Lasers & Fiber Optics – Cheat Sheet (Theory Only)

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1. LASERS (Light Amplification by Stimulated Emission of Radiation)

Principles of Lasers

Lasers produce **coherent, monochromatic, and highly directional** light.
Based on **stimulated emission** where photons amplify light waves.
Used in **medical, industrial, communication, and defense applications**.

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2. Spontaneous & Stimulated Emissions

Spontaneous Emission → An excited electron **randomly falls** to a lower energy level, emitting light.
Stimulated Emission → An **incoming photon** forces an excited electron to release an **identical photon**, leading to amplification.

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3. Einstein's Coefficients

Define the probabilities of **absorption, spontaneous emission, and stimulated emission** in quantum systems.
Help in understanding **energy level transitions and laser action**.

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4. Population Inversion & Laser Action

Population Inversion → More atoms in an excited state than in the ground state, necessary for laser operation.
Laser Action Process:
1st **Pumping** → Excites electrons to a higher energy state.
2nd **Population Inversion** → More electrons in excited states.
3rd **Stimulated Emission** → Emission of coherent light.
4th **Amplification** → Continuous stimulated emissions strengthen laser output.

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5. Components of a Laser

Active Medium → Generates laser light (e.g., gas, solid, semiconductor).
Energy Source (Pump Source) → Excites electrons (e.g., electric discharge, flashlamp).
Optical Resonator → Reflective mirrors that amplify light inside the laser cavity.

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6. Types of Lasers

1. Nd:YAG Laser (Neodymium: Yttrium-Aluminum-Garnet)

Solid-state laser using **neodymium-doped YAG crystal**.
High power output and used in **laser cutting, welding, and medical surgeries**.

2. CO_2 Laser (Carbon Dioxide Laser)

Gas laser using a CO_2 mixture.
Emits infrared light and is used in **industrial cutting, engraving, and medical applications**.

3. GaAs Laser (Gallium Arsenide Laser)

Semiconductor laser (Diode Laser) based on GaAs material.
Used in **fiber optic communication, barcode scanners, and medical instruments**.

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7. Fiber Optics & Light Propagation

Principle of Optical Fiber

Works on the principle of **Total Internal Reflection (TIR)**.
Light propagates through a **core** surrounded by a **cladding layer**.
Used in **telecommunication, medical imaging, and data transmission**.

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8. Numerical Aperture (NA) & Acceptance Angle

Numerical Aperture (NA) measures the **light-gathering ability** of an optical fiber.
Acceptance Angle is the **maximum angle** at which light can enter and still propagate inside the fiber.

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9. Types of Optical Fibers

Based on Material

Glass Fiber → High-quality transmission (used in telecom).
Plastic Fiber → Low cost, used in short-distance communication.

Based on Refractive Index

Step-Index Fiber → Sharp refractive index difference between core and cladding.
Graded-Index Fiber → Gradual refractive index change for reduced signal loss.

Based on Mode (Light Propagation)

Single-Mode Fiber (SMF) → Carries one light mode, **long-distance communication**.
Multi-Mode Fiber (MMF) → Carries multiple light modes, **short-distance applications**.

This **Laser & Fiber Optics Cheat Sheet** covers **laser principles, types, components, fiber optics, numerical aperture, and optical fiber classification**. Let me know if you need further explanations!