Requirements of transmitter and receiver in WDM networks, types of tunable lasers, optical amplifiers, SOA and FOA, EDFA and EBFA.

WDM (Wavelength Division Multiplexing)

- In **WDM (Wavelength Division Multiplexing)** networks, multiple data signals are sent simultaneously over a single optical fiber by using different wavelengths (colors) of laser light.
- To make this work, the hardware—transmitters, receivers, and amplifiers—must meet specific high-performance requirements.

1. Transmitter and Receiver Requirements

- **Transmitter Requirements:**
  - **Precision Wavelength:** The laser must emit a very specific wavelength to avoid interfering with adjacent channels (Crosstalk).
  - **Stability:** The wavelength must remain constant regardless of temperature changes (often using "wavelength lockers").
  - **Narrow Linewidth:** The light beam must be "pure" so the signal doesn't spread out (dispersion) over long distances.

wavelength lockers

- Wavelength lockers হলো অপটিক্যাল কমিউনিকেশন সিস্টেমে ব্যবহৃত একটি গুরুত্বপূর্ণ ডিভাইস, যা লেজারের নির্দিষ্ট তরঙ্গদৈর্ঘ্য (wavelength) স্থির রাখতে সাহায্য করে।
- লেজার থেকে যে আলো বের হয়, তার wavelength কখনো কখনো তাপমাত্রা বা অন্য কারণে পরিবর্তিত হতে পারে। কিন্তু **fiber optic communication**-এ নির্দিষ্ট wavelength খুব গুরুত্বপূর্ণ (বিশেষ করে WDM সিস্টেমে)।
  - এই wavelength ঠিক রাখার কাজই করে **wavelength locker**।

- **Receiver Requirements:**
  - **Selectivity:** The receiver must be able to pick out one specific wavelength from the many arriving at the end of the fiber.
  - **Sensitivity:** It must be able to detect very weak signals after they have traveled hundreds of kilometers.
  - **Wide Bandwidth:** It needs to handle the high data rates (e.g., 100Gbps or 400Gbps) sent by the transmitter.

2. Types of Tunable Lasers

- A tunable laser can change its operating wavelength.
- This is useful because one backup laser can replace any failed laser in a WDM system.
  - **External Cavity Lasers (ECL):** Uses a physical grating that moves to change the color. Very precise but mechanically complex.
  - **Distributed Bragg Reflector (DBR):** Uses electrical current to change the refractive index of a built-in grating, changing the wavelength.
  - **Vertical Cavity Surface Emitting Lasers (VCSEL):** Small and cheap; they tune by moving a tiny top mirror using MEMS technology.

MEMS technology

- MEMS technology এর পূর্ণরূপ হলো Micro-Electro-Mechanical Systems l.
- MEMS হলো এমন একটি প্রযুক্তি যেখানে খুব ছোট (micro-level) **mechanical + electrical components** একসাথে একটি চিপের মধ্যে তৈরি করা হয়।
- **উদাহরণ:**
  - Mobile phone-এর **accelerometer** (ফোন ঘোরালে screen rotate হয়)
  - Car airbag sensor
  - Inkjet printer head

3. Optical Amplifiers

- In the past, to boost a signal, we had to convert light to electricity, amplify it, and turn it back to light.
- Modern **Optical Amplifiers** boost the light signal directly.

3. Optical Amplifiers

- **SOA (Semiconductor Optical Amplifier)**
  - **Mechanism:** Uses a semiconductor chip (similar to a laser but without the mirrors).
  - **Pros:** Small, can be integrated on circuits.
  - **Cons:** Higher noise and lower power than fiber-based amplifiers.
- **EDFA (Erbium-Doped Fiber Amplifier)**
  - **Mechanism:** A piece of glass fiber is "doped" with Erbium ions.
    - A "pump laser" excites these ions, and when the signal passes through, the ions release energy to boost the signal.
  - **Standard:** This is the "gold standard" for long-distance internet because it can amplify many WDM channels at once without distortion.
- **EBFA (Erbium-Bismuth Fiber Amplifier)**
  - **Evolution:** Similar to EDFA but uses Bismuth-doped glass to provide a **wider bandwidth**, allowing even more WDM channels to be packed into the fiber.

Example: The Highway Analogy

- Imagine a 40-lane highway (WDM Fiber).
  - **Transmitter:** A specialized ramp that ensures only Blue cars enter Lane 1 and only Red cars enter Lane 2.
  - **Receiver:** A specialized exit that only lets the Blue cars off at a specific destination.
  - **Amplifier (EDFA):** A "speed boost" zone in the middle of the highway that gives every car more fuel as they drive through, without them having to stop at a gas station.

WDM Power Calculation

- A WDM system has 8 channels. Each channel enters an EDFA with a power of **-20 dBm**. The EDFA (Erbium-Doped Fiber Amplifier) has a gain of **25 dB**.
  - Calculate the output power of a single channel in dBm.
  - Calculate the total output power of the EDFA in milliwatts (mW).

Solution:

1. **Output per channel:** $P_{out(dBm)} = P_{in(dBm)} + Gain_{(dB)}$

   $P_{out} = -20\ \text{dBm} + 25\ \text{dB} = \mathbf{5}\ \text{dBm}$

2. **Total Power in mW:**

   First, convert 5 dBm to mW: $P_{(mW)} = 10^{(P_{dBm}/10)} = 10^{(5/10)} = 3.16\ \text{mW}.$

   Since there are 8 identical channels:

   $TotalPower = 8 \times 3.16\ \text{mW} = \mathbf{25.28}\ \text{mW}.$

১. কী কী তথ্য দেওয়া আছে (Given Data):

- **Channels:** ৮টি চ্যানেল (অর্থাৎ ৮টি আলাদা সিগন্যাল একসাথে যাচ্ছে)।
- **Input Power per channel (P_{in}):** -২০ dBm (প্রতিটি সিগন্যাল যখন অ্যাম্প্লিফায়ারে ঢুকছে তখন তার শক্তি)।
- **EDFA Gain (G):** ২৫ dB (এটি একটি অ্যাম্প্লিফায়ার যা সিগন্যালকে ২৫ ডেসিবল পর্যন্ত বাড়িয়ে দেয়)।

২. প্রশ্নটি সাধারণত যা জানতে চায় (Expected Output):

এই ধরণের প্রশ্নে সাধারণত দুটি জিনিস বের করতে বলা হয়:

- **Output power of each channel:** অ্যাম্প্লিফায়ার থেকে বের হওয়ার সময় প্রতিটি চ্যানেলের পাওয়ার কত?
- **Total output power:** ৮টি চ্যানেল মিলিয়ে মোট কত পাওয়ার আউটপুট হিসেবে বের হচ্ছে?

2. The Calculation Logic

In the second part of your slide, the goal is to find the **Total Output Power** for all 8 channels.

- **Step A:** The output of one channel is **5 dBm**.
- **The Trap:** You **cannot** do $8 \times 5\ \text{dBm} = 40\ \text{dBm}$. This is a common mistake! In the log world, adding or multiplying dB values represents massive exponential changes, not simple addition.
- **The Solution:** You must convert the 5 dBm back into a "real" number (milliwatts) using the antilog formula:

$$P_{(mW)} = 10^{(P_{dBm}/10)}$$

$$P = 10^{(5/10)} = 10^{0.5} \approx 3.16\ \text{mW}$$