UTC-PD
(Unitraveling-carrier photodiode)

Contents (UTC-PD)

1. UTC-PD operation (UTC-PD vs pin-PD)

2. Device characteristics

3. Digital, Analog application

4. Conclusion
UTC–PD operation (UTC–PD vs pin–PD)

- **Pin–PD characteristic**
  - Both electrons and holes contribute to the response
  - Carrier velocity: hole < electron
  - Response: hole transport dominant

< Pin–PD band diagram >

- **UTC–PD characteristic**
  - Use of electrons as the only active carriers
  - Active part: absorption layer (p-type) + carrier collection layer (lightly n-type)
  - Diffusion block layer: unidirectional motion of electrons
  - Band gap grading: reduce electron traveling time

< UTC–PD band diagram >
UTC–PD operation (UTC–PD vs pin–PD)

 UTC–PD advantage 1: high speed
  ➢ Electron diffusion time dominant
  ➢ Large minority mobility of electron in p–InGaAs
  ➢ And design thin absorption layer without sacrificing the RC charging time

Photocurrent ↑
  → Mobile charge density ↑
  → Modulate field profile

(Charge distribution, field, and band bending at high carrier injection levels)
UTC–PD operation (UTC–PD vs pin–PD)

- UTC–PD advantage 2: higher saturation current
  - electron velocity overshoot $\gg$ hole velocity (pin–PD)

Electric field $\downarrow$
- carrier velocity $\downarrow$
- charge storage $\uparrow$
- current saturation

< Pin–PD >

< UTC–PD >
Device characteristics

- Basic photoresponse

  - Slow tail caused by slow hole transport
  - Low saturation output
  - Slow response by space charge effect

- UTC-PD advantage 3: wide linearity
Device characteristics

- **Bandwidth**

  UTC–PD advantage 1: **high speed**
  - Large minority mobility of electron in p-InGaAs
  - And design thin absorption layer without sacrificing the RC charging time

\[ J(x)_\text{hole} + J(x)_\text{electron} = \text{const.}, \quad J(x)_\text{hole} \text{ is hole current density at position } x \]

induced electric field \[ E(x)_\text{ind} \cong J(x)_\text{hole}/\sigma_p, \quad \sigma_p \text{ is conductance} \]
Device characteristics

- Zero-biased operation
  - maintained high electron velocity by the built-in field of the pn junction
  - Simple, small, light and less expensive system

- Zero biased UTC–PD: restricted output
  - Solution: cascaded UTC–PD
  - Twice output voltage

UTC–PD advantage 4: Zero–biased operation
1. Photoreceiver

- For ultra-high bitrate communications system
- Wider bandwidth, simpler system, better sensitivity
2. Ultrafast optical gate
   - Optical driver to overcome the speed limitation of electronic circuits
   - O–E–O type optical gate
   - UTC–PD supply sufficient voltage to drive the EAM
1. High-power millimeter wave generation
   - Key parameters: RC time constant & intrinsic carrier traveling time
   - Solution: matching circuit to overcome the RC time constant

< matching circuit integrated UTC-PD >  < UTC-PD performance >  < UTC-PD vs pin-PD >

Space charge effect
2. Signal source for measurement systems
   - Use high frequency and very short electrical pulse generated by UTC–PD

3. Transmitter for Fiber–radio communications system

4. Nonlinear photonic up–conversion
   - Pin–PD based solution: low conversion efficiency
   - UTC–PD saturation → strong nonlinearity → high power frequency converter
Conclusion

1. UTC–PD operation
2. UTC–PD characteristic
   - High speed, High output saturation current,
   - Linearity, Zero bias operation
3. Digital/Analog application
   - Digital
     ① Photoreceiver
     ② Ultrafast optical gate
   - Analog
     ① High-power millimeter generation
     ② Signal source for measurement systems
     ③ Transmitter for Fiber–radio communications system
     ④ Nonlinear photonic up–conversion
Thank you for listening

Q&A