Laterally Transported Quantum Structure Infrared Photodetector

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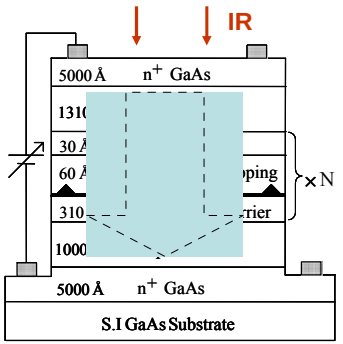


Figure of merit (FOM) of QSIP

- Reponsivity (R)

$$R = \eta \frac{e}{h\nu} g \ (A/W)$$

- Detectivity (D*)

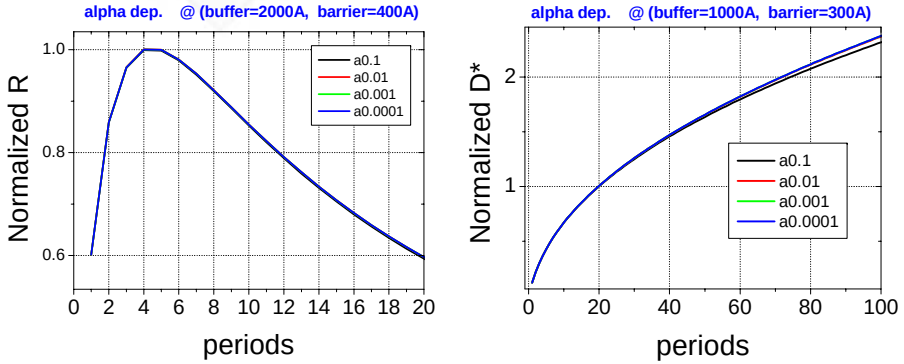
$$D^* = \frac{(A_d \Delta f)^{1/2}}{I_n} R \ (cm\sqrt{Hz}/W)$$

$$g = \frac{\tau_{life}}{\tau_{transit}} \qquad \eta \propto (1 - \exp(-\alpha L'))$$

L': absorption layer thickness

N↑ → η↑ → increase total device length → τ_{life}↑ → g↓

Periods of QD layer vs. FOM



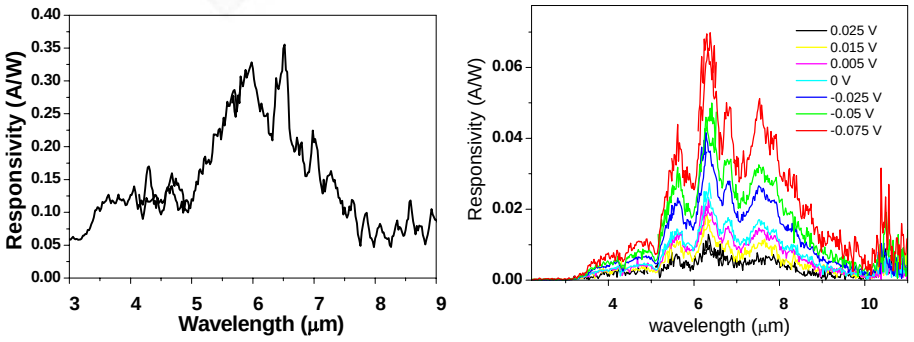
We can't increase responsivity and detectivity at the same time by increasing periods of QD layer

U.H. Lee, S. Hong, Journal of the Korean Physical Society Vol. 45, No. 2 pp.529

Example of VQDIP

5 periods, 18 K

15 periods, 18 K



Responsivities of VQDIP (VQWIP) are under 1 A/W

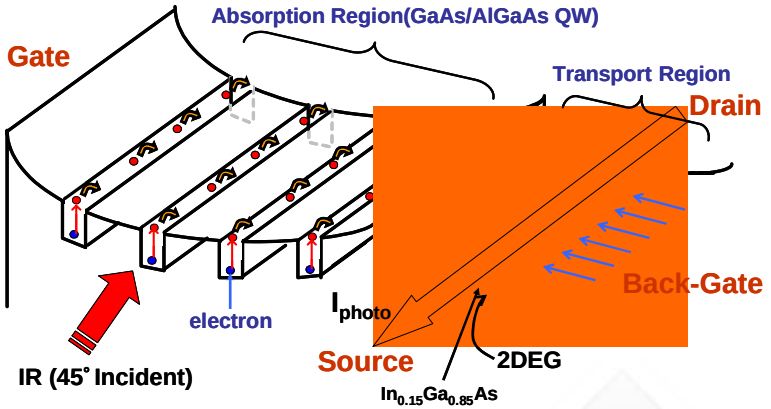
How can we increase responsivity of QWIP or QDIP?

→Use transistor type QDIP! Laterally transpored QWIP or QDIP

Laterally transported QWIP (LQWIP)

Laterally transported QWIP

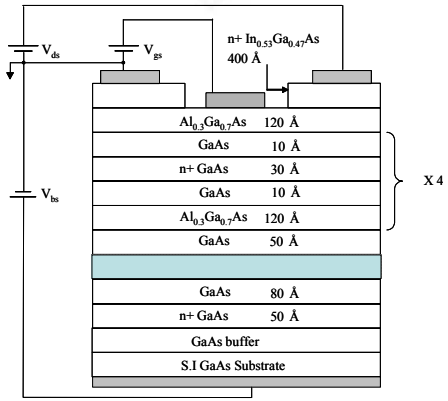
L-QWIP Structure



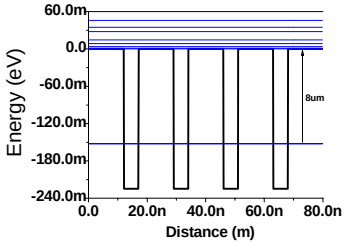
Laterally transported QWIP

Wave Embedded Integrated Systems

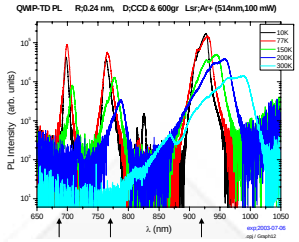
Epitaxial structure of LQWIP



Energy levels in QW layer



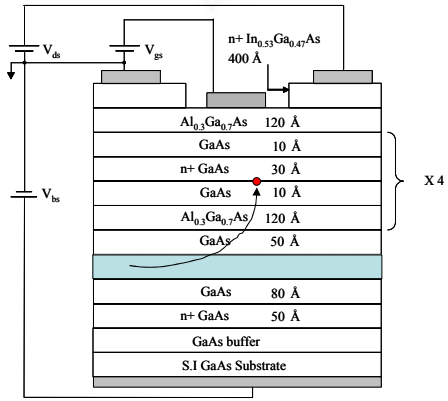
Photoluminescence (PL) of LQWIP



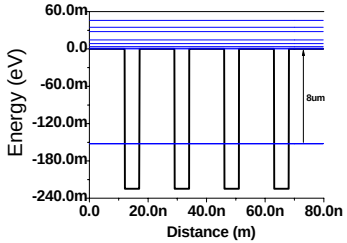
Laterally transported QWIP

Wave Embedded Integrated Systems

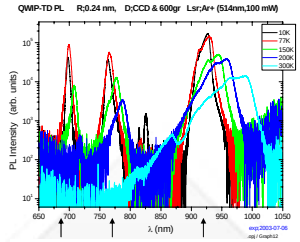
Epitaxial structure of LQWIP



Energy levels in QW layer

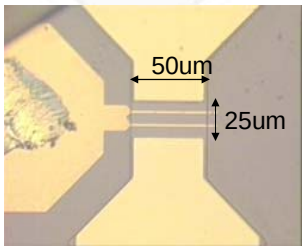


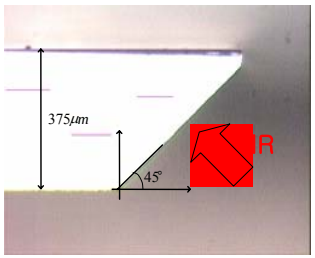
Photoluminescence (PL) of LQWIP



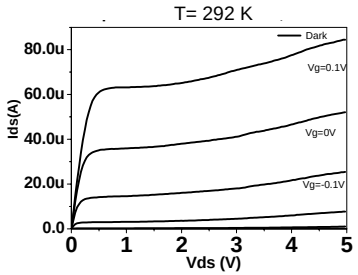
Laterally transported QWIP

Wave Embedded Integrated Systems

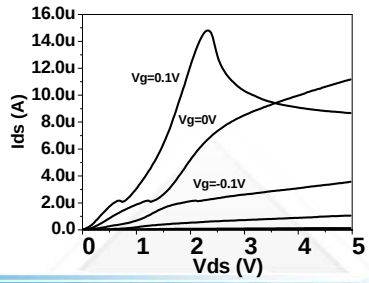




T= 292 K



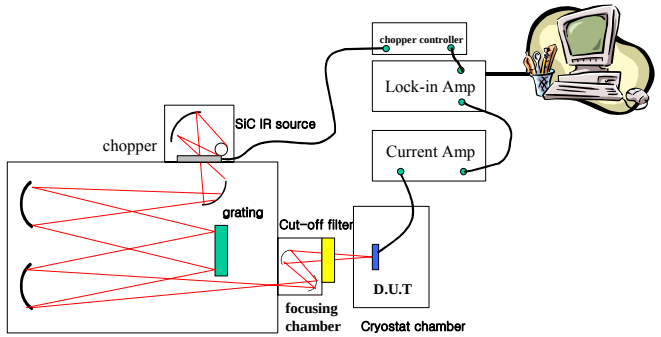
T= 45 K



Responsivity Spectrum Measurement

Wave Embedded Integrated Systems

Responsivity Spectrum Measurement

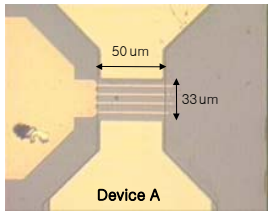


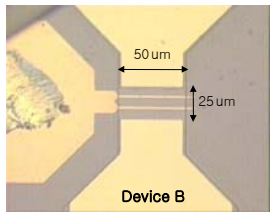
Standard MCT detector is used to calibrate responsivity spectrum

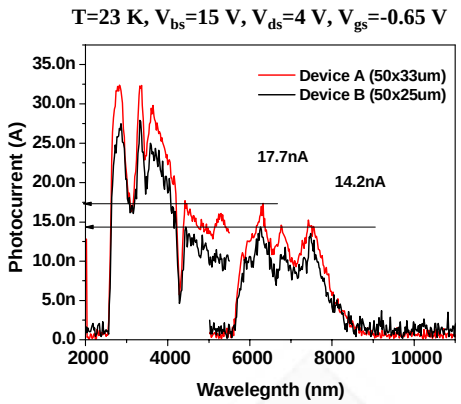
Three optical long-wavelength pass filter(2.5㎛, 4㎛, 5.5㎛) is used

Laterally transported QWIP

Photocurrent Spectra (raw data) with different window area

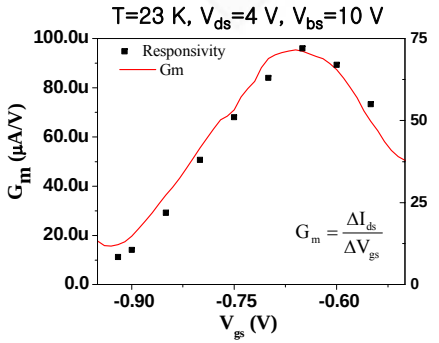


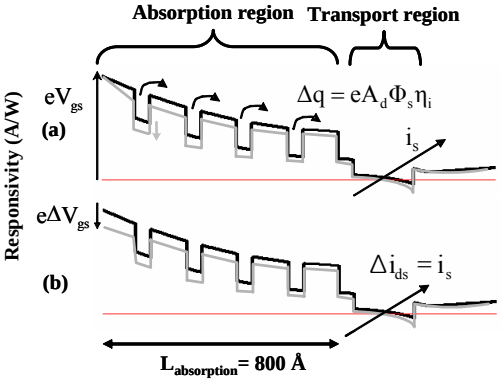




Laterally transported QWIP

Wave Embedded Integrated Systems





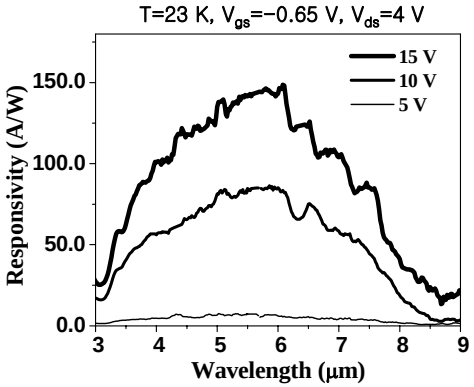
$$i_s = G_m \Delta V_{gs} \approx G_m \left(\frac{eA_d\Phi_s}{2\varepsilon_s}\sum_i \eta_i\right) L_{absorption} = \frac{eA_d\Phi_s L_{absorption}}{2\varepsilon_s} G_m \eta$$

$$R = \frac{i_s}{A_d\Phi_s h\nu} = \eta \frac{e}{h\nu}\frac{G_m L_{absorption}}{2\varepsilon_s} = \eta \frac{e}{h\nu} g_{LQWIP} \quad \Rightarrow \eta = 2.85\ \%,\ g_{LQWIP} = 474$$

Laterally transported QWIP

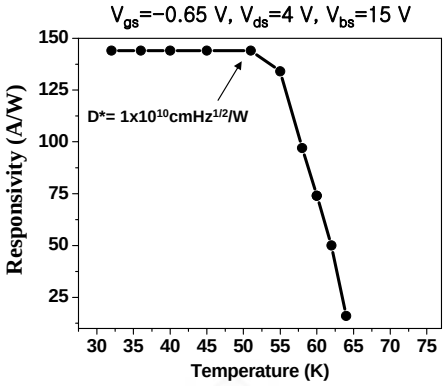
Wave Embedded Integrated Systems

Responsivity spectra with different V_{bs}



λp= 6 ㎛, λc= 7.5 ㎛

Peak responsivity at λ= 6 ㎛



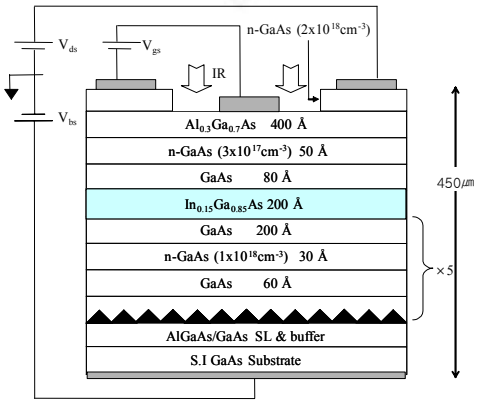
T_{max} : 65 K

Maximum Responsivity of LQWIP ~ 140 A/W !!

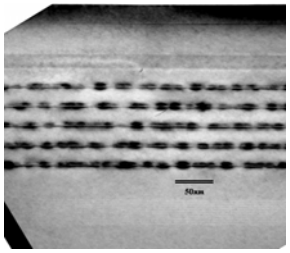
Laterally transported QDIP (LQDIP)

Laterally transported QDIP

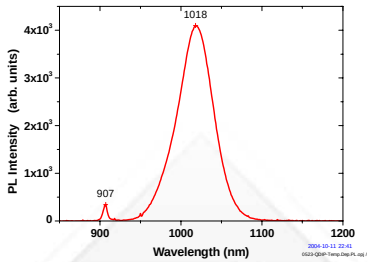
Structure of LQDIP



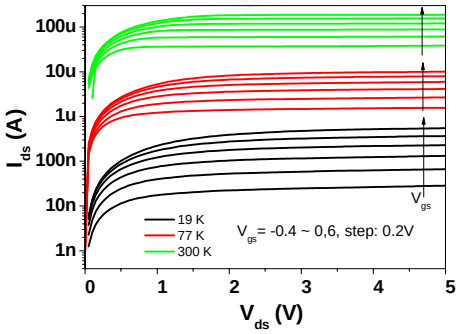
TEM image

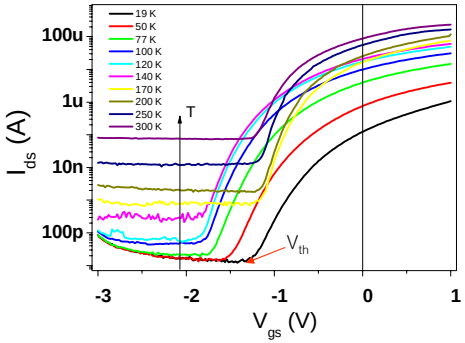


PL at T=10 K



Laterally transported QDIP

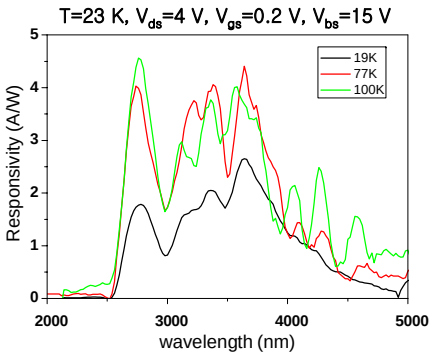


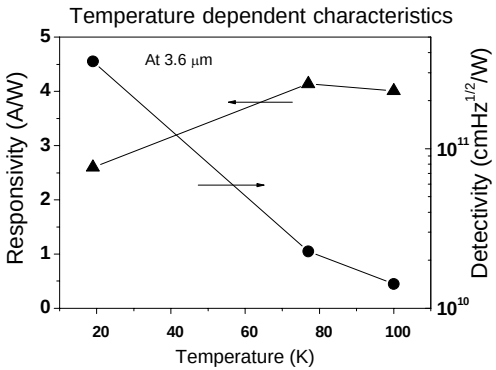


Threshold voltage (V_{th}) is changing as a function of temperature!

Laterally transported QDIP

Spectral response

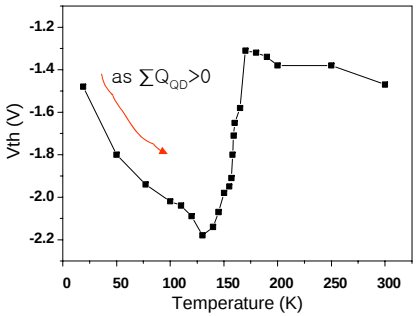


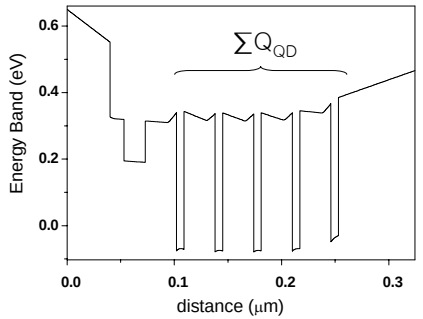


T=19 K, λp = 3.6 ㎛, λc = 4 ㎛, R=2.5 A/W, D*= $3x10^{11}$cmHz$^{1/2}$/W

T=100 K, λp = 3.6 ㎛, λc = 4 ㎛, R=4 A/W, D*= $1.4x10^{10}$cmHz$^{1/2}$/W

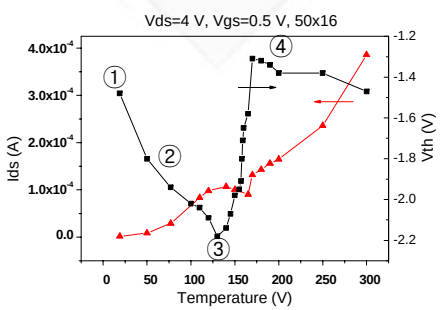
Laterally transported QDIP

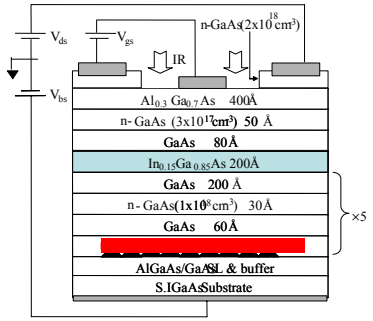


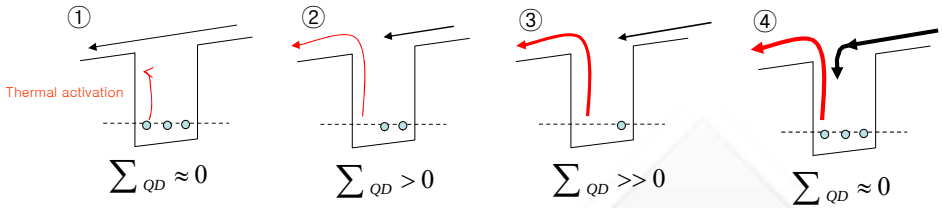


V_{th} decreases if $\sum Q_{QD}$ becomes positive

Laterally transported QDIP



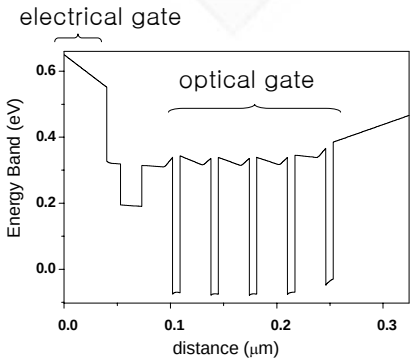


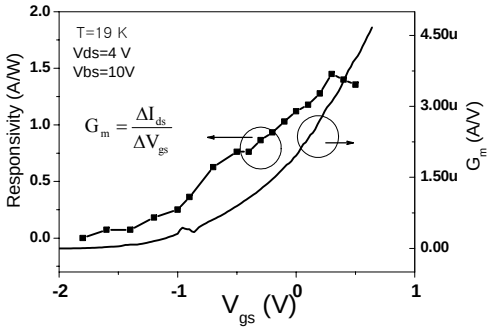


Conclusion

- Absorption layers (QD or QW) act as a optical gate in proposed LQSIP
- Responsivities of LQSIP are proportional to trans-conductance (G_m)
- Photocurrent of LQSIP can be switched by its gate voltage
- Maximum operation temperature (T_{max}) can be predicted from temperature dependent I_{ds}–V_{gs} measurement

Laterally transported QDIP





When the light is incident, net charge of QD layers becomes positive by $eA_d\Phi_s\eta_i$

→ QD layers act as a optical gate