UTC-PD
(Unitraveling-carrier photodiode)

Contents (UTC-PD)

1. UTC-PD operation (UTC-PD vs pin-PD)
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3. Digital, Analog application
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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

- **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 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 \uparrow
  \rightarrow Mobile charge density \uparrow
  \rightarrow Modulate field profile

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

1. UTC–PD advantage 1: lower saturation current
2. UTC–PD advantage 2: higher saturation current
   - electron velocity overshoot >> hole velocity (pin–PD)

Electric field ↓
→ carrier velocity ↓
→ charge storage ↑
→ current saturation

UTC–PD operation
Device characteristics

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

- Pulse photoresponse of Pin–PD

- Pulse photoresponse of UTC–PD
  - High speed (advantage 1)
  - Wide linearity

- 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

 UTC–PD frequency response

- Effect of self–induced field
  
  \[ J(x)_{\text{hole}} + J(x)_{\text{electron}} = \text{const.}, \quad J(x)_{\text{hole}} \text{ is hole current density at position } x \]

  induced electric field \( E(x)_{\text{ind}} \cong \frac{J(x)_{\text{hole}}}{\sigma_p}, \quad \sigma_p \text{ is conductance} \)
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

(a) optical amplifier
    (b) pin-PD

Digital application
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

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**Diagram:**
- MSL: microstrip line
- TW–EAM: electroabsorption modulator having a traveling wave electrode
Analog application

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