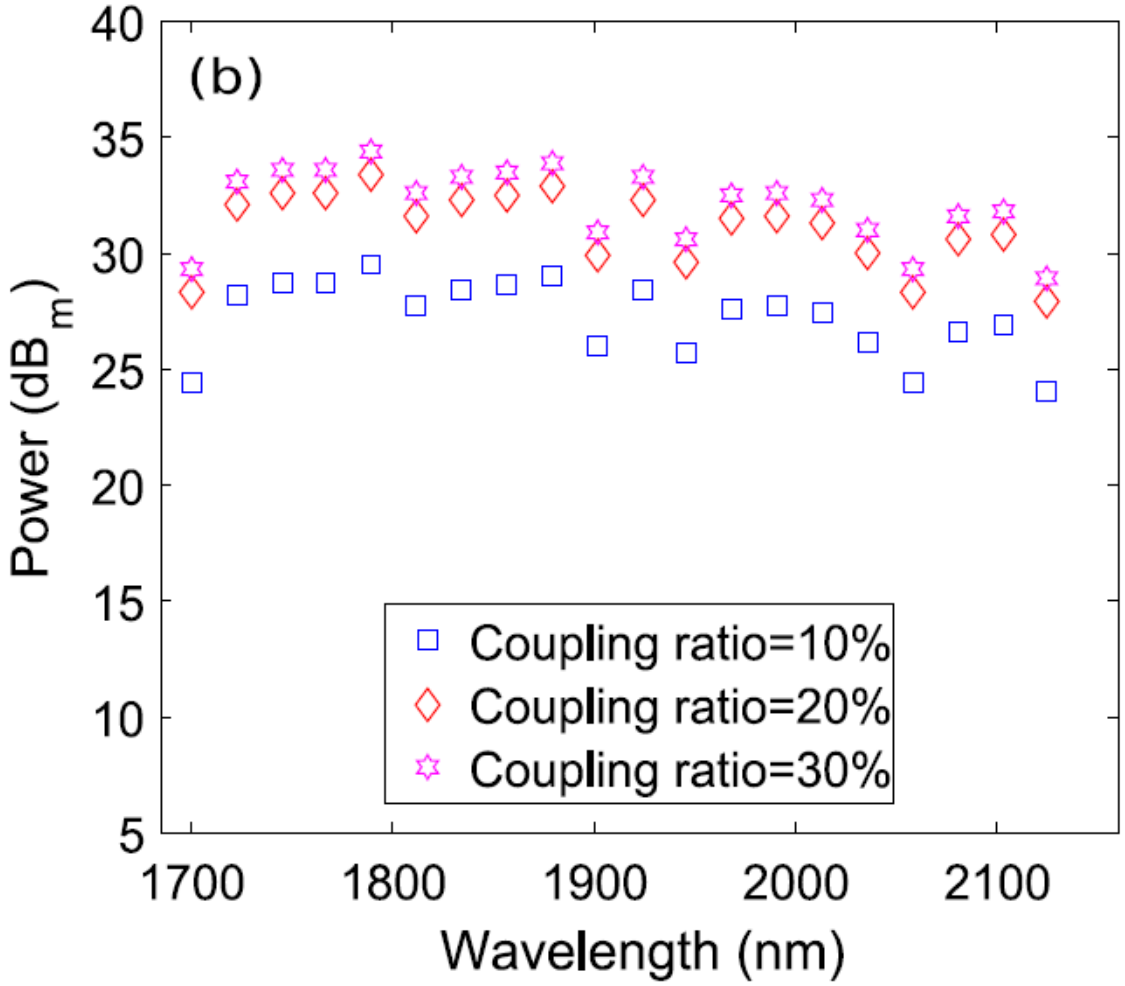


Fig. 5. Tuning of cavities for different coupling ratios (a) EDF (b) TDF.

HDFA Performance – I

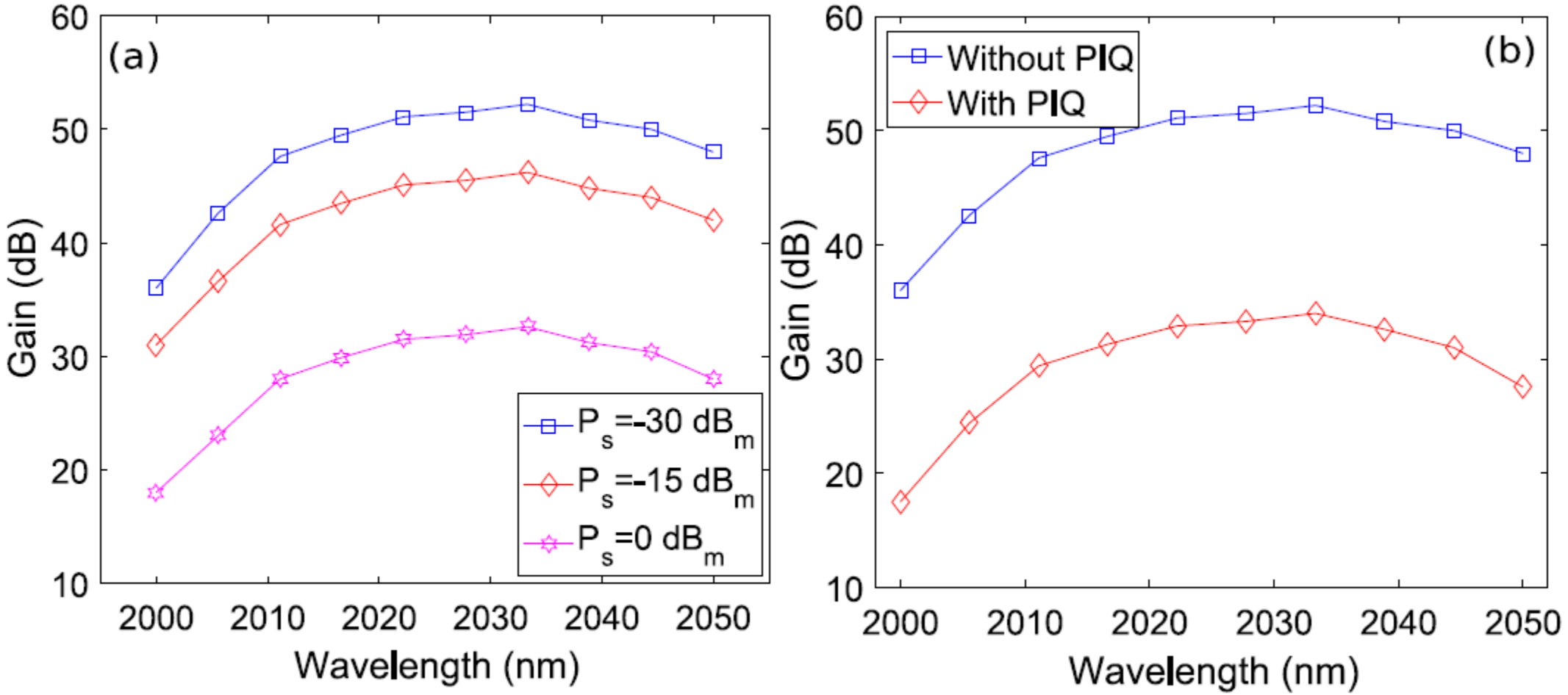


Fig. 8. Gain versus input signal wavelength plots of the HDFA (a) as a function of signal power without PIQ (b) with PIQ.

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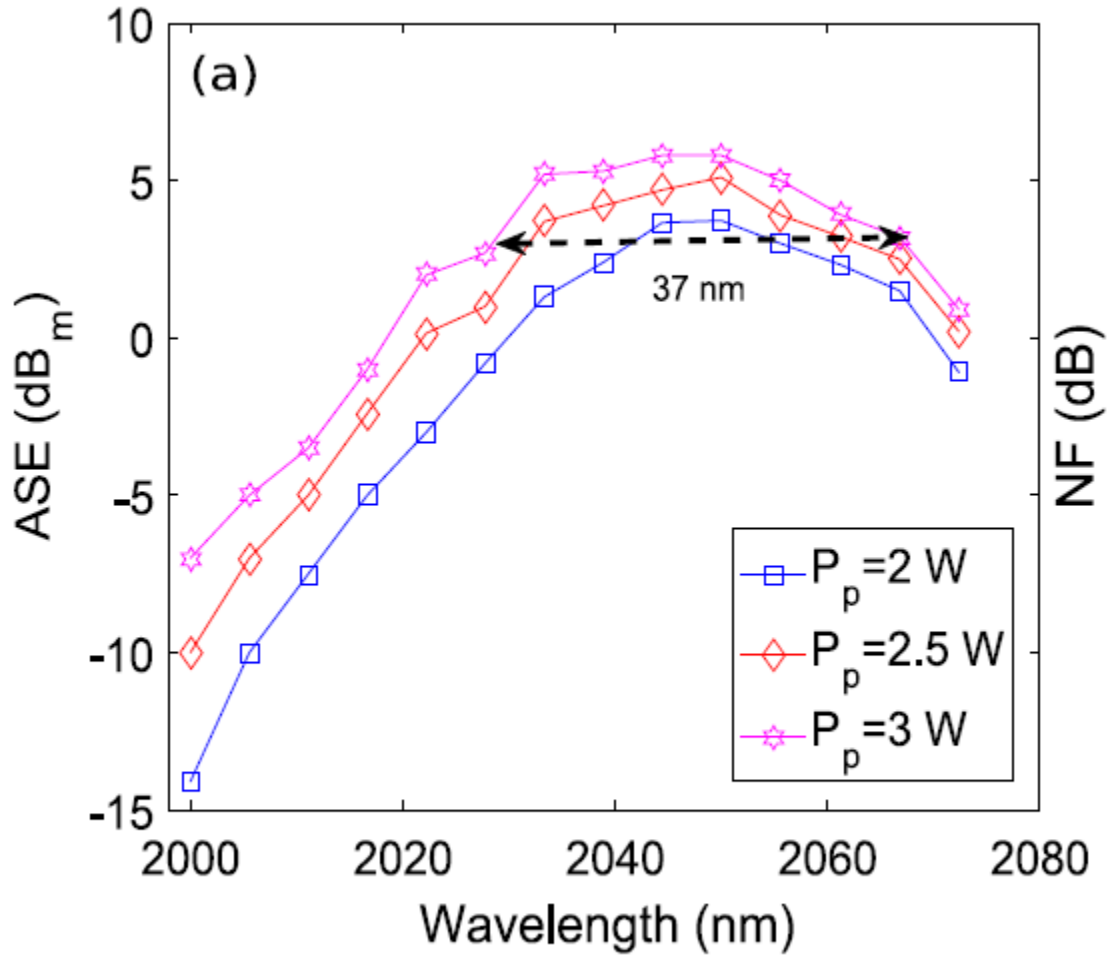
HDFA Performance – II



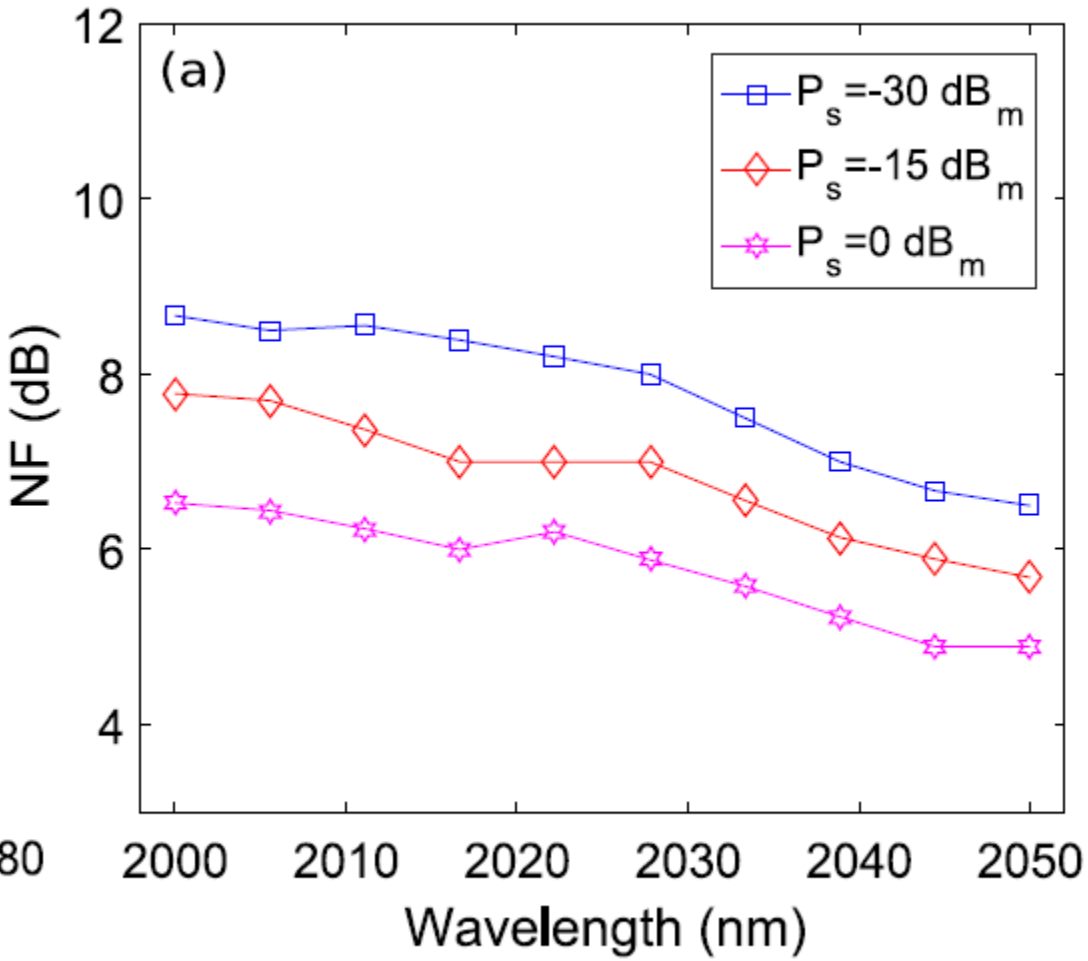


Fig. 9. Input signal wavelength versus (a) ASE plots as a function of pump power (b) NF plots as a function of input signal power.

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HDFA Performance – III

Table 3
Comparison of the important results of the proposed work with results of the past related studies.

Study	Gain	NF	HDF length	Pump type	No. of pumps & pumping stages
[7]	54 dB	7 dB	3 m	TDFL	1, 2
[14]	41 dB	10 dB	3.5 m	TDFL	1, 1
[15]	28 dB	9.5 dB	7 m	TDFL	1, 1
[16]	43 dB	–	4 m	TDFL	2, 2
[17]	33 dB	–	–	YDFL	1, 1
[18]	49 dB	6.5 dB	5.5 m	Laser diode	1, 2
[19]	55 dB	–	7.3 m	TDFL	1, 2
[Proposed]	**52.5 dB**	**5.6 dB**	**13.6 m**	**Laser diode**	**1, 1**

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Published Paper

Novel pumping scheme of Holmium doped fiber amplifiers operating around 2um using 1.48um lasers exploiting cascaded fiber lasers.pdf - Adobe Acrobat Reader DC (64-bit)

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Original research article

Novel pumping scheme of Holmium doped fiber amplifiers operating around 2 μm using 1.48 μm lasers exploiting cascaded fiber lasers

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Pumping scheme
Cascaded fiber lasers
Holmium-doped fiber amplifier

ABSTRACT

The optical communication window around 2 μm is attracting significant research attention for future optical communication systems as an extension to the C-, L-, and U-bands. One of the research topics in the 2 μm region is optical amplifiers. Holmium-doped fiber amplifier (HDFA) is a suitable candidate for amplifying signals in this region. However, the pump laser for Holmium-doped fiber (HDF) is expensive and not widely available. In this work, we propose

Live Demo

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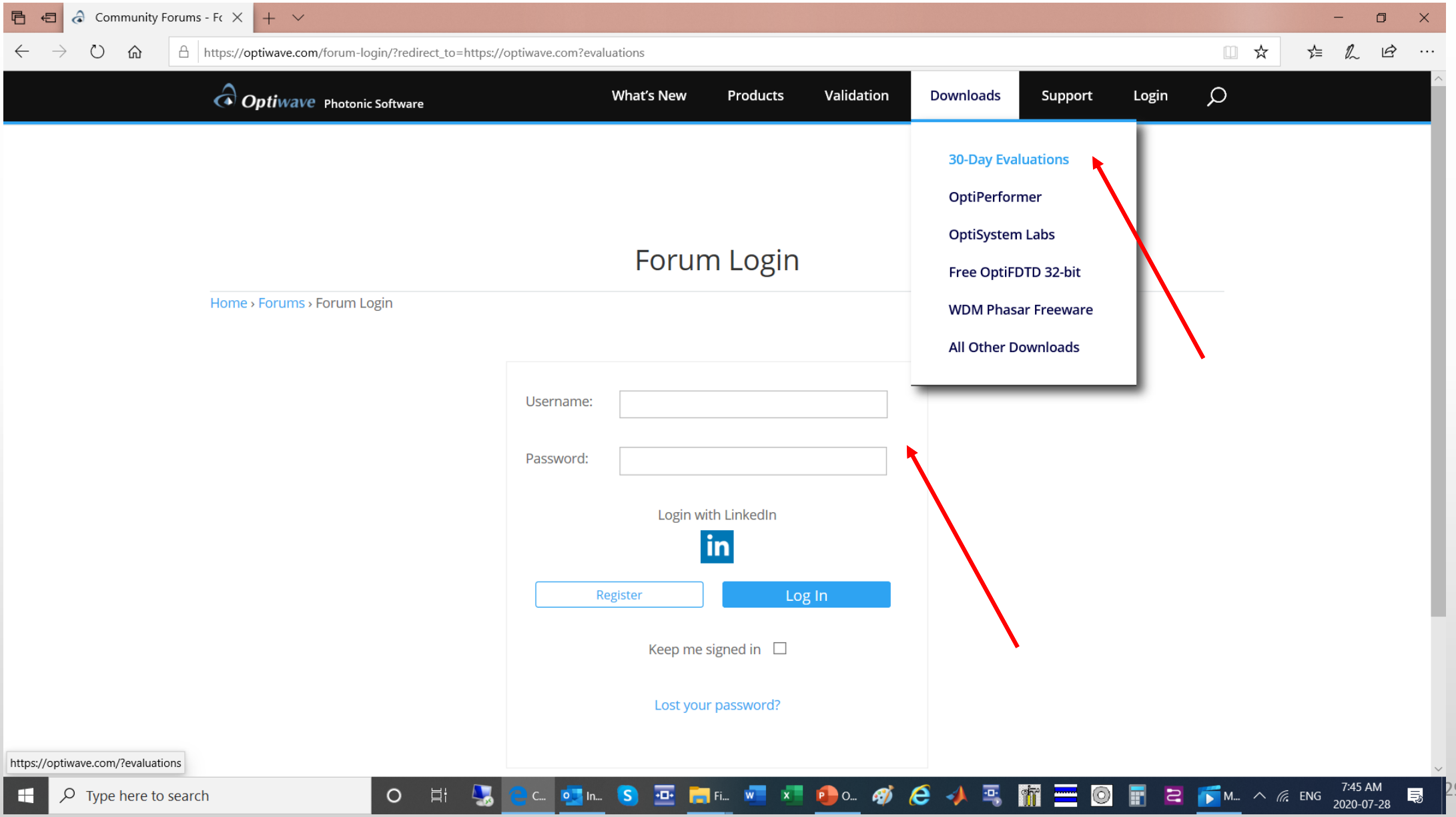
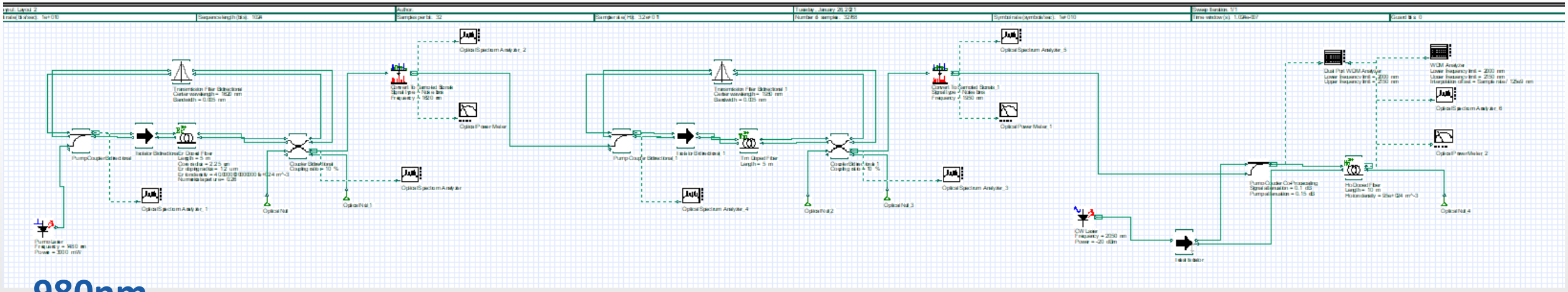


Effect of Coupling ration on Lasers Output

EDFL TDFL HDFA



980nm

1480nm

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Conclusions

- Cascaded fiber lasers are used to enable pumping HDF with 980nm and 1480nm lasers
- The emission spectrum of the 1st stage doped-fiber coincides with the absorption spectrum of the 2nd stage doped-fiber
- The cascaded fiber lasers and HDFA parameters are optimized for best performance
- Experimental validation is under consideration
- US provisional patent application was filed

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Thank You

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