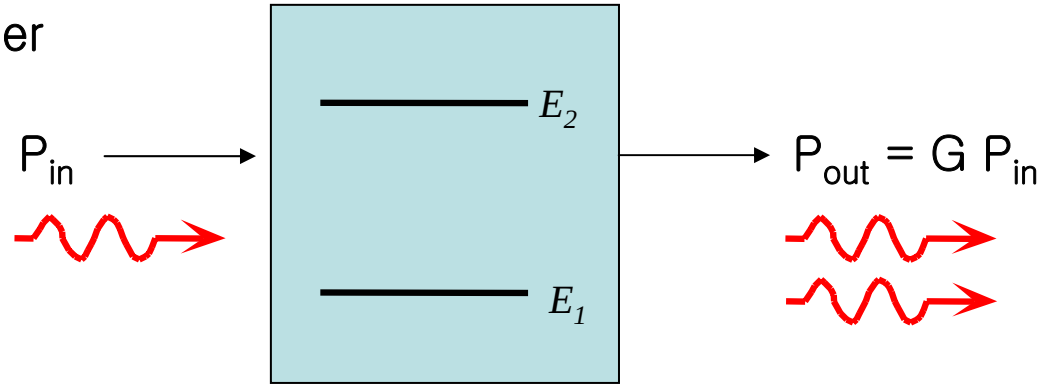
Lect. 17: Optical Pumping and EDFA

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 are possible

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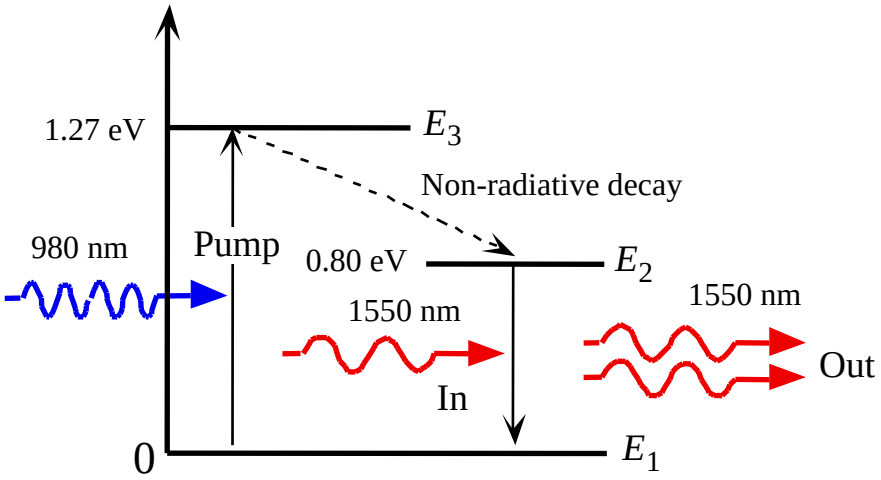
Optical Pumping: Consider Er

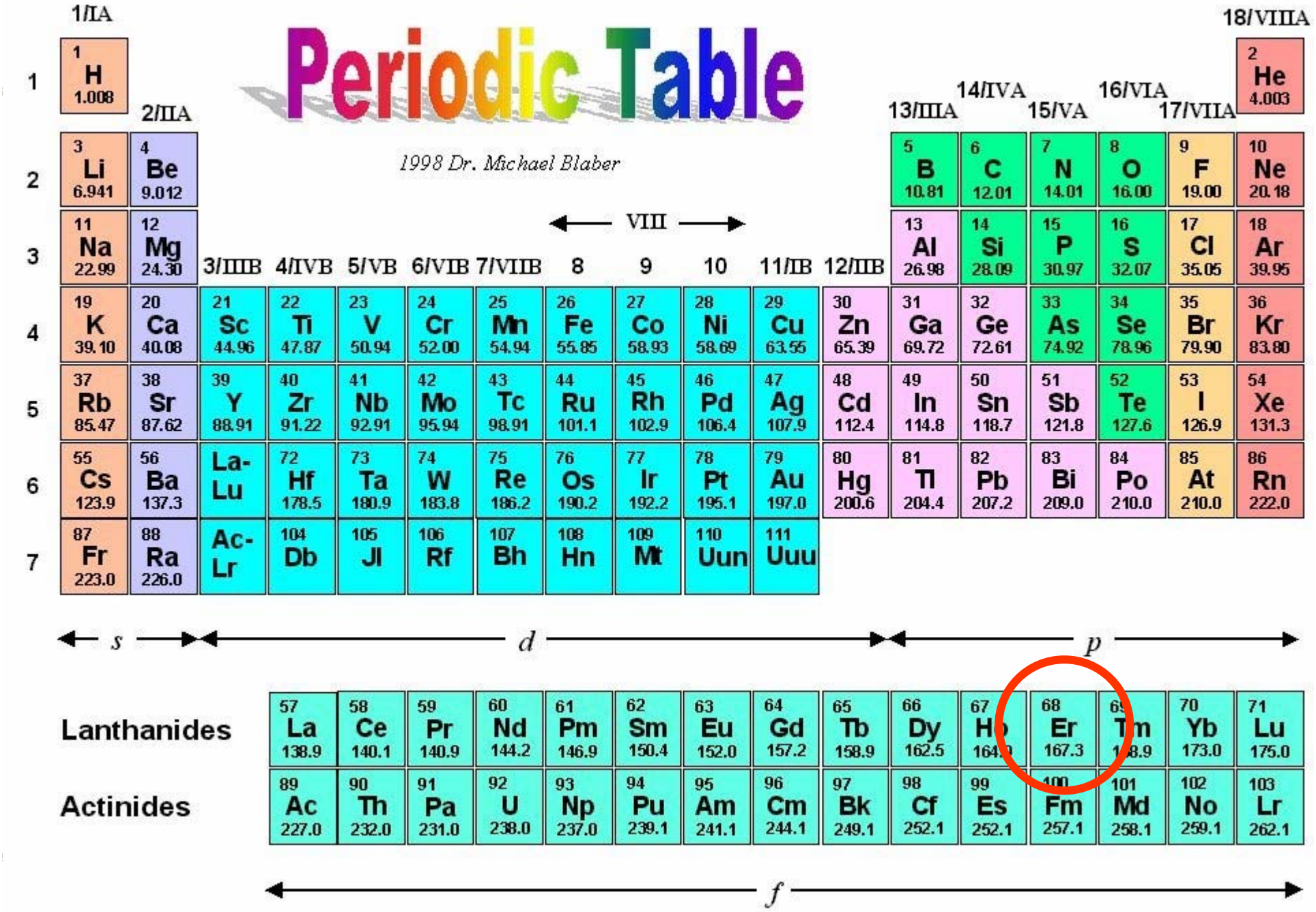
Energy levels in Er



Pump light is absorbed at E_3
carriers at E_3 are rapidly transferred to E_2
(N_2 builds up)

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

➔ Er can be easily added to core of Silica fiber: EDF (Er-doped Fiber)


Periodic Table
1998 Dr. Michael Blaber
1/IA
2/IIA
3/IIIB
4/IVB
5/VB
6/VIB
7/VIIB
VIII
8
9
10
11/IB
12/IIB
13/IIIA
14/IVA
15/VA
16/VIA
17/VIIA
18/VIIIA
1 H 1.008
2 He 4.003
3 Li 6.941
4 Be 9.012
5 B 10.81
6 C 12.01
7 N 14.01
8 O 16.00
9 F 19.00
10 Ne 20.18
11 Na 22.99
12 Mg 24.30
13 Al 26.98
14 Si 28.09
15 P 30.97
16 S 32.07
17 Cl 35.05
18 Ar 39.95
19 K 39.10
20 Ca 40.08
21 Sc 44.96
22 Ti 47.87
23 V 50.94
24 Cr 52.00
25 Mn 54.94
26 Fe 55.85
27 Co 58.93
28 Ni 58.69
29 Cu 63.55
30 Zn 65.39
31 Ga 69.72
32 Ge 72.61
33 As 74.92
34 Se 78.96
35 Br 79.90
36 Kr 83.80
37 Rb 85.47
38 Sr 87.62
39 Y 88.91
40 Zr 91.22
41 Nb 92.91
42 Mo 95.94
43 Tc 98.91
44 Ru 101.1
45 Rh 102.9
46 Pd 106.4
47 Ag 107.9
48 Cd 112.4
49 In 114.8
50 Sn 118.7
51 Sb 121.8
52 Te 127.6
53 I 126.9
54 Xe 131.3
55 Cs 123.9
56 Ba 137.3
La-Lu
72 Hf 178.5
73 Ta 180.9
74 W 183.8
75 Re 186.2
76 Os 190.2
77 Ir 192.2
78 Pt 195.1
79 Au 197.0
80 Hg 200.6
81 Tl 204.4
82 Pb 207.2
83 Bi 209.0
84 Po 210.0
85 At 210.0
86 Rn 222.0
87 Fr 223.0
88 Ra 226.0
Ac-Lr
104 Db
105 Jl
106 Rf
107 Bh
108 Hn
109 Mt
110 Uun
111 Uuu
s
d
p
Lanthanides
57 La 138.9
58 Ce 140.1
59 Pr 140.9
60 Nd 144.2
61 Pm 146.9
62 Sm 150.4
63 Eu 152.0
64 Gd 157.2
65 Tb 158.9
66 Dy 162.5
67 Ho 164.9
68 Er 167.3
69 Tm 168.9
70 Yb 173.0
71 Lu 175.0
Actinides
89 Ac 227.0
90 Th 232.0
91 Pa 231.0
92 U 238.0
93 Np 237.0
94 Pu 239.1
95 Am 241.1
96 Cm 244.1
97 Bk 249.1
98 Cf 252.1
99 Es 252.1
100 Fm 257.1
101 Md 258.1
102 No 259.1
103 Lr 262.1
f

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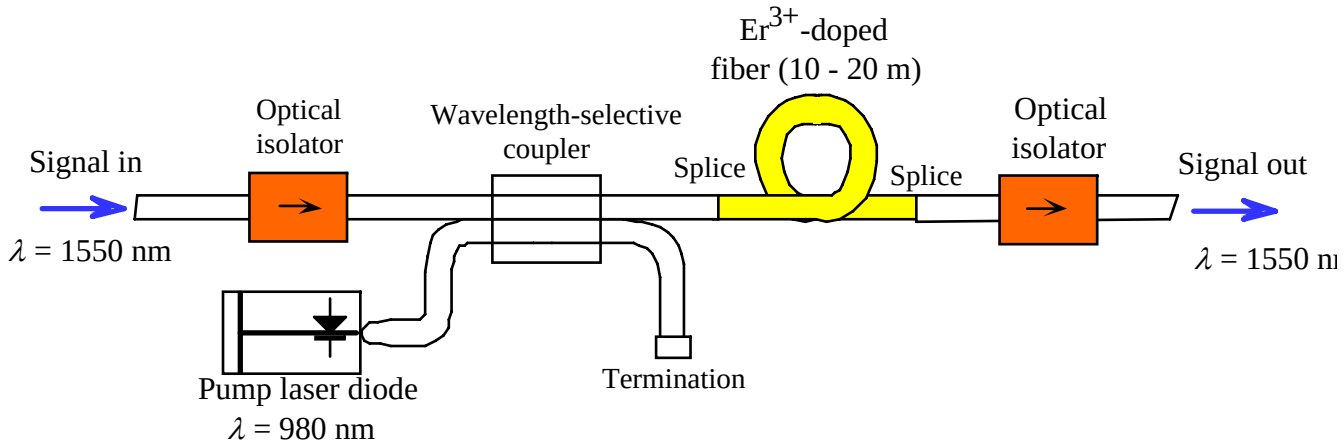
EDFA: Er-doped Fiber Amplifier



Compensates fiber loss: Long distance optical fiber communication

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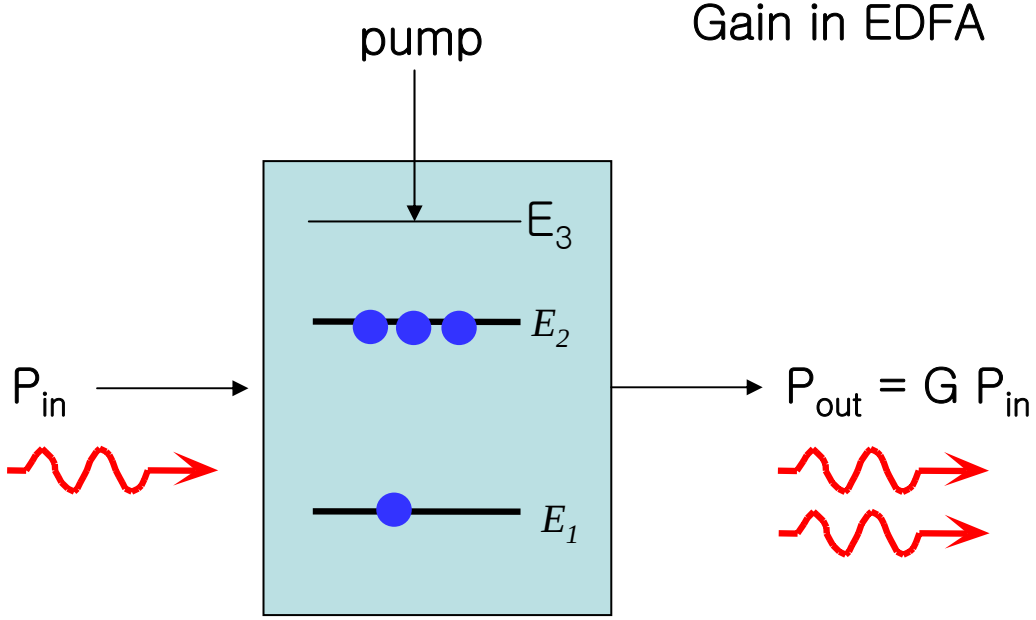
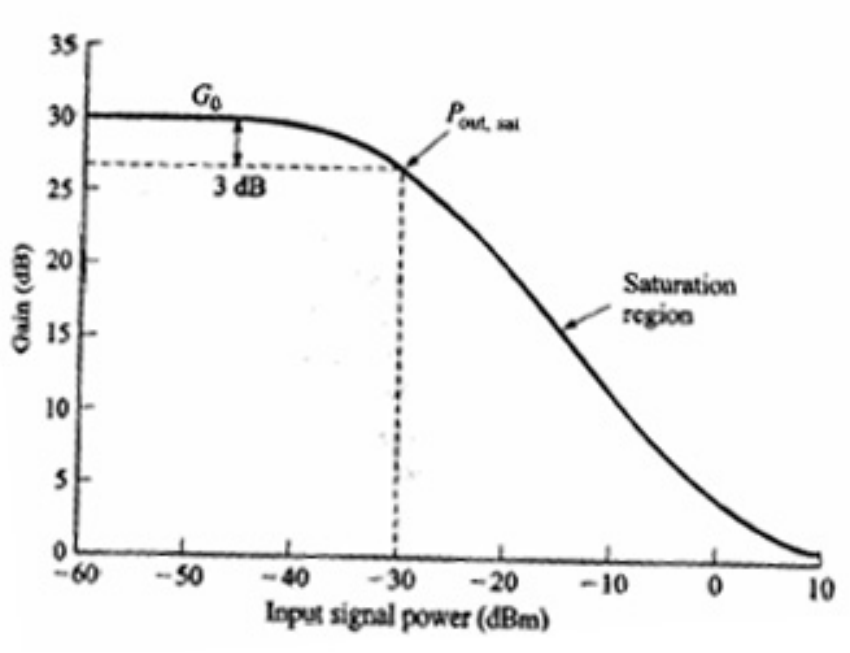


Gain in EDFA



Gain saturation due to limited carrier numbers at E_2

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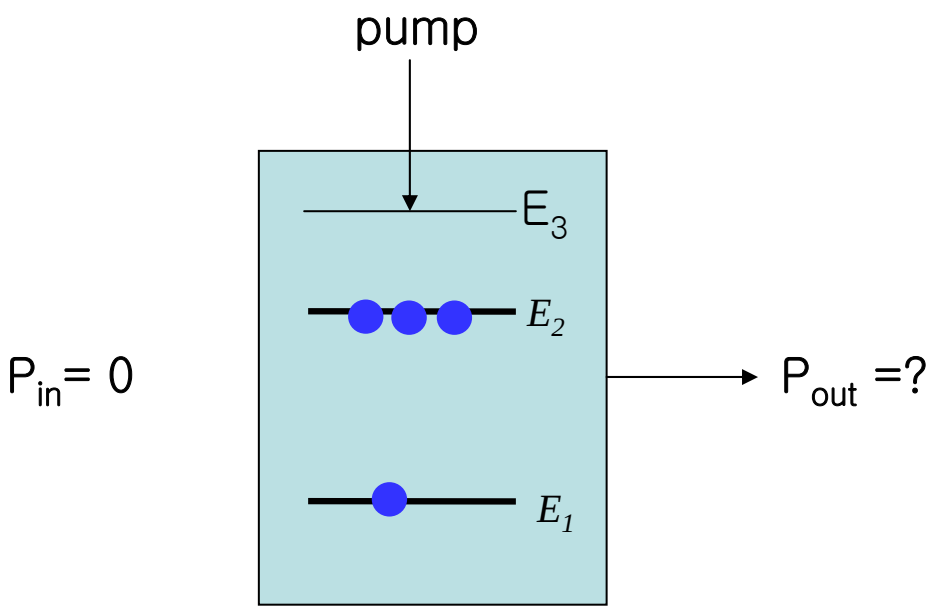
Noises in EDFA



Amplified Spontaneous Emission (ASE)

Lect. 17: Optical Pumping and EDFA

Other materials where optical pumping is possible: Optical gain materials

- Crystals doped with impurities: Ruby doped with Cr ($Al_2O_3:Cr^{3+}$)
- Gases: Ar, N, mixture of He and Ne
- Semiconductors