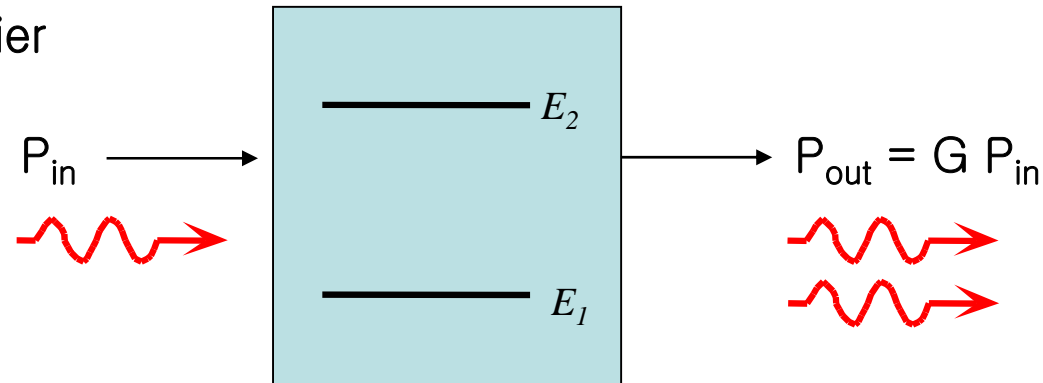


# Lect. 19: Optical Pumping and EDFA

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Optical Amplifier



Which process is useful for optical amplifier?

How can we make stimulated emission dominant over absorption?

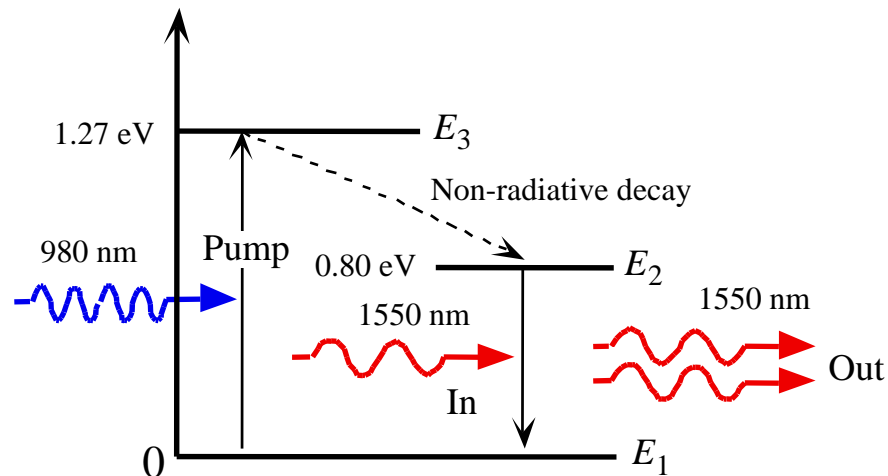
Pump carriers into  $N_2$  so that  $N_2 > N_1$

Optical Pumping and Electrical Pumping

# Lect. 19: Optical Pumping and EDFA

Optical Pumping: Consider Er

Energy levels in Er



– Pump light is absorbed at  $E_3$  generating carriers

– Carriers at  $E_3$  rapidly transfer to  $E_2$   
→  $N_2$  builds up

– When  $N_2 > N_1$  (population inversion),  
stimulated emission  $>$  absorption  
for 1550nm light

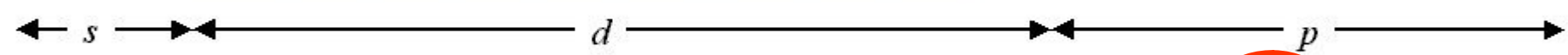
Er can be easily added to core of Silica fiber

→ EDF (Er-Doped Fiber)

# Periodic Table

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1 <b>H</b> 1.008																	2 <b>He</b> 4.003
3 <b>Li</b> 6.941	4 <b>Be</b> 9.012											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18
11 <b>Na</b> 22.99	12 <b>Mg</b> 24.30	← VIII →										13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.07	17 <b>Cl</b> 35.05	18 <b>Ar</b> 39.95
19 <b>K</b> 39.10	20 <b>Ca</b> 40.08	21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.87	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.39	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.61	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80
37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.94	43 <b>Tc</b> 98.91	44 <b>Ru</b> 101.1	45 <b>Rh</b> 102.9	46 <b>Pd</b> 106.4	47 <b>Ag</b> 107.9	48 <b>Cd</b> 112.4	49 <b>In</b> 114.8	50 <b>Sn</b> 118.7	51 <b>Sb</b> 121.8	52 <b>Te</b> 127.6	53 <b>I</b> 126.9	54 <b>Xe</b> 131.3
55 <b>Cs</b> 123.9	56 <b>Ba</b> 137.3	La-Lu	72 <b>Hf</b> 178.5	73 <b>Ta</b> 180.9	74 <b>W</b> 183.8	75 <b>Re</b> 186.2	76 <b>Os</b> 190.2	77 <b>Ir</b> 192.2	78 <b>Pt</b> 195.1	79 <b>Au</b> 197.0	80 <b>Hg</b> 200.6	81 <b>Tl</b> 204.4	82 <b>Pb</b> 207.2	83 <b>Bi</b> 209.0	84 <b>Po</b> 210.0	85 <b>At</b> 210.0	86 <b>Rn</b> 222.0
87 <b>Fr</b> 223.0	88 <b>Ra</b> 226.0	Ac-Lr	104 <b>Db</b>	105 <b>Jl</b>	106 <b>Rf</b>	107 <b>Bh</b>	108 <b>Hn</b>	109 <b>Mt</b>	110 <b>Uun</b>	111 <b>Uuu</b>							

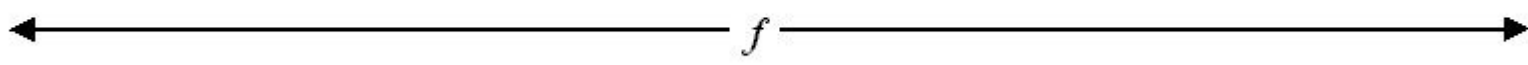


Lanthanides

57 <b>La</b> 138.9	58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> 146.9	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.0	64 <b>Gd</b> 157.2	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
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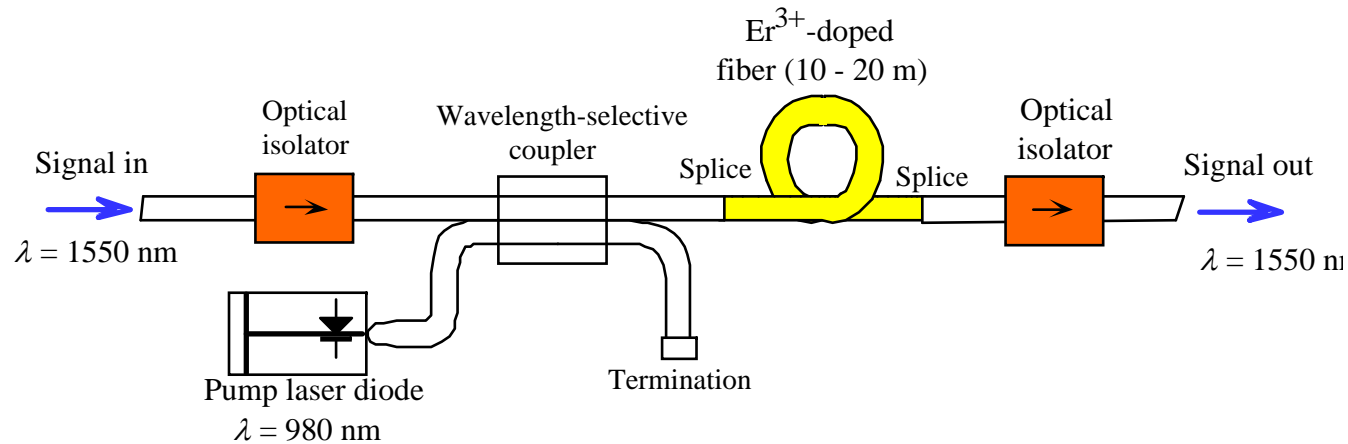
Actinides

89 <b>Ac</b> 227.0	90 <b>Th</b> 232.0	91 <b>Pa</b> 231.0	92 <b>U</b> 238.0	93 <b>Np</b> 237.0	94 <b>Pu</b> 239.1	95 <b>Am</b> 241.1	96 <b>Cm</b> 244.1	97 <b>Bk</b> 249.1	98 <b>Cf</b> 252.1	99 <b>Es</b> 252.1	100 <b>Fm</b> 257.1	101 <b>Md</b> 258.1	102 <b>No</b> 259.1	103 <b>Lr</b> 262.1
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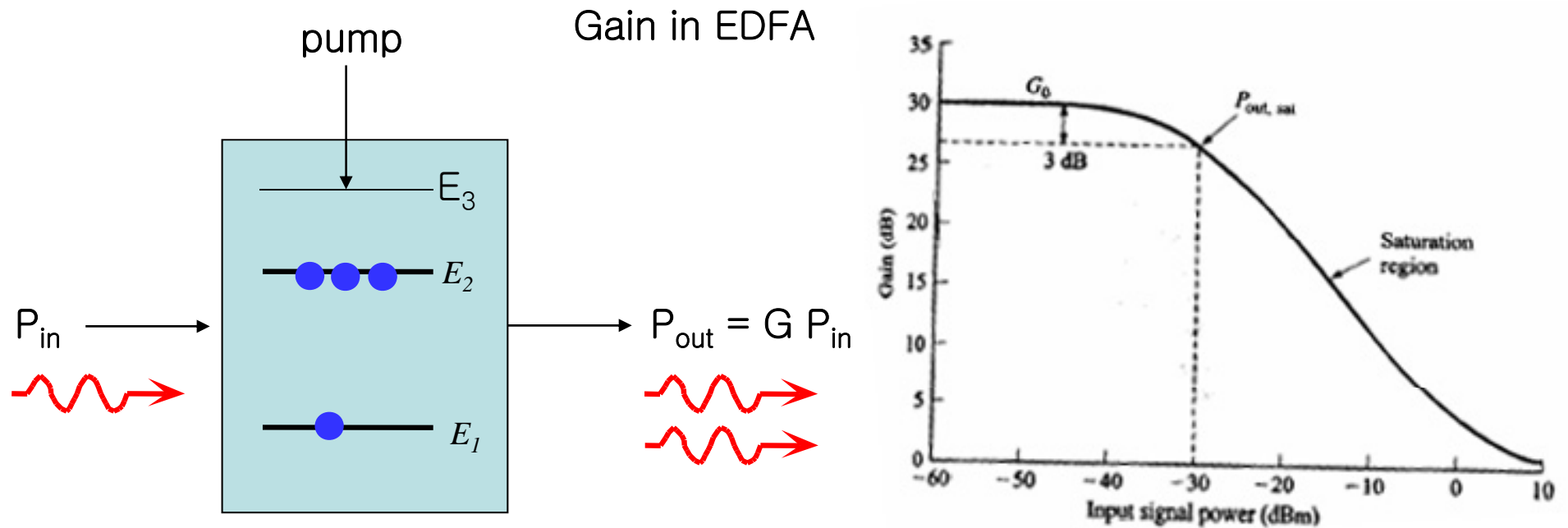
# Lect. 19: Optical Pumping and EDFA

EDFA: Er-doped Fiber Amplifier



Compensates fiber loss for long distance optical fiber communication

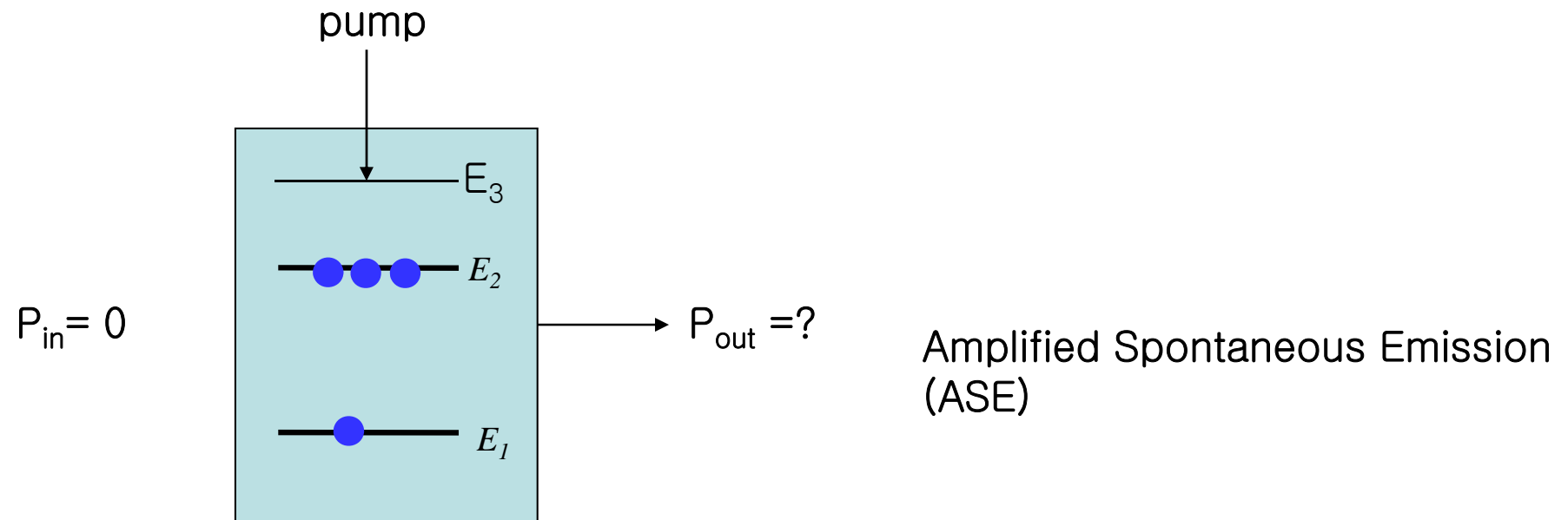
# Lect. 19: Optical Pumping and EDFA



Gain saturation due to limited carriers at  $E_2$

# Lect. 19: Optical Pumping and EDFA

Noise in EDFA



# Lect. 19: Optical Pumping and EDFA

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Other materials where optical pumping is possible: Optical gain materials

- Crystals doped with impurities: Ruby doped with Cr ( $\text{Al}_2\text{O}_3:\text{Cr}^{3+}$ )
- Gases: Ar, N, mixture of He and Ne
- Semiconductors