Fiber Lasers: Fundamentals and Applications

Lecture 2

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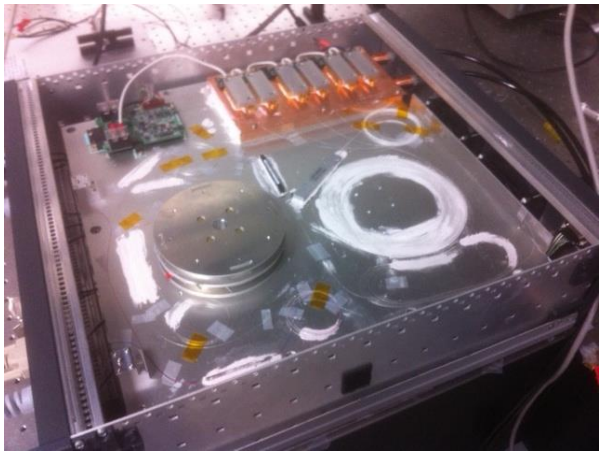
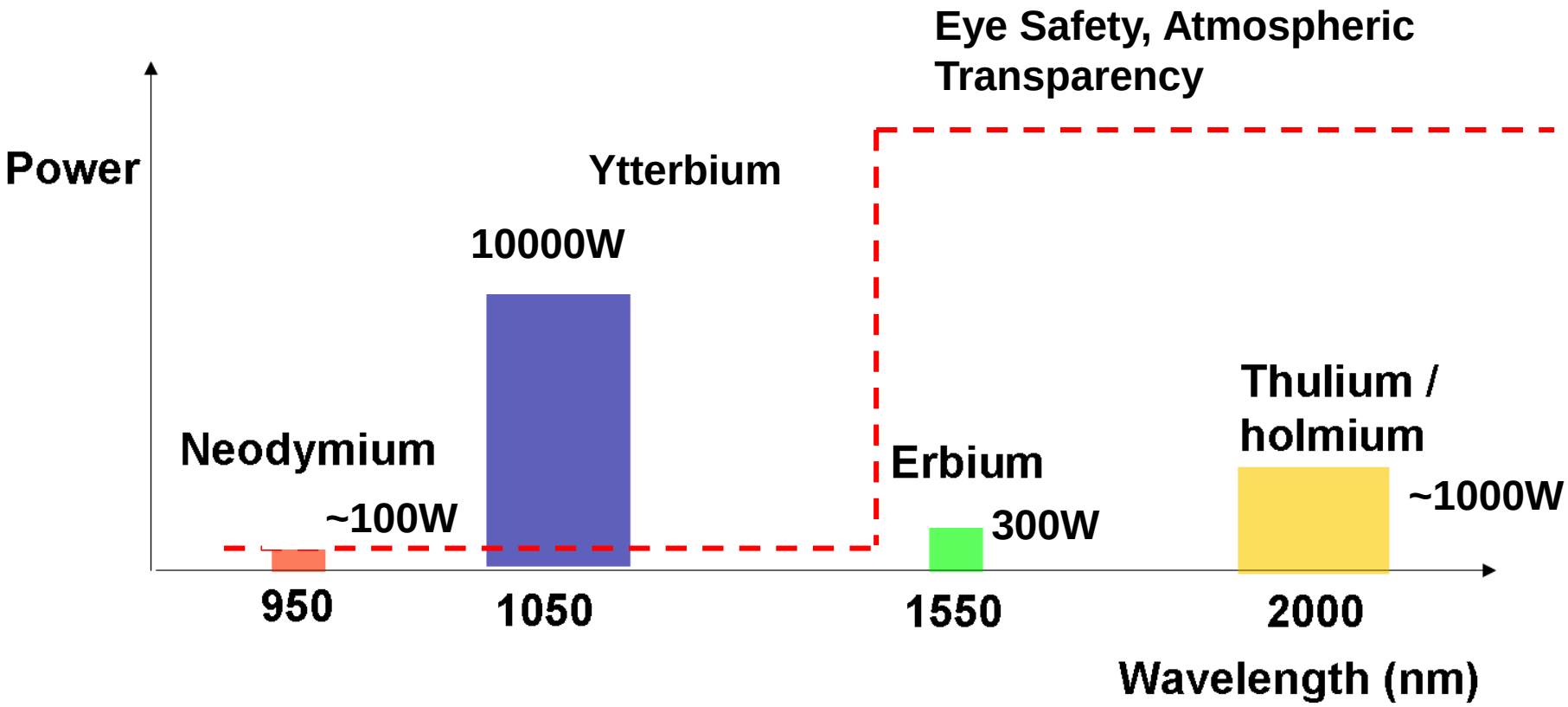


Current State of CW Fiber Lasers



Gain from doped fibers

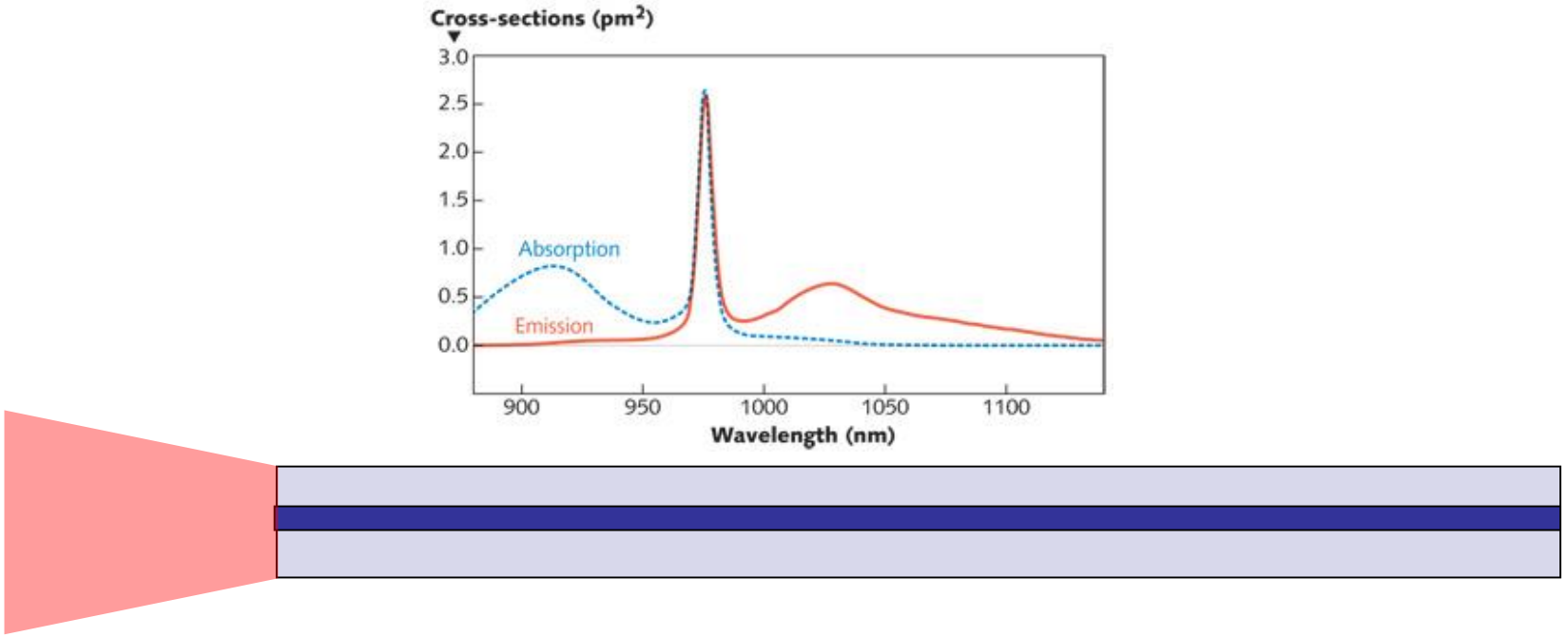
Population inversion achieved in the rare-earth dopants due to pump absorption.

This is then utilized to amplify signal

Most common doped fibers you would interact with –

- Ytterbium doped (Yb) – Used in most high power lasers
- Erbium doped (Er) – Optical communications, Eye safe applications
- Thulium (Th) and Holmium doped – Mid IR applications

Pump Absorption in Double Clad fibers



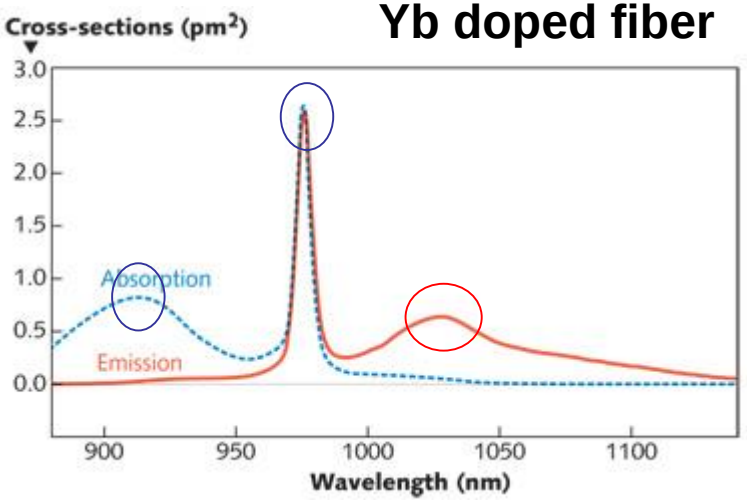
Net absorption ~ core absorption*(core area)/(cladding area) (wavelength dependent)

Some numbers – core abs (Yb doped fiber at 975nm) ~700dB/m, core, cladding dimensions – 6/125 micron

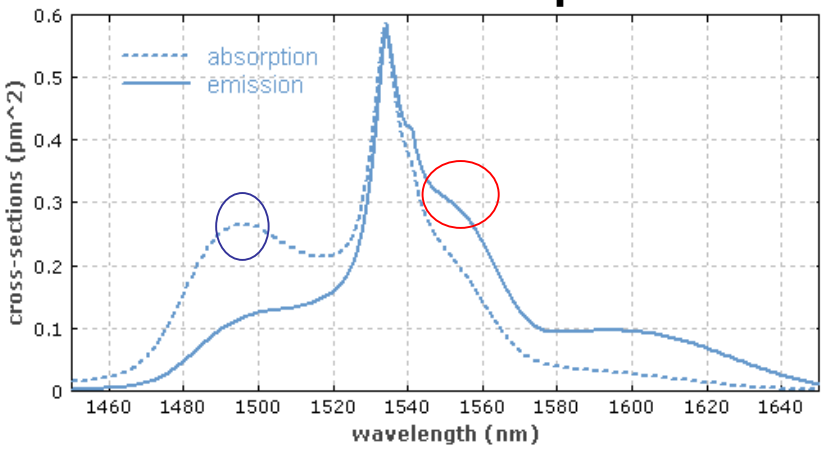
Net absorption ~ 1.6dB/m (at 975nm)

Absorption and Emission in Rare earth Doped Fibers

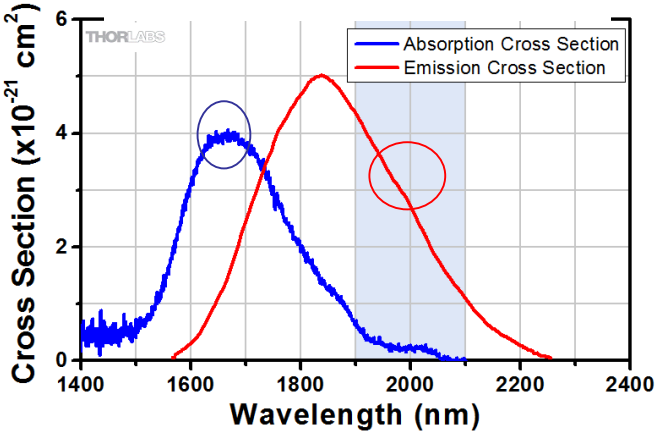
Yb doped fiber



Er doped fiber



Th doped fiber

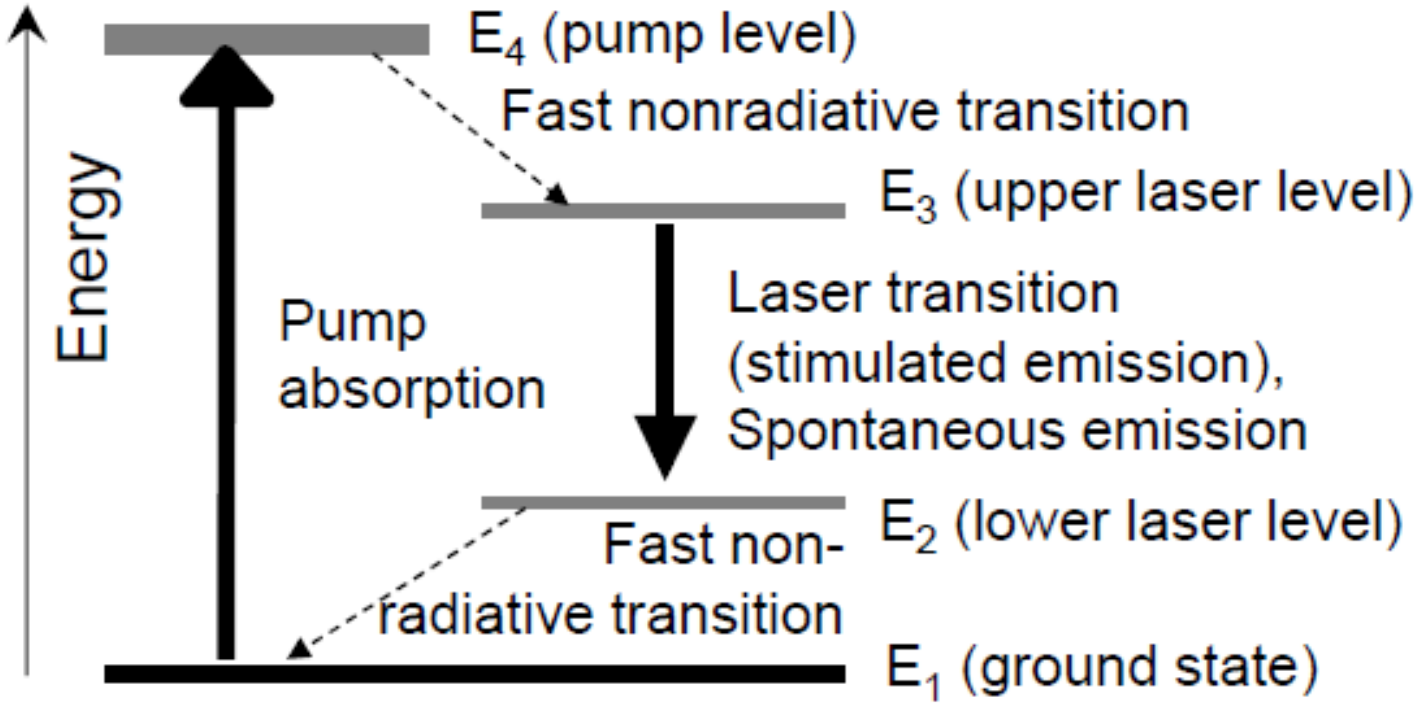


Fundamental Conversion Efficiency

Pump wavelength/Signal Wavelength

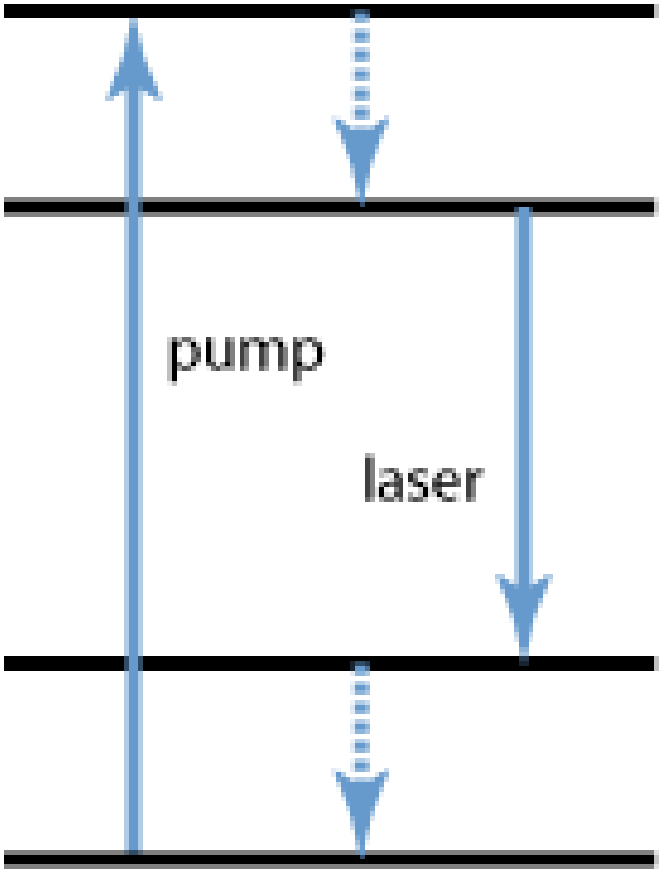
Reduced quantum efficiency = high heat load

Laser operation – Energy levels



Radiative and Non-radiative transitions

4-level laser systems



Occupation of state 4 and state 2 zero

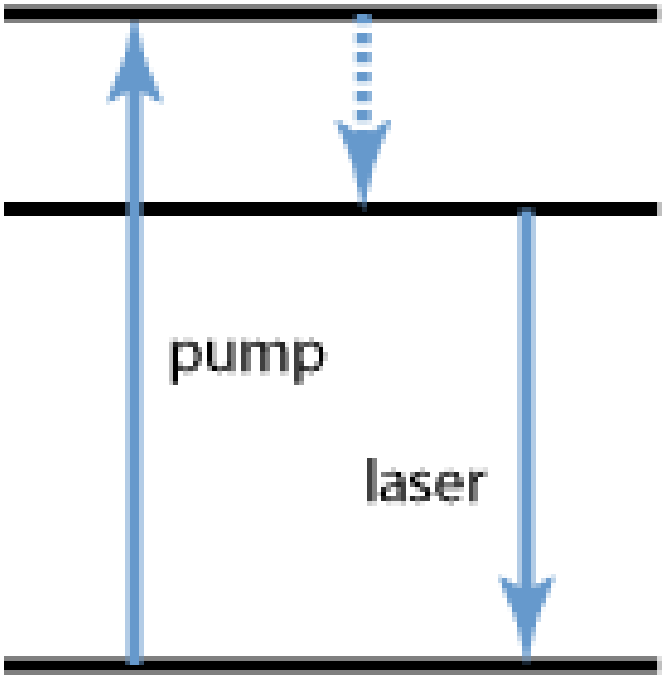
Low threshold laser

Efficiencies not as high

Power scaling limited

From encyclopedia of laser physics and technology

3-level laser systems



Occupation of state 4 is 0

medium threshold laser

Efficiencies medium

Good power scaling

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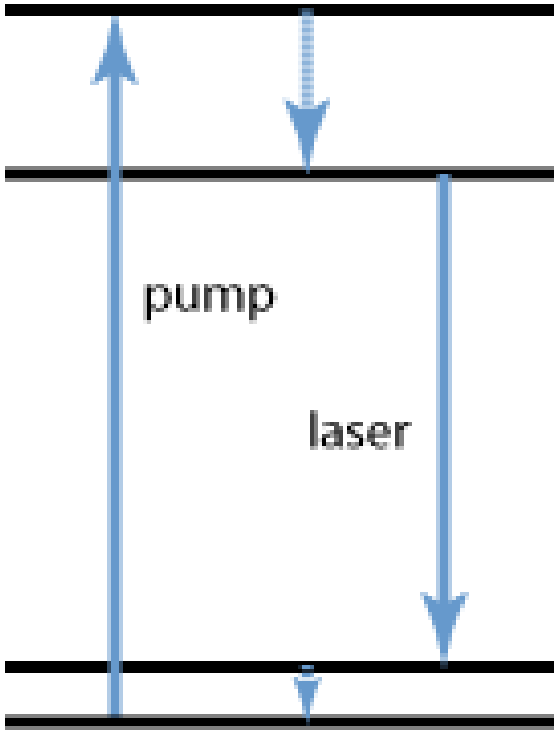
Quasi 4-level laser systems



Performance in between 3 level and 4 level systems

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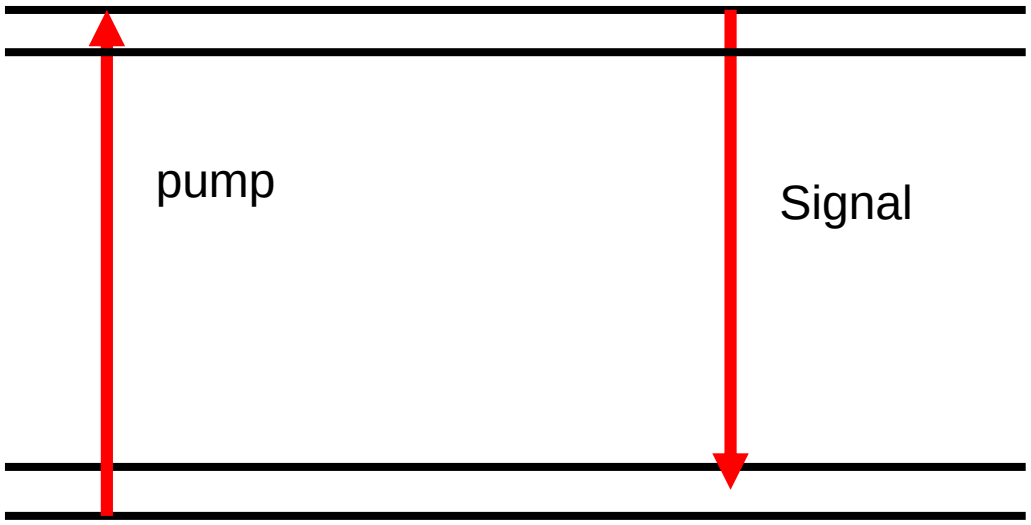
Quasi 3-level laser system



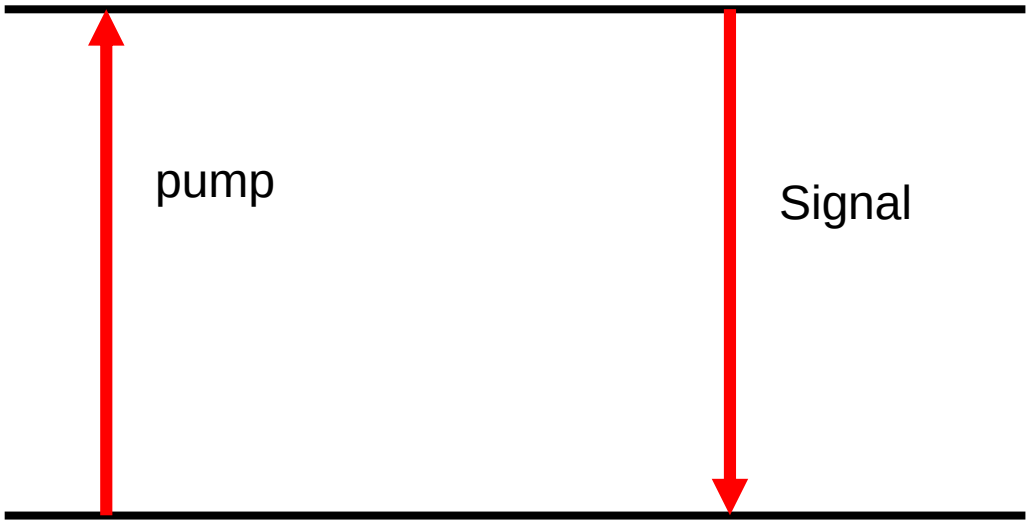
High threshold laser

Efficiencies high

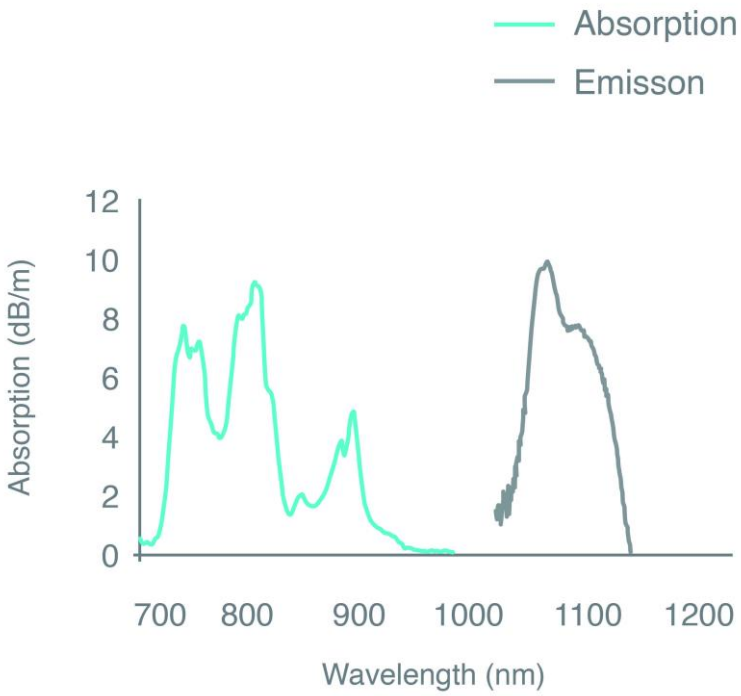
Excellent power scaling

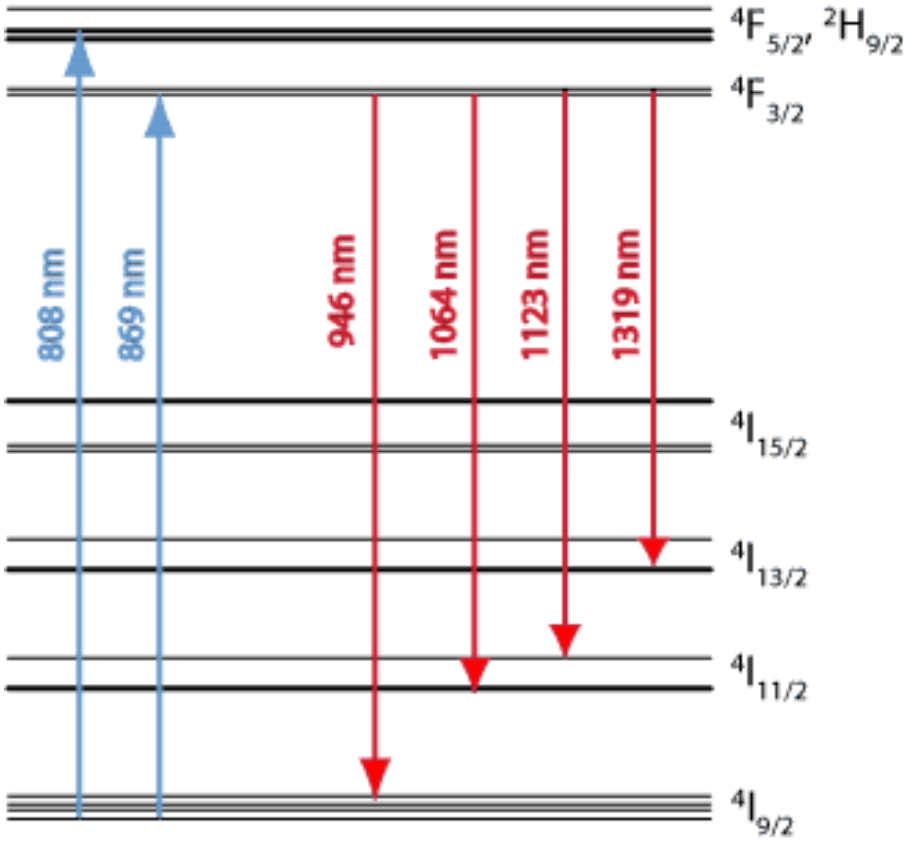
2-level system

A two level system cannot become a laser because population inversion cannot be higher than 50%



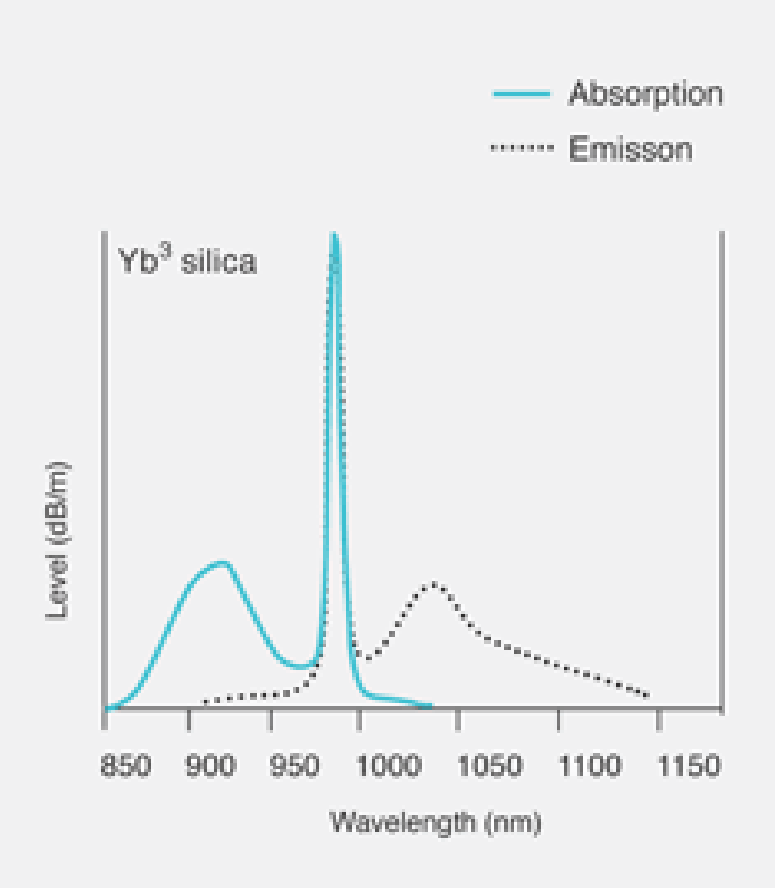
Nd doped fiber

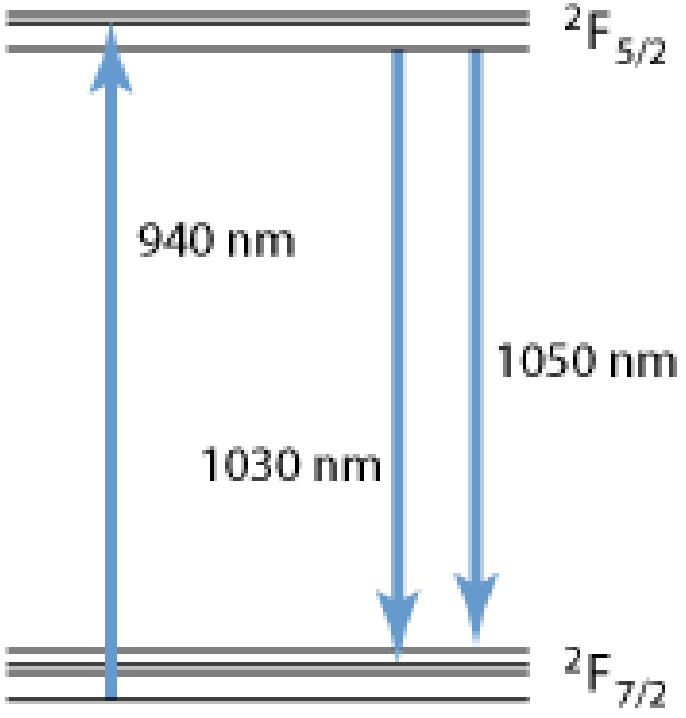




From encyclopedia of laser physics and technology, fibercore

Yb doped fiber





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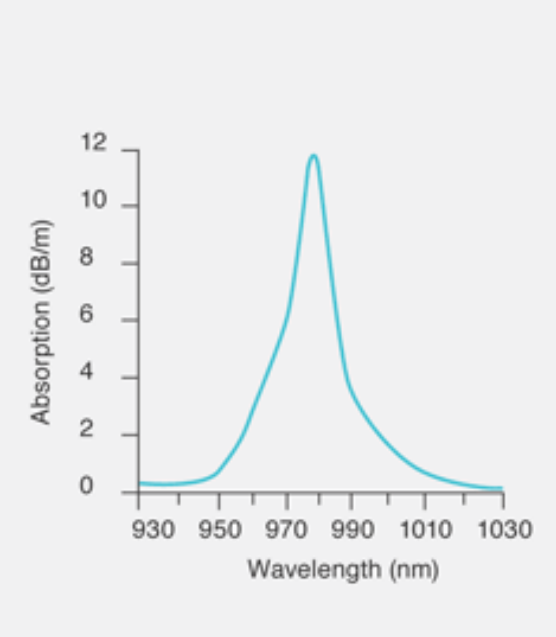
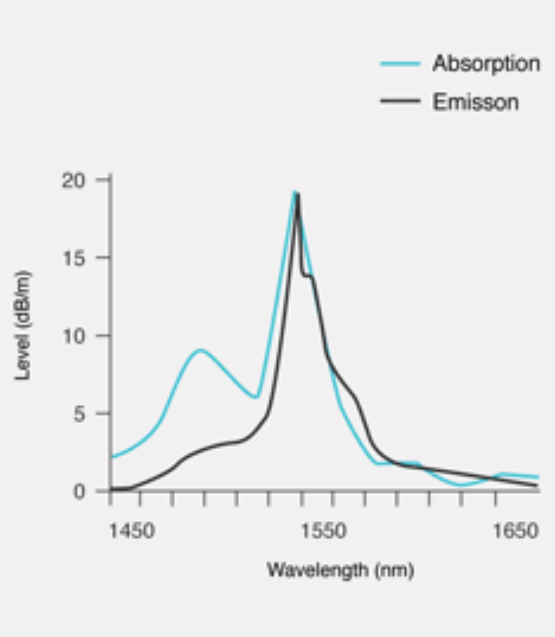
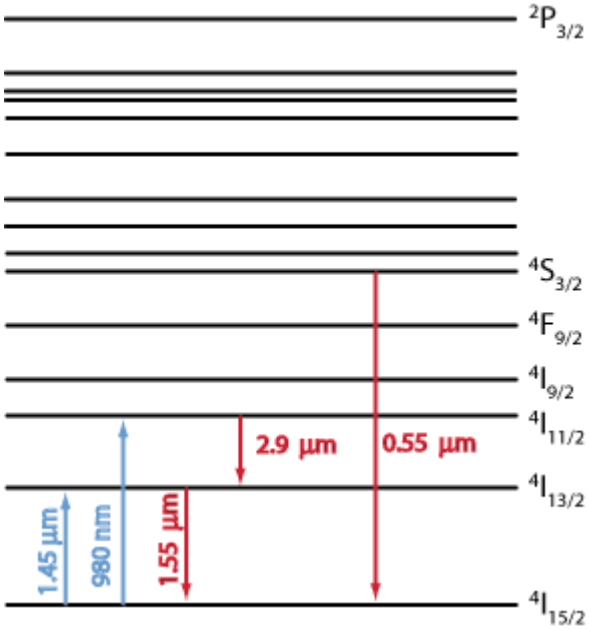
Er doped fiber







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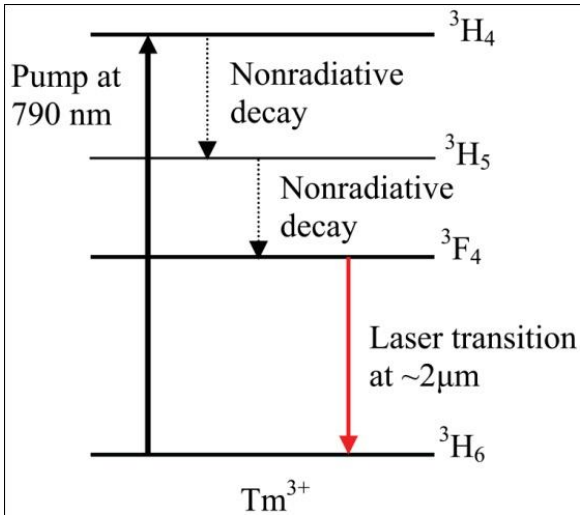
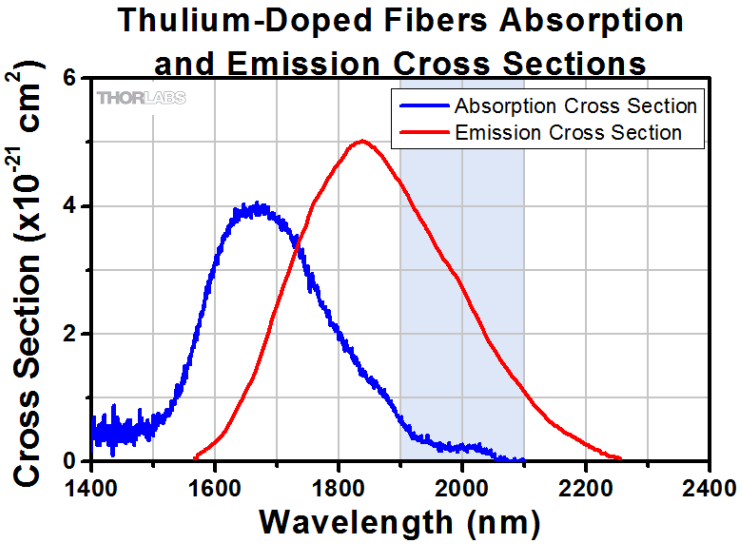
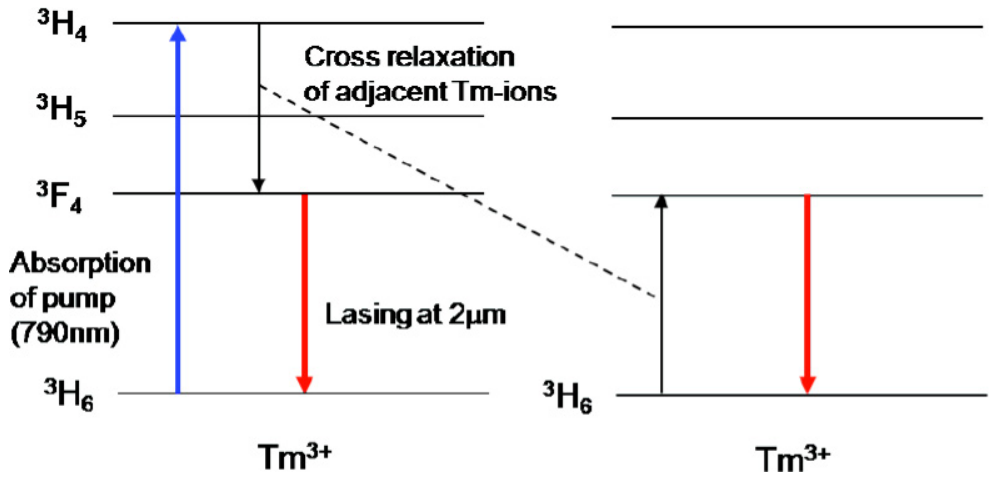
Th doped fiber







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Absorption and Emission Cross-sections

For 3 level and 4 level systems, the absorption and emission cross sections are measured using experiments

For quasi 3-level system – Mccumber relations

$$\sigma_{abs}(\nu) = \sigma_{em}(\nu) \exp\left(\frac{h\nu - E_0}{k_B T}\right)$$

Rate Equations

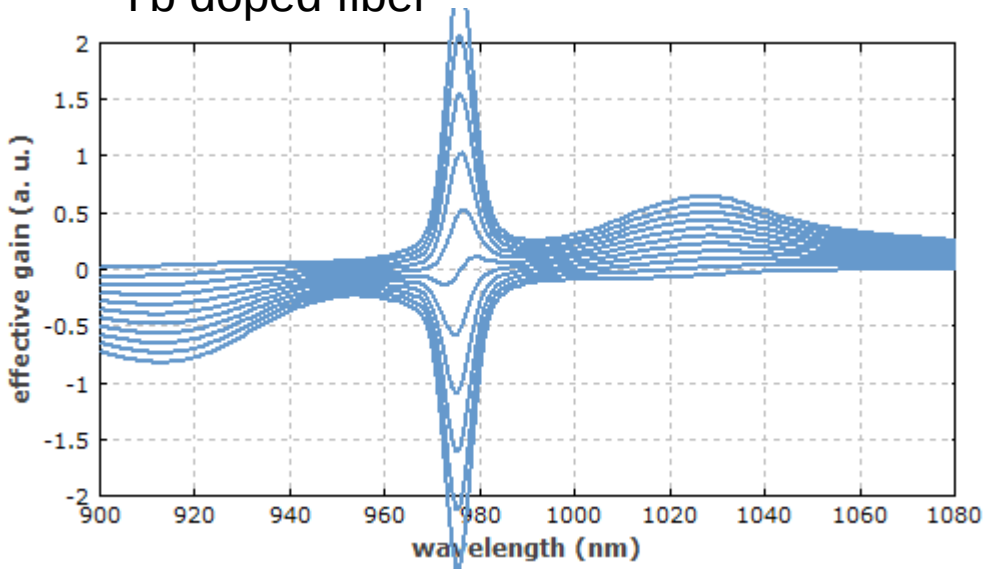
(On the white board)

Pump and Signal Power Equations

(On the white board)

Gain

Yb doped fiber



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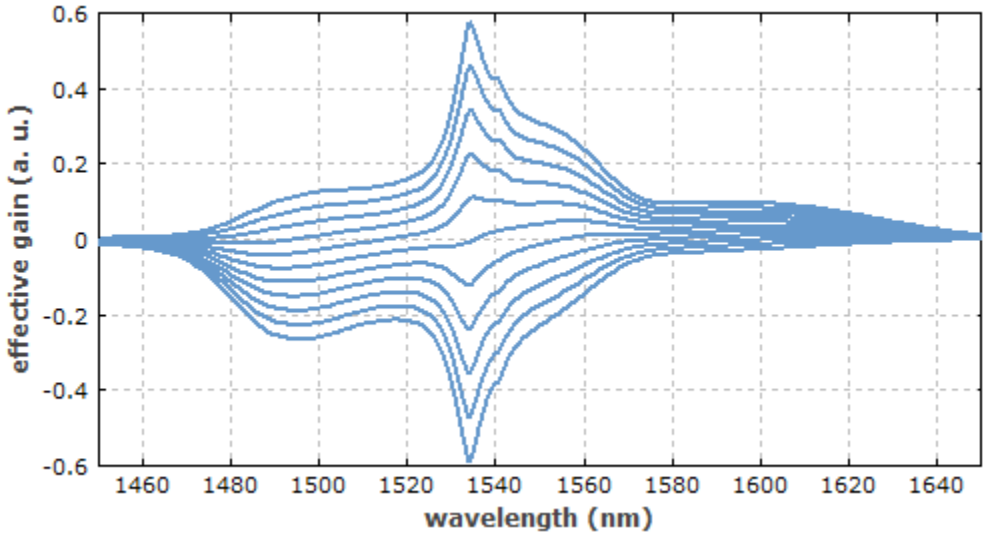

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