Engineering Optics

Lecture 29

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by

Debolina Misra

Dept. of Physics
IIITDM Kancheepuram, Chennai, India

Problem

$P_1 = 0.25, P_2 = 0.5, P_3 = 0.75$ are the probability of occurrence per second of three different atoms. Which wave will be having more life time at excited state.

Answer:

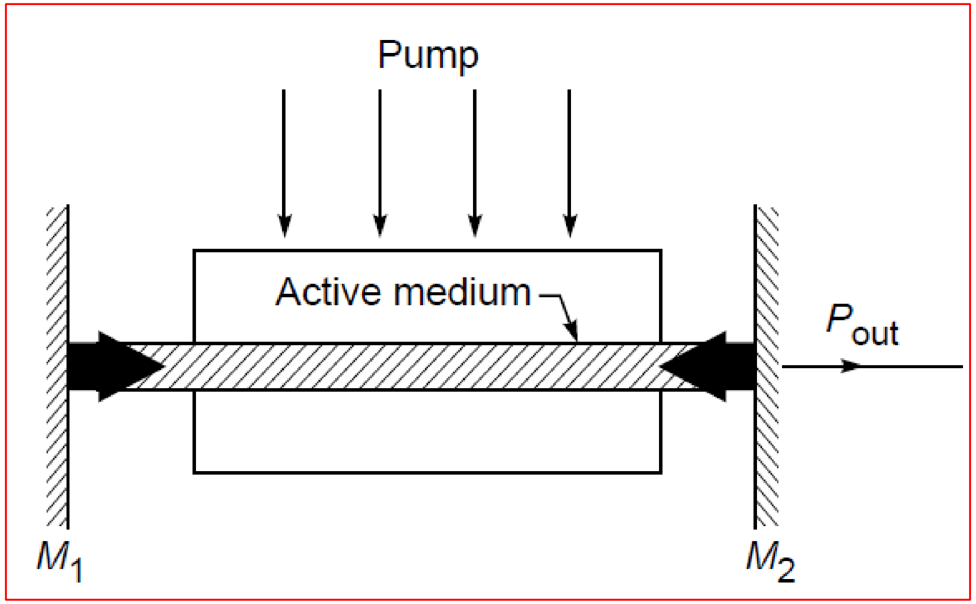
$$P \propto \frac{1}{\tau} \qquad \tau \propto \frac{1}{P}$$

$$P_1 = 0.25, P_2 = 0.5, P_3 = 0.75$$

$\Rightarrow$ 1^{ST} atom will be having more life time

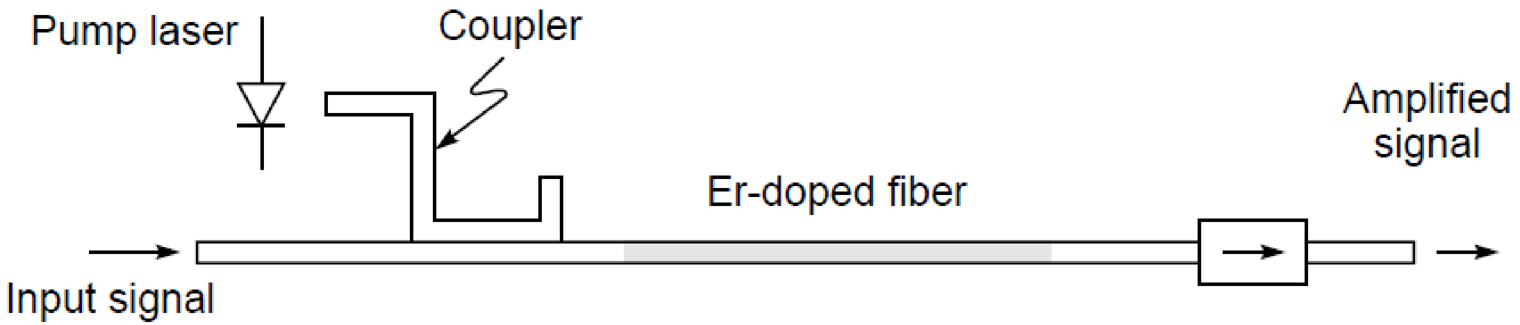
Main Components of the Laser

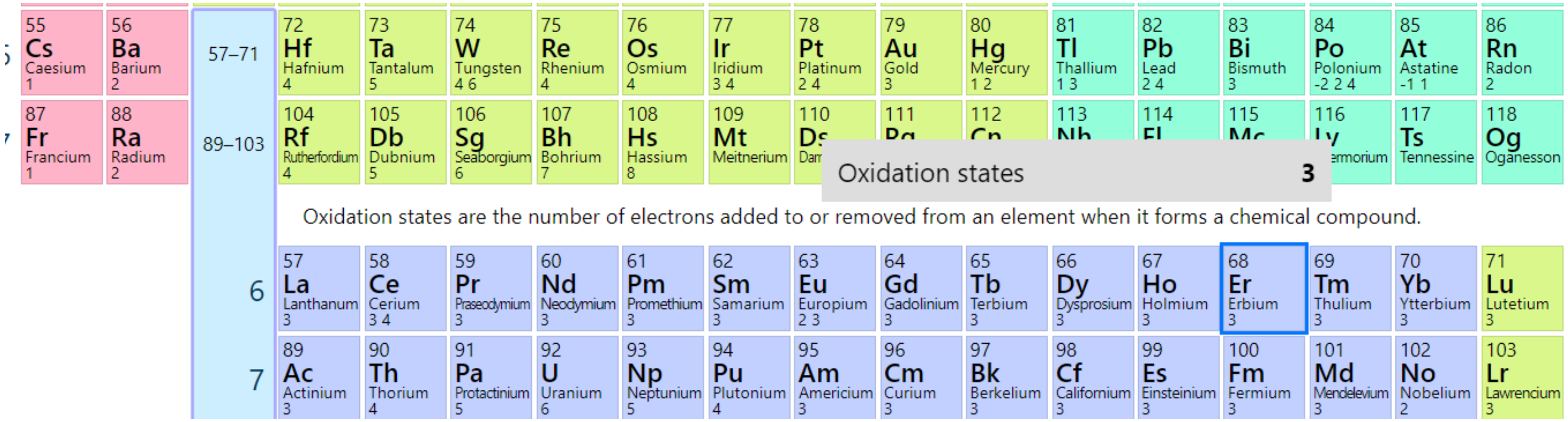
- 1. Active medium
- 2. Pumping source
- 3. Optical resonator

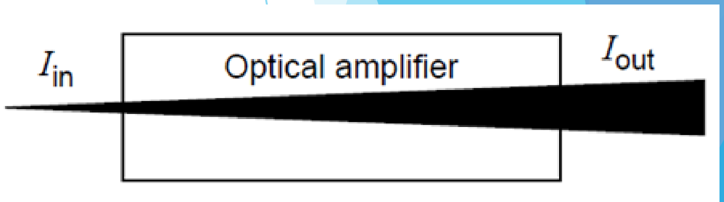


Points to note: *Some of the energy is coupled back to the system → oscillator.*

Understanding Optical Amplification







- understand optical amplification → EDFA
- **Erbium doped fiber amplifier**
- The EDFA: consists of a silica optical fiber the core doped with erbium oxide (Er_2O_3)
- light is guided through the optical fiber
- three discrete energy levels of Er^{3+} ion in silica host glass.

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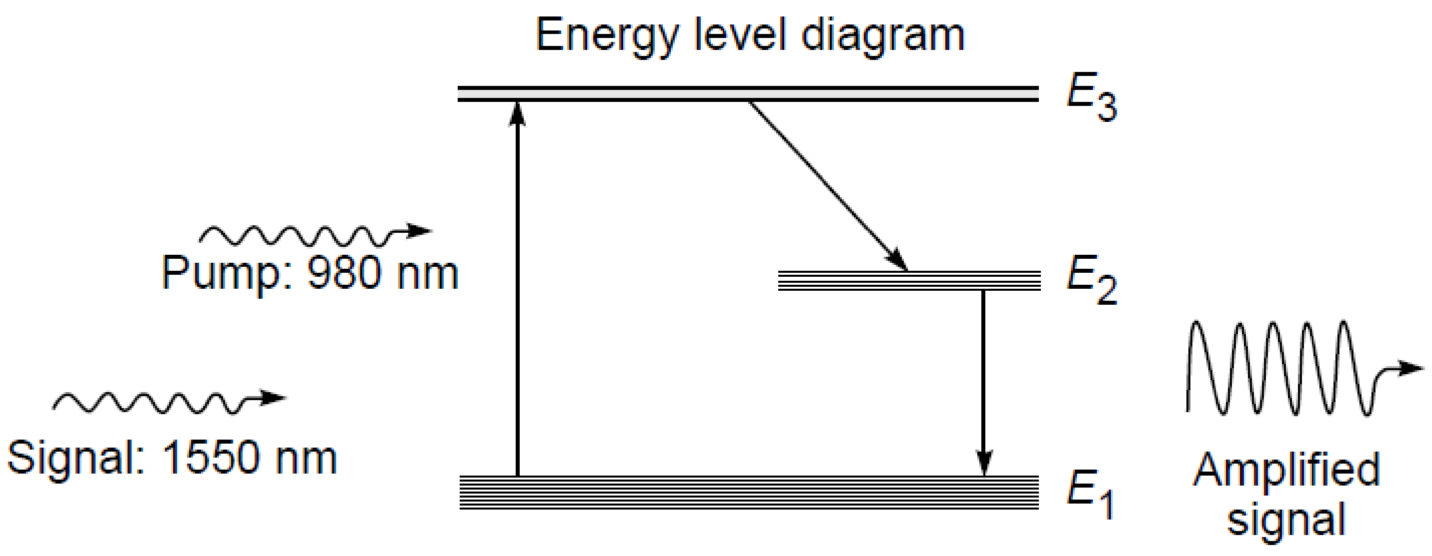
EDFA



Absorption of 980 nm pump
↓
Population inversion between E_2 and E_1
↓
Amplification of signal (at 1550 nm)

Er^{3+} concentration $\approx 7 \times 10^{24}$ ions m^{-3} pump power ≈ 5 mW

and, the optimum length of the erbium doped fiber $\approx$ 7m.

- $E_3 - E_1 = 1.3$ eV → 980 nm
- $E_2 - E_1 = 0.81$ eV → 1550 nm
- When a trigger of 980 nm is fed → Er atoms jump to E_3 → *pump*
- Atoms in E_3 jumps to E_2 → *heating*
- State E_2 is ***metastable*** → long lifetime (few milliseconds).
- large lifetime of state E_2 than E_3 → the population of the erbium atoms in state E_2 grows with time
- Population inversion can be achieved
- $N_2 > N_1$
- Send a signal beam (1550 nm) → it gets amplified
- Why? → stimulated emission of radiation

$$\text{Gain (dB)} = 10 \log \frac{P_{output}}{P_{input}}$$

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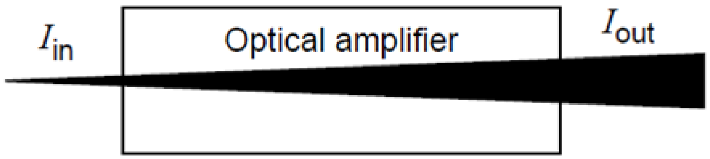
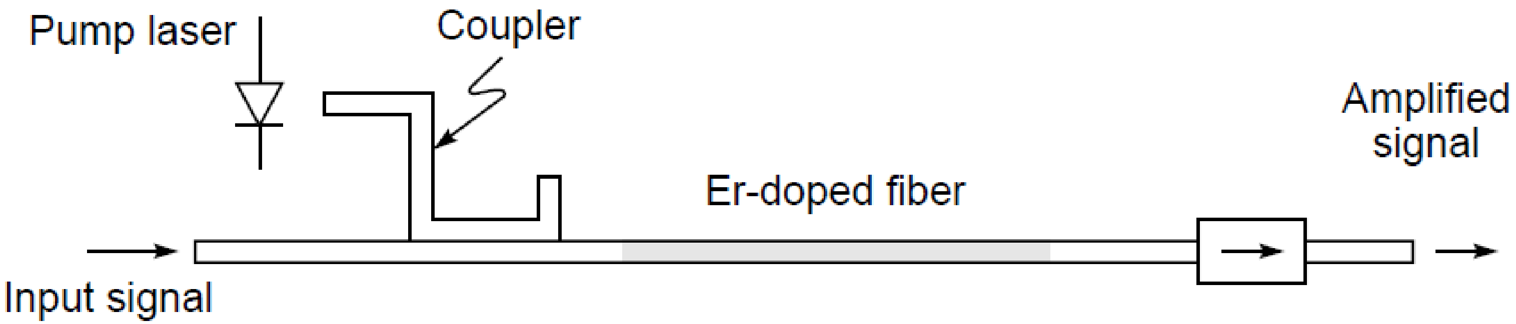
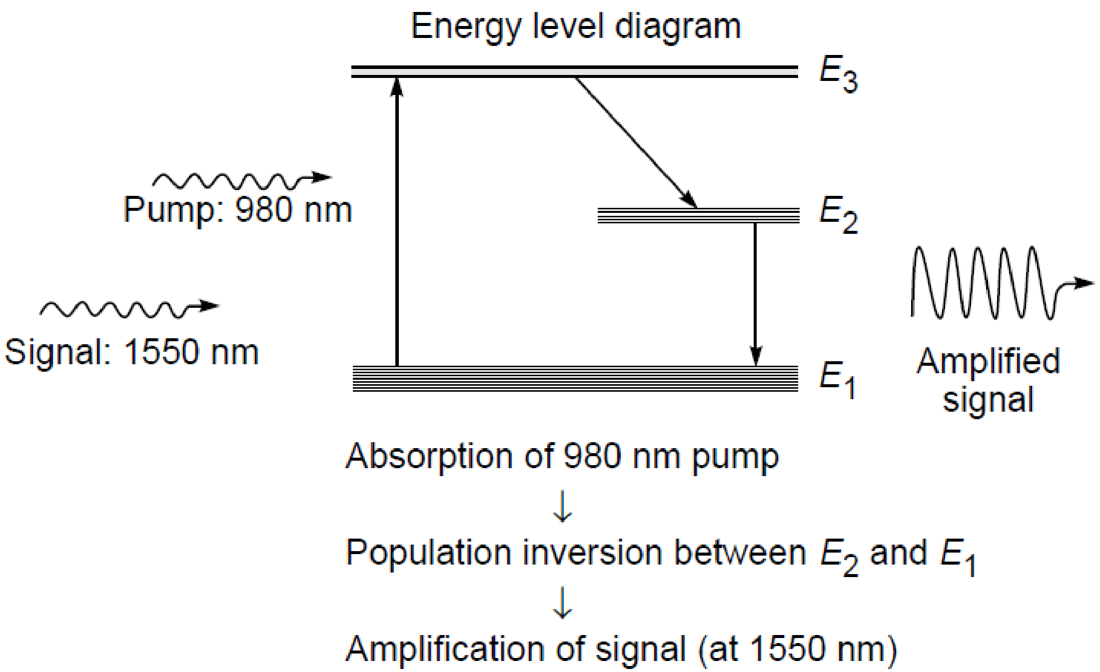
Understanding Optical Amplification through EDFA







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Loss: scattering from the laser medium, absorption at the mirrors

When the laser oscillates in steady state, the losses are exactly compensated for by the gain provided by the medium

→ wave coming out of the laser can be represented as a continuous wave

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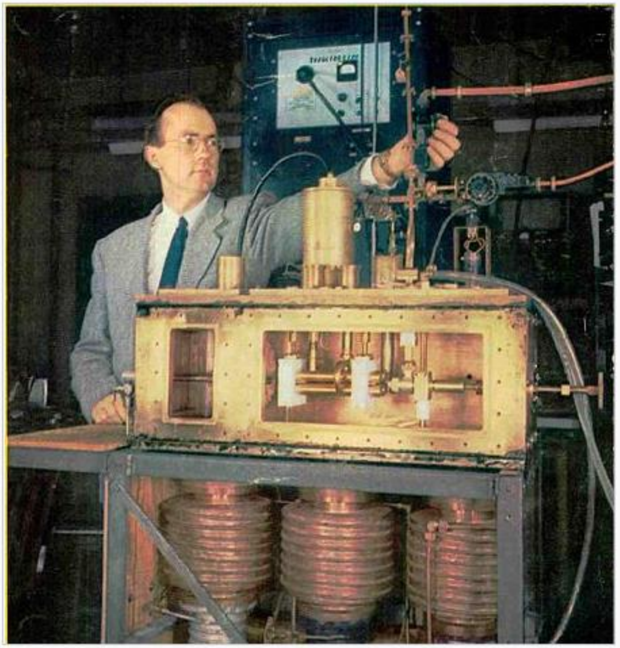
Do you know?



First prototype ammonia maser and inventor Charles H. Townes. The ammonia nozzle is at left in the box, the four brass rods at center are the quadrupole state selector, and the resonant cavity is at right. The 24 GHz microwaves exit through the vertical waveguide Townes is adjusting. At bottom are the vacuum pumps. wikipedia

The Nobel Prize in Physics 1964

Photo from the Nobel Foundation archive.

Charles Hard Townes

Prize share: 1/2

Photo from the Nobel Foundation archive.

Nicolay Gennadiyevich Basov

Prize share: 1/4

Photo from the Nobel Foundation archive.

Aleksandr Mikhailovich Prokhorov

Prize share: 1/4

Maiman with his laser in July 1960.

World's first laser

wikipedia

https://www.aps.org/publications/apsnews/201005/physicshistory.cfm

The Nobel Prize in Physics 1964 was divided, one half awarded to Charles Hard Townes, the other half jointly to Nicolay Gennadiyevich Basov and Aleksandr Mikhailovich Prokhorov "for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle."

https://www.nobelprize.org/prizes/physics/1964/summary/

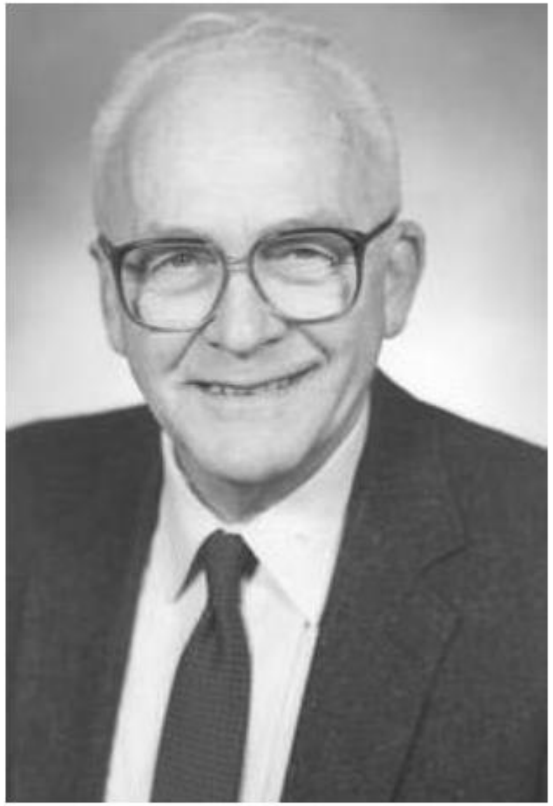
THE FIBER LASER

- put the doped fiber between two mirrors (resonator), + appropriate pump → fiber laser
- 1960: Maiman's demonstration of the first ever laser
- 1961: Elias Snitzer wrapped a flash lamp around a glass fiber (having a 300 mm core doped with Nd^{3+} ions clad in a lower-index glass) and when suitable feedback was applied, the first fiber laser was born.
- *Contribution in EDFA*
- *commercially available in the market*
- Applications: widespread → in welding, cutting, drilling, and in medical surgery.

Oxidation states are the number of electrons added to or removed from an element when it forms a chemical compound.

57 La Lanthanum 3	58 Ce Cerium 3 4	59 Pr Praseodymium 3	60 Nd Neodymium 3	61 Pm Promethium 3	62 Sm Samarium 3	63 Eu Europium 2 3	64 Gd Gadolinium 3	65 Tb Terbium 3	66 Dy Dysprosium 3	67 Ho Holmium 3	68 Er Erbium 3	69 Tm Thulium 3	70 Yb Ytterbium 3	71 Lu Lutetium 3
89 Ac Actinium 3	90 Th Thorium 4	91 Pa Protactinium 5	92 U Uranium 6	93 Np Neptunium 5	94 Pu Plutonium 4	95 Am Americium 3	96 Cm Curium 3	97 Bk Berkelium 3	98 Cf Californium 3	99 Es Einsteinium 3	100 Fm Fermium 3	101 Md Mendelevium 3	102 No Nobelium 2	103 Lr Lawrencium 3

Elias Snitzer



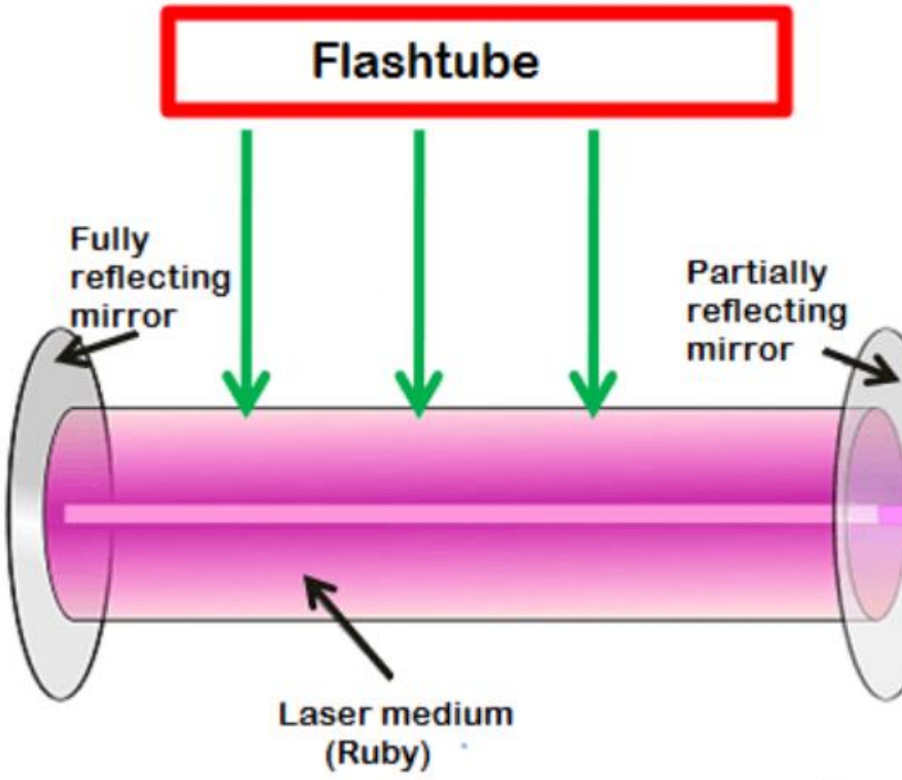
OSA Awards & Distinctions

- John Tyndall Award
- Charles Hard Townes Medal
- Fellow

https://www.osa.org/en-us/history/biographies/bios/elias_snitzer/

https://www.photonics.com/Articles/Fiber_Laser_Pioneer_Honored_with_IEEE_Milestone/a52186

The Ruby LASER



Maiman's original device → the first operative laser

Active medium → a small, cylindrical, synthetic, pink ruby rod

What is Ruby? Al_2O_3 crystal containing about 0.05 percent (by weight) of Cr_2O_3.

Helical discharge tube (flashtube) → pump

The rod's end faces were polished flat, parallel and normal to the axis. Then both were silvered to form the **resonator**

Maiman with his laser in July 1960.

World's first laser

https://www.physics-and-radio-electronics.com/physics/laser/rubylaserdefinitionconstructionworking.html

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Thank You