Optical Feedback and Laser Oscillation

Mechanism of Optical Feedback:

- A laser consists of an active medium (where light is generated) placed between two mirrors, forming an **optical cavity** or resonator. +1
- When light is emitted within the medium, it bounces back and forth between these mirrors . This process is known as **optical feedback**.
- As the light passes through the medium repeatedly, it triggers **stimulated emission**, which amplifies the signal.
- **Oscillation** occurs when the gain (amplification) within the medium exactly matches the losses (light escaping or being absorbed). At this point, the device emits a steady, coherent beam of laser light.

Spectral Output:

- This feedback mechanism provides a **distinctive spectral output** because the cavity only supports specific "resonant frequencies" (wavelengths) that fit perfectly between the mirrors.
- Unlike an LED, which has a broad spectral width ($\Delta\lambda$), a laser using optical feedback has a **narrow linewidth**, meaning the light beam is extremely "pure" and concentrated on specific colors.

Fusion Splicing of Optical Fibers

Definition:

- **Fusion splicing** is a technique used to join two optical fibers permanently by using localized heat (usually from an electric arc) to melt the glass ends together.

Advantages:

- **Low Loss:** It provides the lowest signal loss (attenuation) of all jointing methods, typically less than 0.1 dB.
- **High Reliability:** The resulting joint is almost as strong as the original fiber and is highly stable against temperature changes.
- **No Reflection:** Because the glass becomes one continuous piece, there is virtually no "back-reflection" that could damage sensitive lasers.

Drawbacks:

- **High Initial Cost:** Requires expensive, specialized equipment (a fusion splicer).
- **Precision Required:** The fibers must be perfectly cleaned and "cleaved" (cut) before splicing; even a tiny speck of dust can ruin the joint.
- **Fragility:** The spliced area is stripped of its protective coating and becomes brittle, requiring a specialized "protection sleeve" to be added afterward.

Direct and Indirect Band Gap Semiconductors

- These terms describe how electrons move within a material to release energy (light)

1. Direct Band Gap Semiconductors:

- **Definition:** The maximum energy level of the valence band and the minimum level of the conduction band occur at the same "momentum" (k-value).
- **Result:** Electrons can drop directly from the conduction band to the valence band, releasing their energy as a **photon (light)**.
- **Usage:** Used to make **LEDs and Lasers**.
- **Example:** Gallium Arsenide (GaAs).

2. Indirect Band Gap Semiconductors:

- **Definition:** The conduction band minimum and valence band maximum occur at different "momenta."
- **Result:** An electron cannot drop directly; it must change its momentum, which usually releases energy as **heat (vibrations)** rather than light.
- **Usage:** Generally poor for light emission but excellent for electronic switching.
- **Example:** Silicon (Si) and Germanium (Ge).

A four-port multimode fiber FBT coupler has 60 μW optical power launched into port 1. The measured output powers at ports 2, 3 and 4 are 0.004, 26.0 and 27.5 μW respectively. Determine the excess loss, the insertion losses between the input and output ports, the crosstalk and the split ratio for the device.

Given Data for Port 1 input:

- Input Power (P_1) = $60\ \mu\mathrm{W}$
- Output Port 2 (P_2) = $0.004\ \mu\mathrm{W}$ (Crosstalk/Isolated port)
- Output Port 3 (P_3) = $26.0\ \mu\mathrm{W}$
- Output Port 4 (P_4) = $27.5\ \mu\mathrm{W}$

1. Excess Loss: * This measures the power lost inside the coupler itself.

- Formula: $10\log_{10}[P_1/(P_3+P_4)]$
- Calculation: $10\log_{10}[60/(26.0+27.5)] = 10\log_{10}[60/53.5] \approx \mathbf{0.50}\ \mathrm{dB}$

2. Insertion Loss:

- Loss from input port to a specific output port.
- **Port 3:** $10\log_{10}(60/26.0) \approx \mathbf{3.63}\ \mathrm{dB}$
- **Port 4:** $10\log_{10}(60/27.5) \approx \mathbf{3.39}\ \mathrm{dB}$

3. Crosstalk:

- Measures how much light "leaks" into the isolated port.
- Formula: $10\log_{10}(P_2/P_1)$
- Calculation: $10\log_{10}(0.004/60) \approx -\mathbf{41.76}\ \mathrm{dB}$

4. Split Ratio:

- The ratio of power between the two main output ports.
- $\mathrm{Ratio} = [P_3/(P_3+P_4)] \times 100\%$
- $\mathrm{Ratio} = [26.0/53.5] \times 100\% \approx \mathbf{48.6\%}$ (Port 3) and **51.4%** (Port 4).

- **ইনপুট পাওয়ার (P_1):** $60 \backslash\mathrm{muW}$ (পোর্ট ১ দিয়ে আলো ঢুকছে)।
- **আউটপুট পাওয়ার:**
  - **পোর্ট ২ (P_2):** $0.004 \backslash\mathrm{muW}$ (এটি মূলত ব্যাক-রিফ্লেকশন বা লিক হওয়া আলো)।
  - **পোর্ট ৩ (P_3):** $26.0 \backslash\mathrm{muW}$ (মূল আউটপুট ১)।
  - **পোর্ট ৪ (P_4):** $27.5 \backslash\mathrm{muW}$ (মূল আউটপুট ২)।

যা বের করতে বলা হয়েছে:

১. এক্সেস লস (Excess Loss):

- **সহজ ব্যাখ্যা:** কাপলারের ভেতরে কতটুকু আলো হারিয়ে গেছে বা নষ্ট হয়েছে।
- **হিসাব:** আমরা মোট $60 \backslash\mathrm{muW}$ দিয়েছি, কিন্তু আউটপুটে ($P_3 + P_4$) মোট পেয়েছি ৫৩.৫ মাইক্রোওয়াট। বাকিটুকু লস।

২. ইনসার্শন লস (Insertion Loss):

- **সহজ ব্যাখ্যা:** ইনপুট পোর্ট থেকে একটি নির্দিষ্ট আউটপুট পোর্টে পৌঁছাতে কতটুকু সিগন্যাল কমেছে।
- **হিসাব:** পোর্ট ১ থেকে পোর্ট ৩-এ যাওয়ার সময় লস এবং পোর্ট ১ থেকে পোর্ট ৪-এ যাওয়ার সময় লস আলাদাভাবে বের করতে হবে।

৩. ক্রসটক (Crosstalk):

- **সহজ ব্যাখ্যা:** আলো যাওয়ার কথা পোর্ট ৩ ও ৪ দিয়ে, কিন্তু কতটুকু আলো ভুল করে পোর্ট ২ (Isolated port)-এ চলে এসেছে।
- **গুরুত্ব:** ক্রসটকের মান যত বেশি নেগেটিভ (যেমন -40 dB বা -50 dB) হবে, কাপলারটি তত ভালো।

৪. স্প্লিট রেশিও (Split Ratio):

- **সহজ ব্যাখ্যা:** আউটপুট পাওয়ারের কত শতাংশ পোর্ট ৩ দিয়ে আর কত শতাংশ পোর্ট ৪ দিয়ে বের হচ্ছে তার অনুপাত।
- **ফলাফল:** এখানে প্রায় ৫০:৫০ অনুপাতে আলো ভাগ হয়েছে।