Detectors For Optical Communication

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What are they?

- The first element of an optical receiver.
- Senses incident luminescent power, and converts the variation of this power into a correspondingly varying electric current.

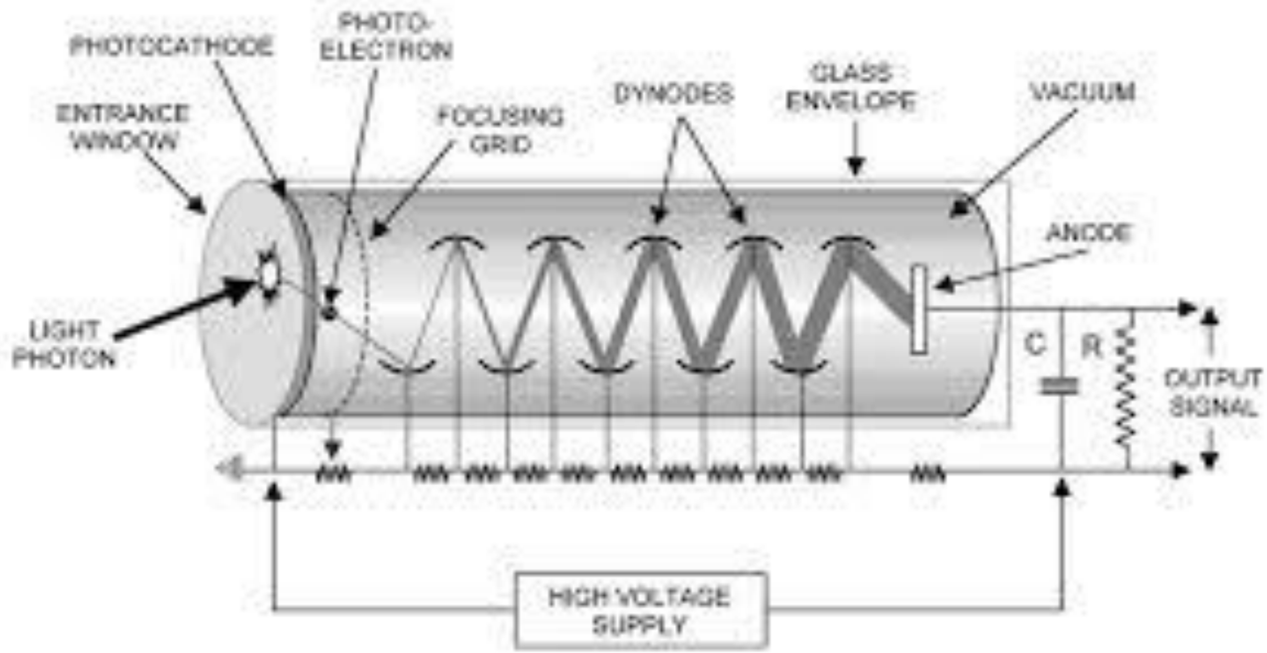
Common Types of Detectors

- Photomultiplier Tubes (PMT)
- Photo Diodes (PD)
- Avalanche Photo Diodes (APD)
- Detector Arrays

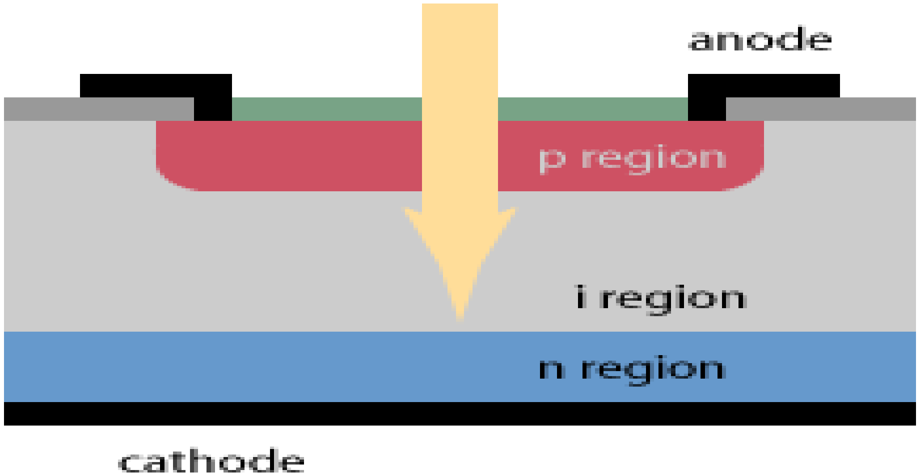
Photomultiplier Tube

- Consists of:
  - An evacuated glass tube
  - A photosensitive cathode
  - An array of dynodes that serves as an electron multiplier
  - An anode
  - An external circuit

Photomultiplier Tube



PIN Photo Diode

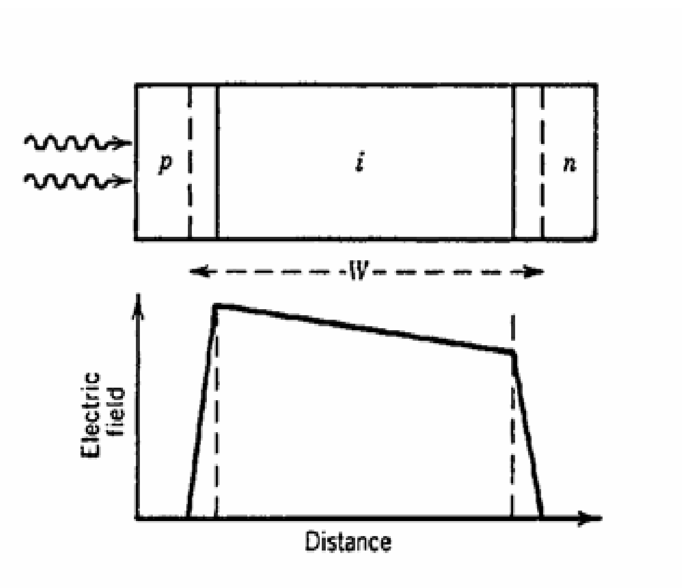


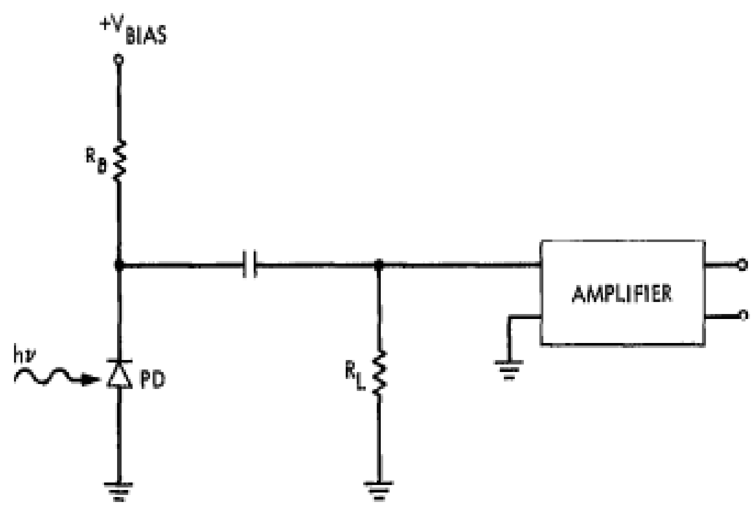
The PIN PD's sensing mechanism is Intrinsic Absorption: An incident photon that has an energy greater than or equal to the band-gap energy of the semiconductor material can excite an electron from the valence band to the conduction band.

Has an extra "I" region in between the "n" and "p" regions. The "I" stands for "intrinsic," because it is either undoped or has very light n-type doping. This area is where most of the photon absorption occurs.

PIN Photo Diode

The PIN Diode is operated in reverse bias. This creates a large electric field in the depletion region. The depletion region grows to encompass the i-layer.



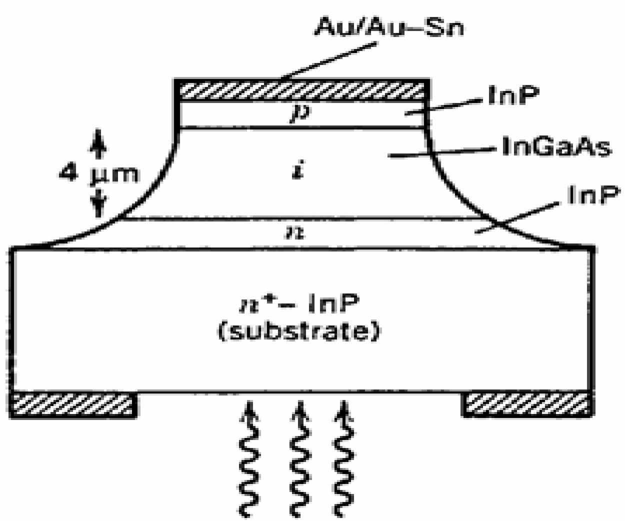


Quantum Efficiency

- $\eta = \dfrac{number\ of\ electron{-}hole\ pairs\ generated}{number\ of\ incident\ photons}$
- $\eta \cong 30 - 90\%$ is possible for photo diodes for 0.4 < λ < 1.1 μm
- η can be increased by widening the i-layer. This will increase the response time, since carriers will have to travel farther.
- Therefore, there is a tradeoff between speed and quantum efficiency

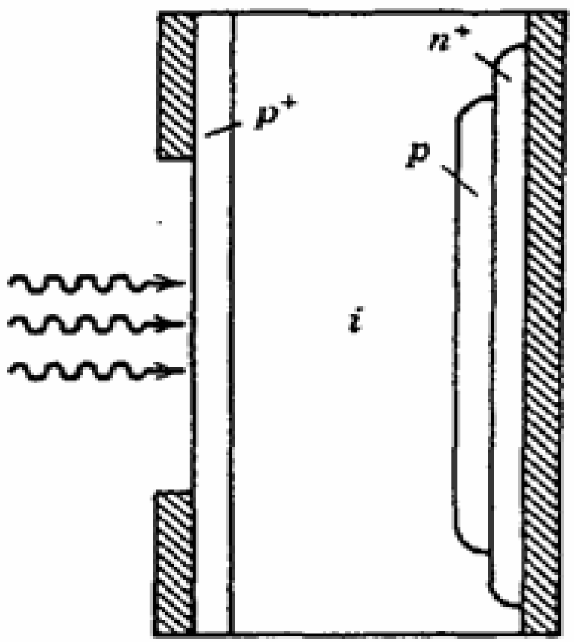
Double-Hetero Structure

- Significantly increase the quantum efficiency
- The band-gap energy of the n and p layer is selected such that only the intrinsic layer absorbs light.



Avalanche Photo Diode

- Similar to the PIN photo diode
- Has an internal gain mechanism called *impact ionization*

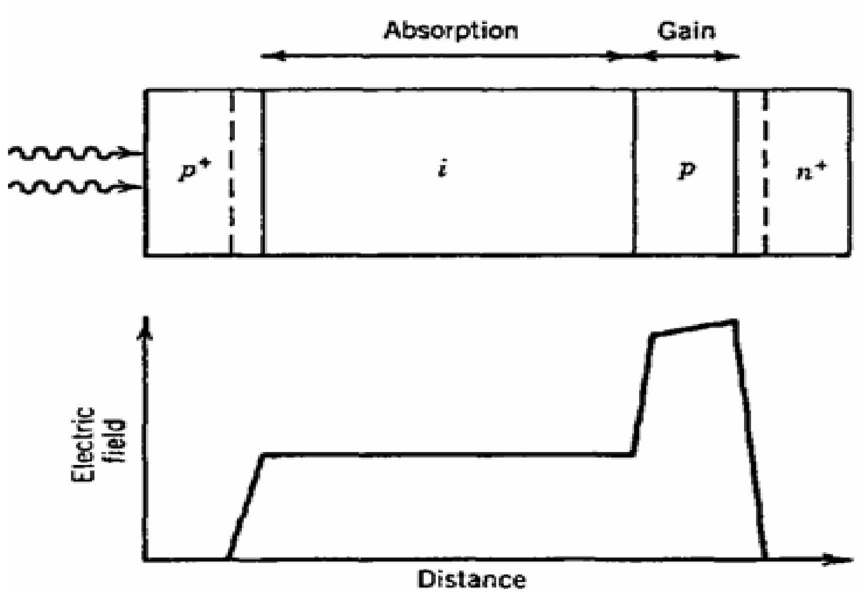


Impact Ionization

- An Avalanche Photo Diode’s internal gain mechanism
- A large electric field is present in the gain area of the PD
- Photo-generated carriers are accelerated by the electric field
- If these carriers gain enough kinetic energy, they can ionize bound electrons in the valence band by colliding with them

Reach-Through APD

- Similar to the PIN PD structure, but includes a high-resistivity P-type layer.
- A large electric field in this area serves as the gain mechanism
- A reverse bias voltage of about 5-10% of what would cause avalanche breakdown is present across the p-n$^+$ junction, creating the electric field.
- Photo-generated electrons multiply by impact ionization in the gain region, amplifying the current.

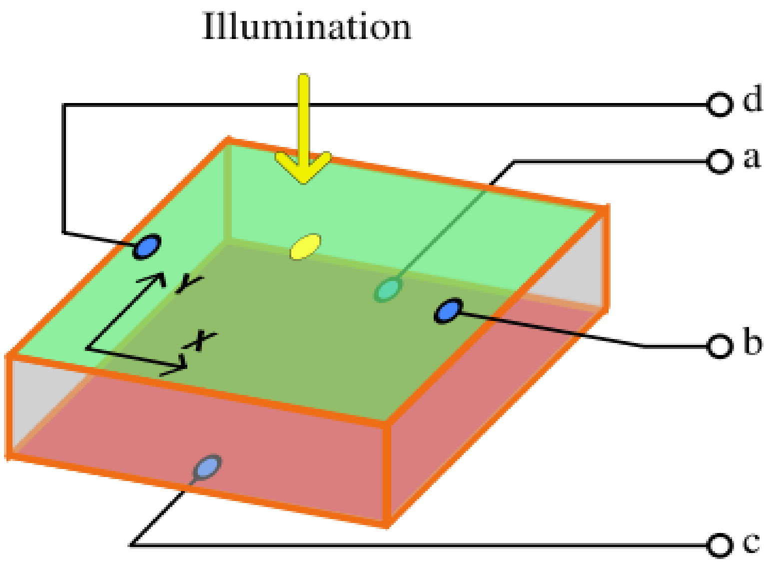


Detector Arrays

- Position Sensors
- Small Arrays (Quadrant Detectors)
- Large Arrays

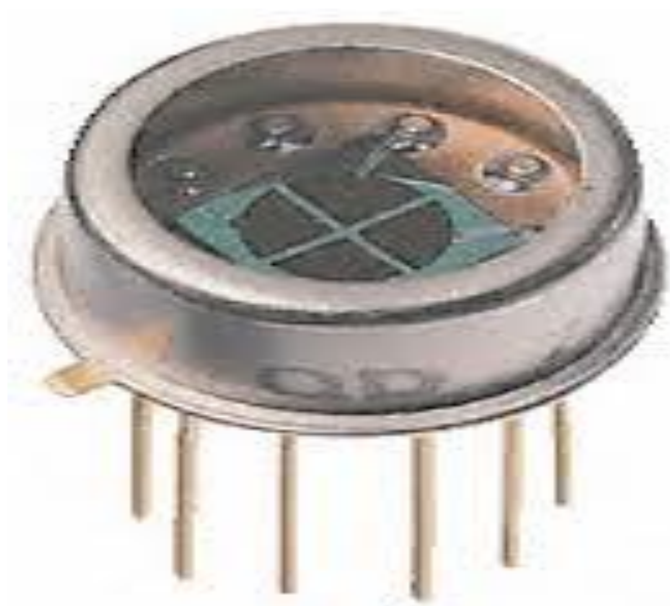
Position Sensors

- PIN PDs with large areas
- Detect the position of a light spot by calculating the relative magnitude of the photo-generated current at four electrodes



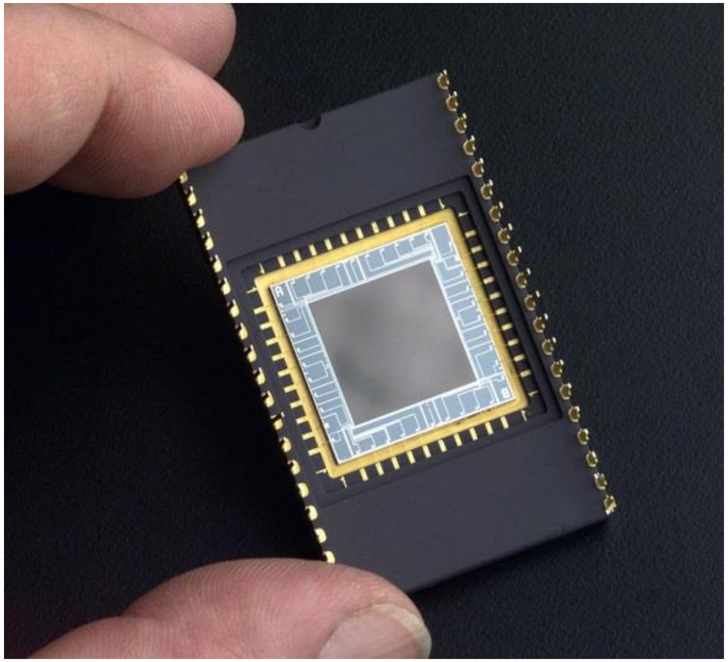
Quadrant Detectors

- Can be made of PDs or APDs
- Four Photodiode surfaces output signals proportional to an incident beam's power distribution



CCD Arrays

- Charge Coupled Devices (CCDs) are composed of arrays of PDs, which contain, on the same chip, a mechanism for charge readout, similar to a serial data connection
- Usually used for imaging
- [Here's a cool visualization]



References

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