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FACULTÉ DES SCIENCES

Course Optoelectronic

Parcours électronique S6 2025-2026

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Chapitre 6: : Laser diode

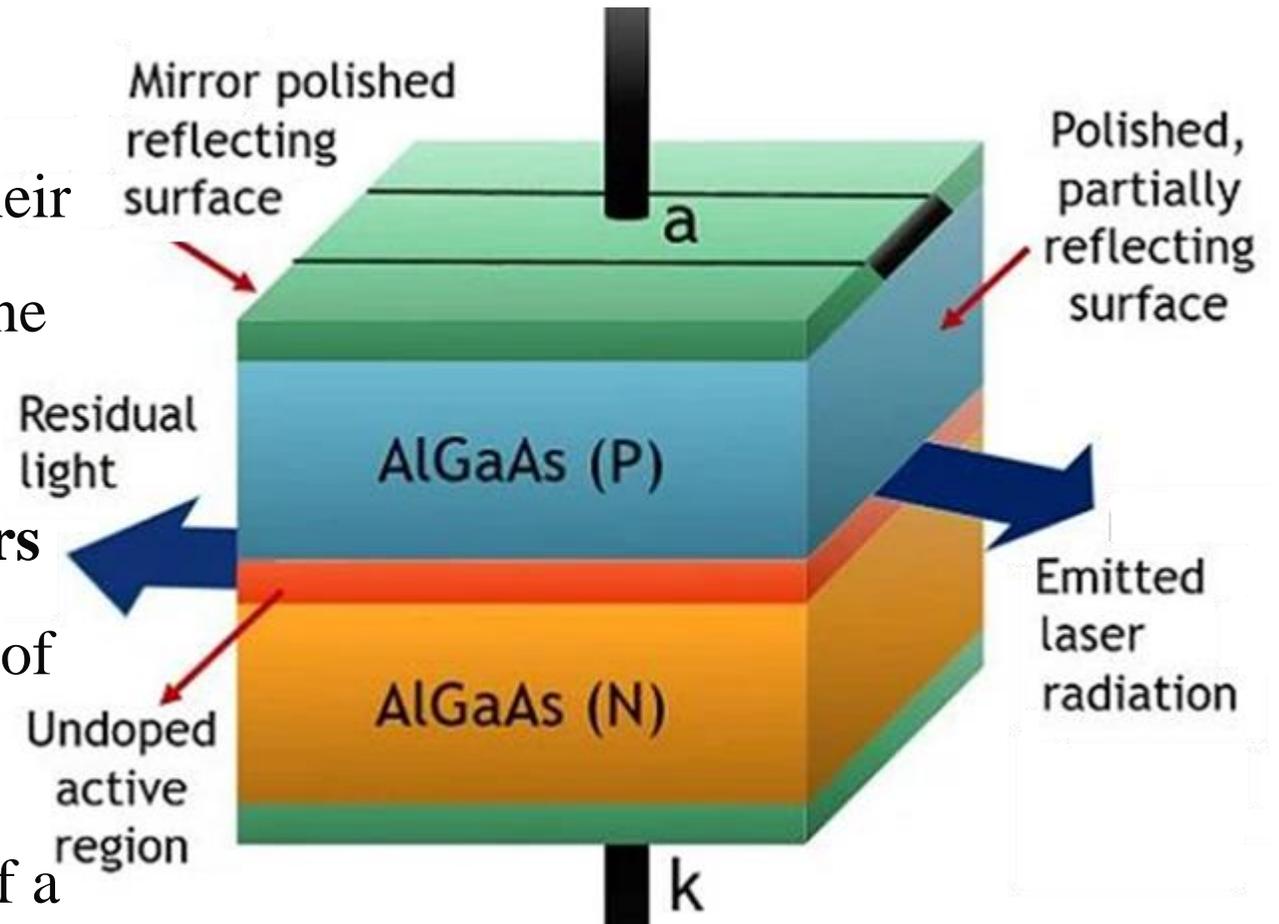
- Different types of Laser Diode
- Principle and working Laser Diode
- Application of Laser Diode

Different Types of Laser Diodes

Laser diodes are categorized based on their internal architecture and how they confine light and electrical carriers.

➤ Double Heterostructure (DH) Lasers

- **Architecture:** A thin active layer of one semiconductor material is sandwiched between two layers of a different material.
- **Benefit:** Provides better confinement of electrons and holes, significantly reducing the current needed to start lasing compared to basic p-n junction lasers.

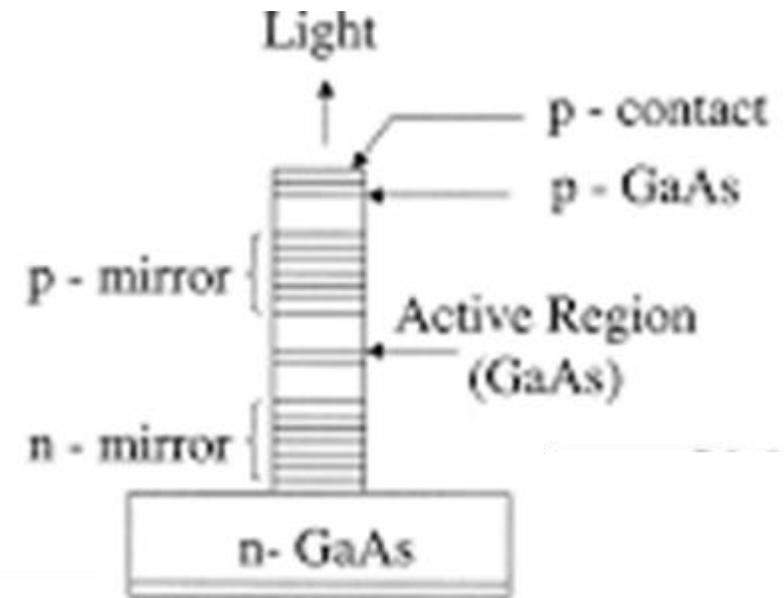


Different Types of Laser Diodes

➤ Quantum Well (QW) Lasers

- **Architecture:** Features an extremely thin active region (less than 10nm).
- **Benefit:** Maximizes efficiency and lowers the threshold current.

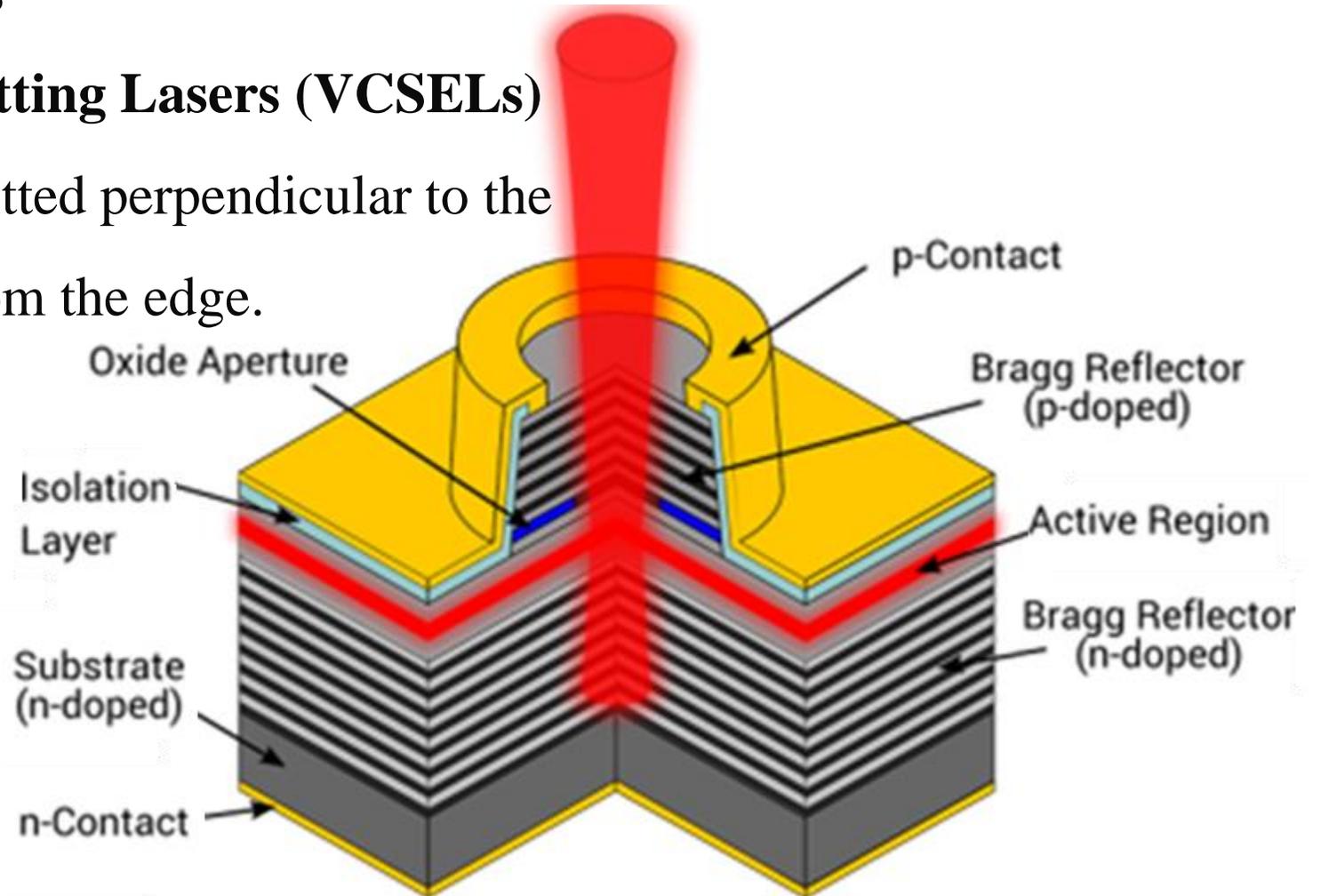
Variations include **Multi-Quantum Well (MQW)** lasers used for higher power output.



Different Types of Laser Diodes

➤ Vertical-Cavity Surface-Emitting Lasers (VCSELs)

- **Architecture:** Light is emitted perpendicular to the chip surface rather than from the edge.

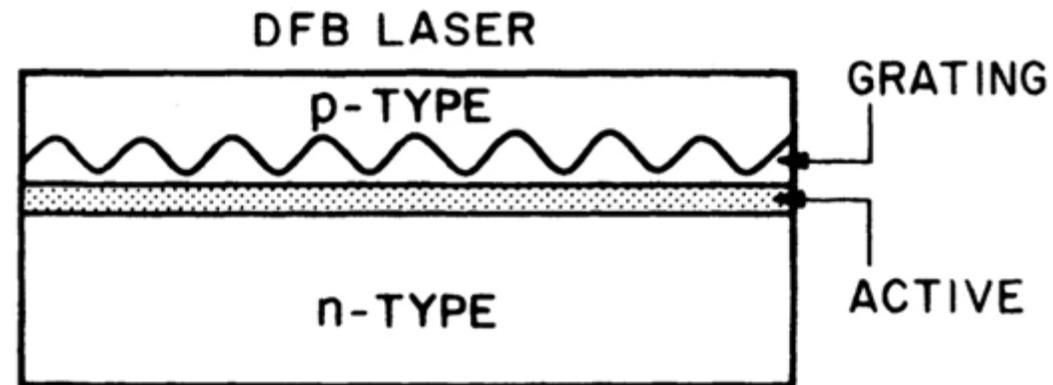


- **Application:** Widely used for **3D sensing**, facial recognition in smartphones, and short-range high-speed data communication.

Different Types of Laser Diodes

➤ Distributed Feedback (DFB) Lasers

- **Architecture:** Incorporates a "diffraction grating" built into the active region.



- **Benefit:** Forces the laser to operate at a very specific, stable wavelength.
- **Application:** The gold standard for **Long-Haul Fiber Optic Communication.**

Different Types of Laser Diodes

➤ Quantum Cascade Lasers (QCLs)

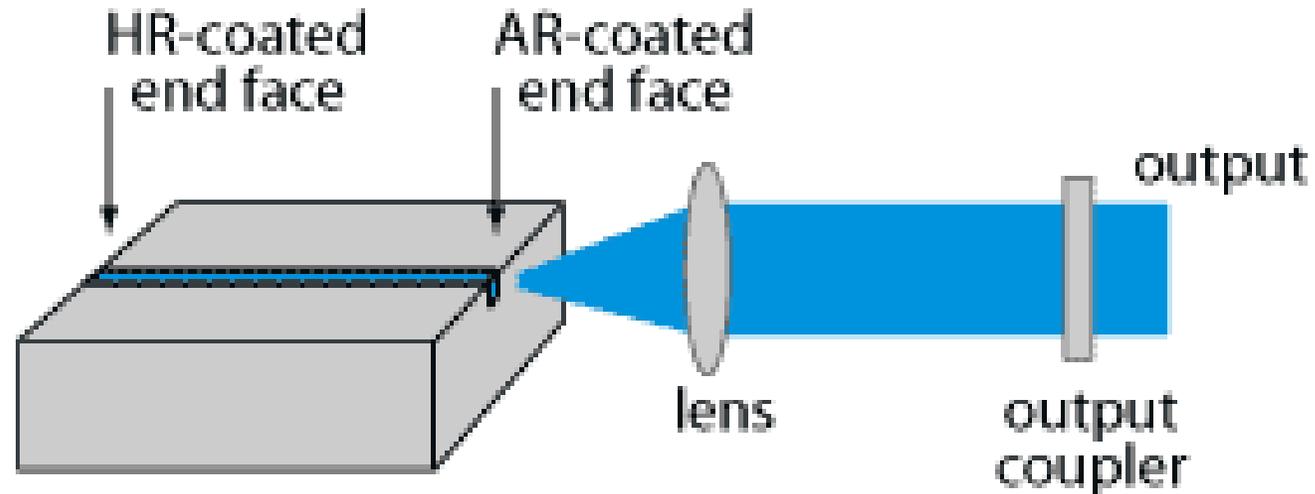
- **Architecture:** Uses "intersubband transit rather than electron-hole recombination.
- **Application:** Emits in the mid-to-far infr spectrum; essential for gas sensing and environmental monitoring.



Different Types of Laser Diodes

➤ External Cavity Laser Diodes (ECLs)

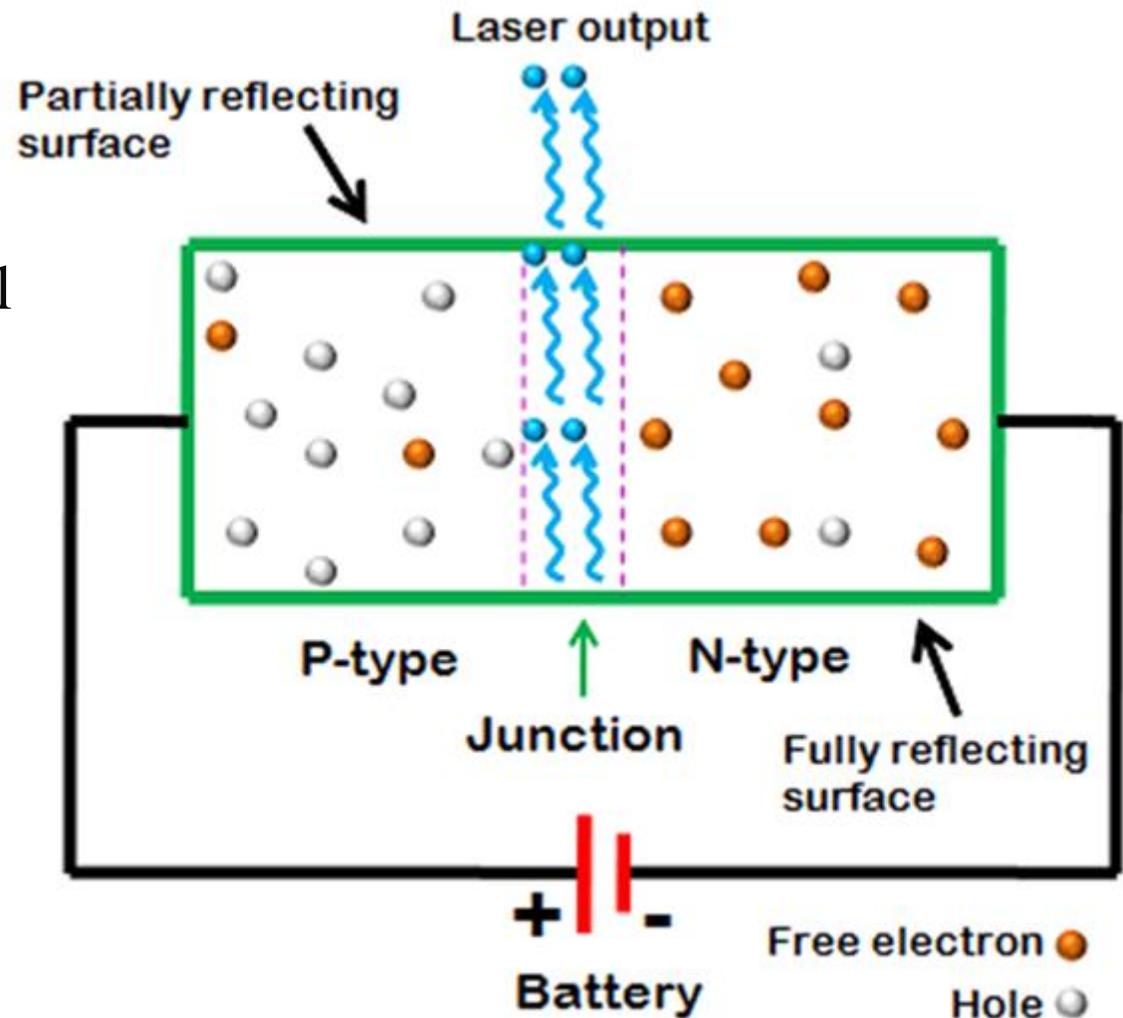
- **Architecture:** Uses an external grating or mirror to tune the wavelength.



- **Benefit:** Provides extremely narrow spectral linewidth and wavelength tunability for scientific research.

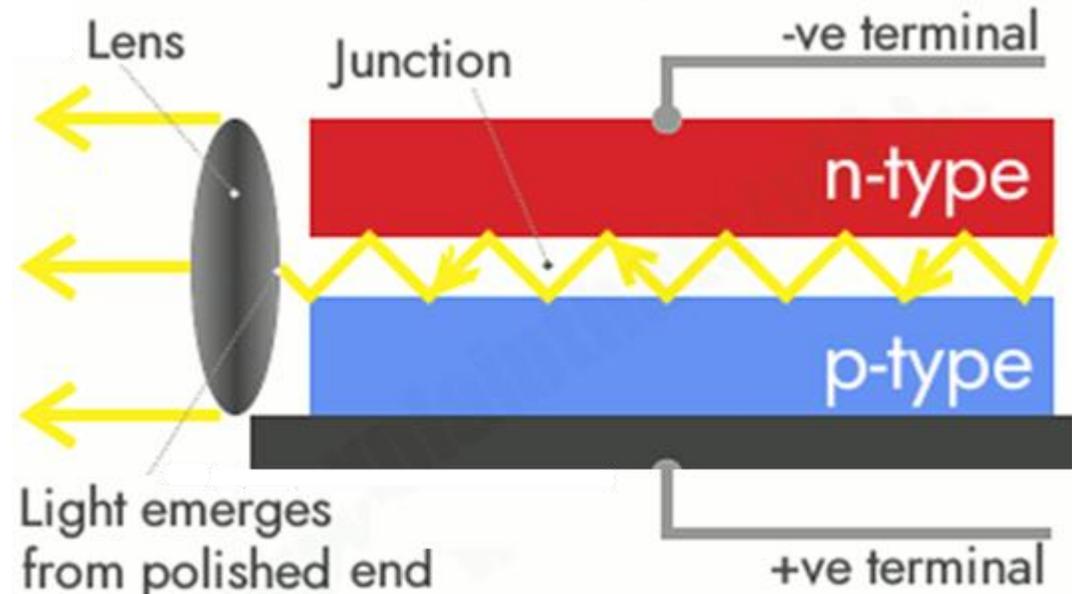
Principle of Laser Diodes

Core Concept: The Laser Diode is a semiconductor device that converts electrical energy directly into coherent light through **Stimulated Emission**.



Principle of Laser Diodes

- **P-N Junction:** At its heart, it is a heavily doped p-n junction. When forward-biased, electrons and holes are injected into the "Active Region."
- **Population Inversion:** For lasing to occur, a higher concentration of electrons must exist in the conduction band than the valence band.
- **Optical Cavity (Resonator):** The ends of the semiconductor crystal are polished to act as mirrors. This traps photons, forcing them to bounce back and forth through the active medium, amplifying the light.



Working Mechanism

Step-by-Step Process:

- **Injection:** Current flows through the diode, injecting carriers into the active layer.
- **Spontaneous Emission:** Initially, electrons drop into holes and release photons randomly (like a standard LED).
- **Stimulated Emission:** A photon interacts with an excited electron, causing it to drop and release a second photon that is identical in phase, direction, and wavelength.
- **Feedback & Amplification:** The mirrors provide optical feedback. Once the internal gain exceeds the optical losses, the device reaches the "Lasing Threshold."
- **Output:** A monochromatic, coherent, and highly directional beam of light is emitted through the partially reflective front mirror.

Applications of Laser Diodes

➤ Industrial & Commercial:

- **Fiber Optic Communications:** High-speed data transmission across the globe.
- **Barcode Scanners:** Precision scanning in retail and logistics.
- **Laser Printing:** High-resolution document and industrial printing.

➤ Consumer Electronics:

- **Optical Storage:** Reading and writing data on CDs, DVDs, and Blu-ray discs.
- **LIDAR & 3D Sensing:** Used in autonomous vehicles and smartphone facial recognition (FaceID).

➤ Medical & Scientific:

- **Laser Surgery:** Precise tissue cutting and hair removal.
- **Spectroscopy:** Chemical analysis and environmental monitoring.

Conclusion

- **Efficiency:** Laser diodes are the most efficient light sources available, offering high power in a miniature package.
- **Versatility:** From 2026-era autonomous navigation to high-speed quantum communication, laser diodes remain the backbone of modern optoelectronics.
- **Future:** Development continues in "Green" laser diodes and higher-power VCSEL arrays for augmented reality (AR) hardware.

End chapter 6

[Video](#)

<https://www.youtube.com/watch?v=Yxt72aDjFgY>