Quantum-Dot/Quantum-Well Mixed-Mode Infrared Photodetectors

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Outline

- **Introductions**
  - Quantum-Dot Infrared Photodetectors (QDIPs) vs. Quantum-Well Infrared Photodetectors (QWIPs)

- **The Disadvantages of QDIPs**
  - Why Quantum-Dot/Quantum-Well Mixed-Mode Infrared Photodetectors (MMIPs)

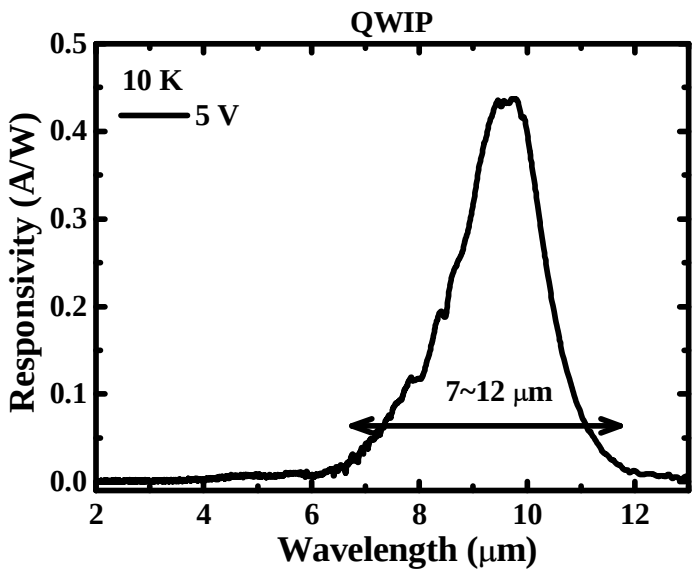
- **The Device Performances of the QD/QW MMIPs**
  - Spectral Responses of the QD/QW MMIPs
  - Transition Mechanisms of the QD/QW MMIPs

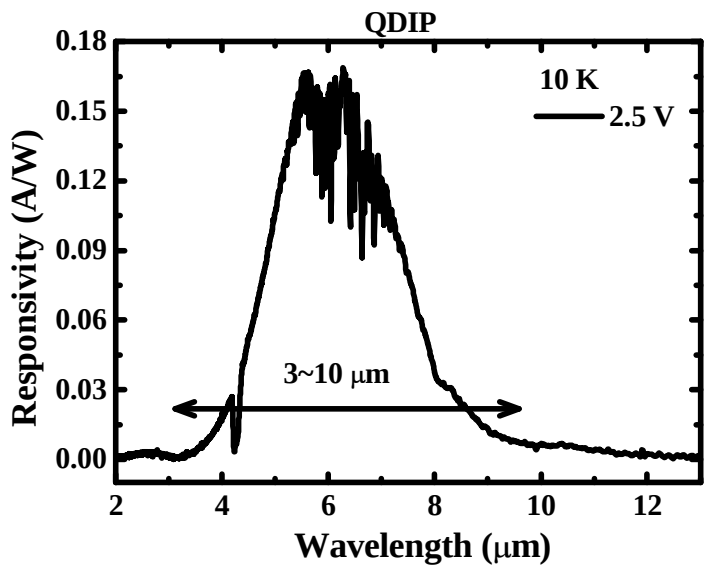
- **Conclusions**

- **Future Work**

QDIPs vs. QWIPs

	QWIP	QDIP
	1 μm GaAs n = 2 x 10^{18} cm^{-3}	0.5 μm GaAs n = 1 x 10^{18} cm^{-3}
	30 nm $Al_{0.23}Ga_{0.77}As$ undoped	30 nm GaAs undoped
30 periods	6.6 nm GaAs n = 5 x 10^{17} cm^{-3}	2.4 ML InAs QD n = 2 x 10^{18} cm^{-3}
	30 nm $Al_{0.23}Ga_{0.77}As$ undoped	30 nm GaAs undoped
	1 μm GaAs n = 2 x 10^{18} cm^{-3}	1 μm GaAs n = 1 x 10^{18} cm^{-3}
	350μm S-I GaAs Substrate	





Normal Incident Absorption

	QWIP	QDIP
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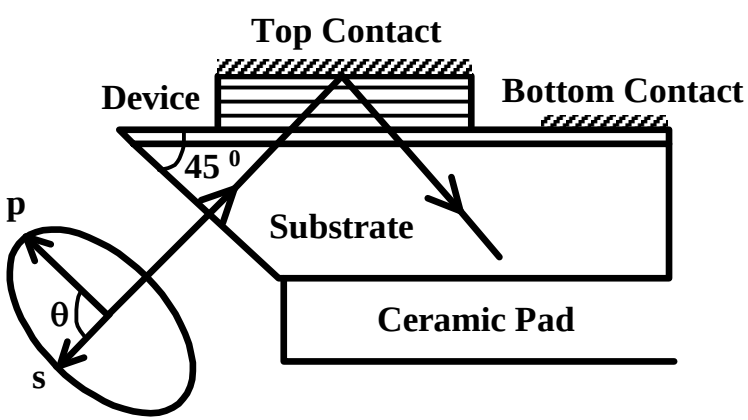
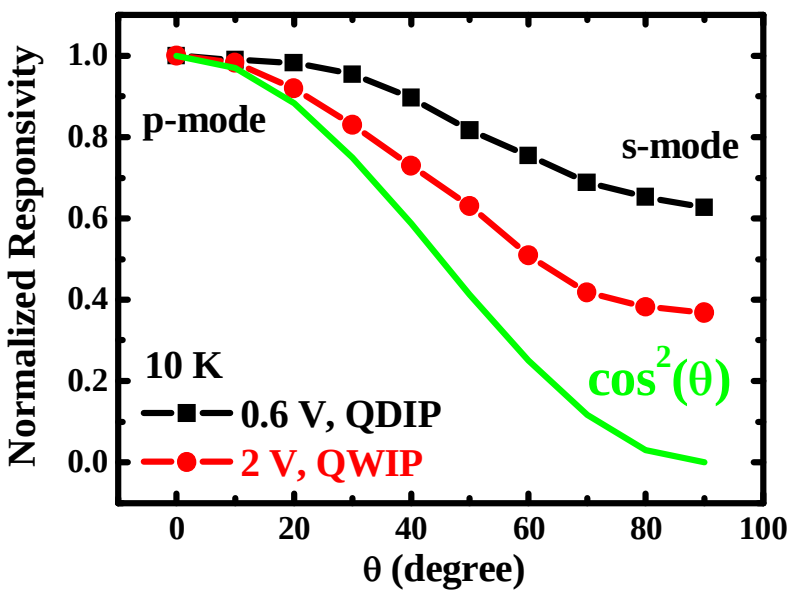
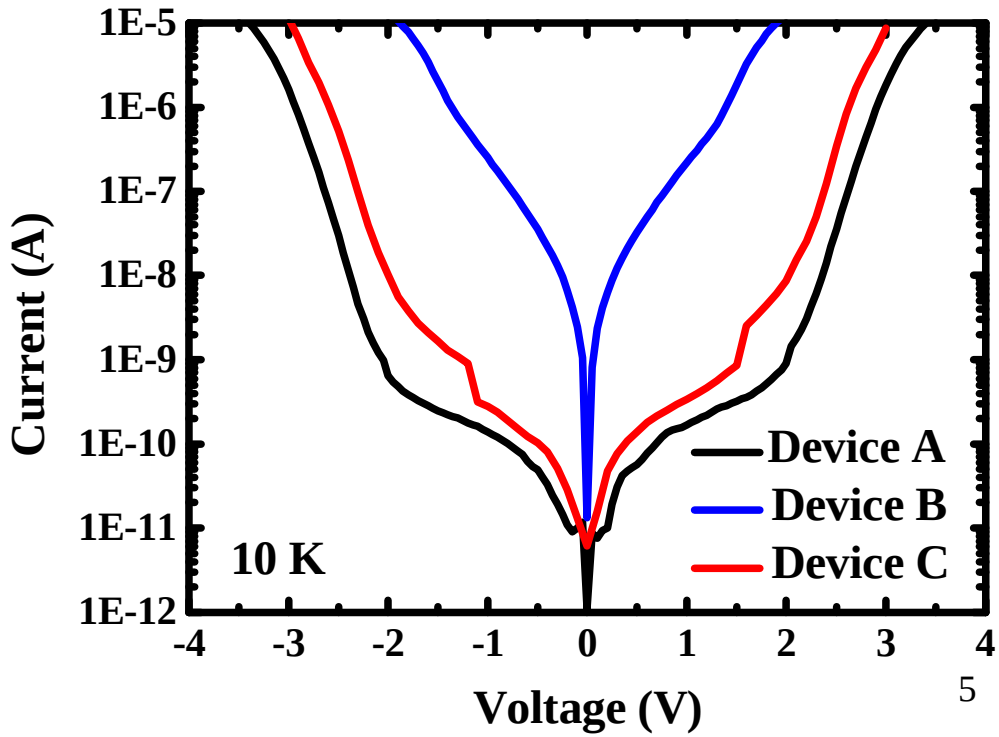




High-Temperature Operation

QDIP Samples	A	B	C
Top Contact	500 nm GaAs n=$2x10^{18}cm^{-3}$		
30 x Barrier Layer	30 nm undoped GaAs		
30 x 2.4 ML InAs QDs (cm^{-3})	$5x10^{17}$	$1x10^{18}$	$2x10^{18}$
Bottom Contact	1000 nm GaAs n=$2x10^{18}cm^{-3}$		
Substrate	350 mm (100) Semi-Insulating GaAs		

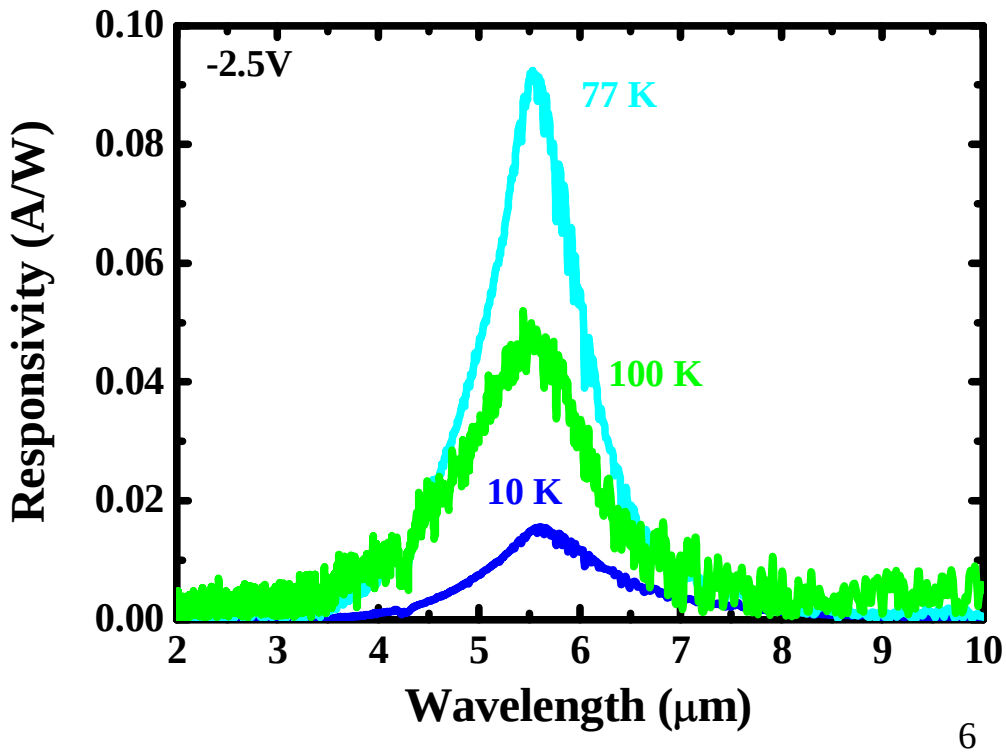
➢**The dark currents of QDIPs would change significantly with the doping densities.**



High-Temperature Operation

	Top Contact	1000 nm GaAs n=2x10^{18}cm^{-3}
15x	Barrier Layer	30 nm undoped GaAs
	2.4 ML InAs QDs	undoped
	Bottom Contact	1000 nm GaAs n=2x10^{18}cm^{-3}
	Substrate	350 mm (100) Semi-Insulating GaAs

- **Decreasing electron capture probability is responsible for the increasing photocurrent with increasing tempera-tures.**



Why QD/QW MMIPs?

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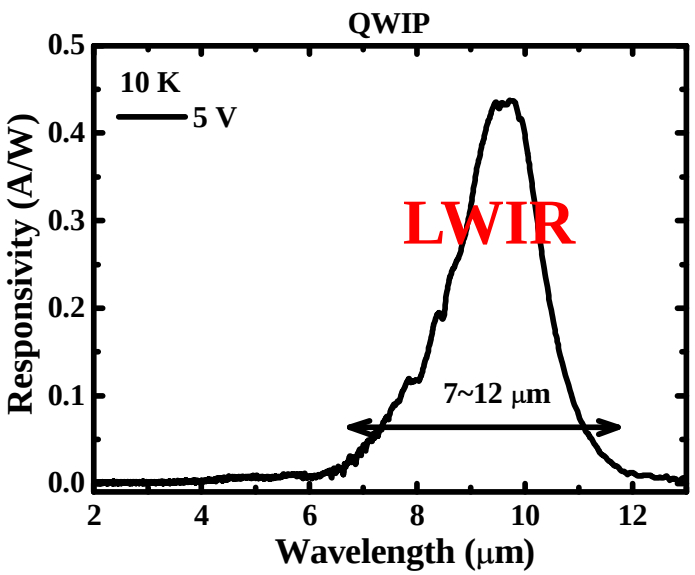
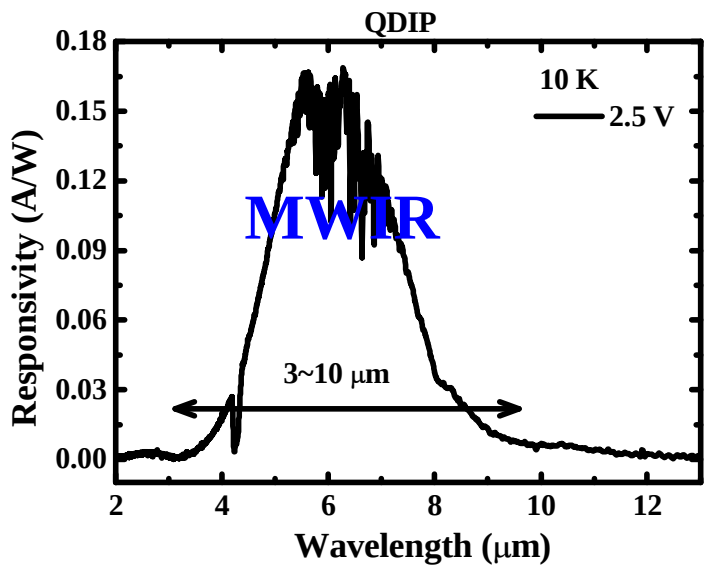




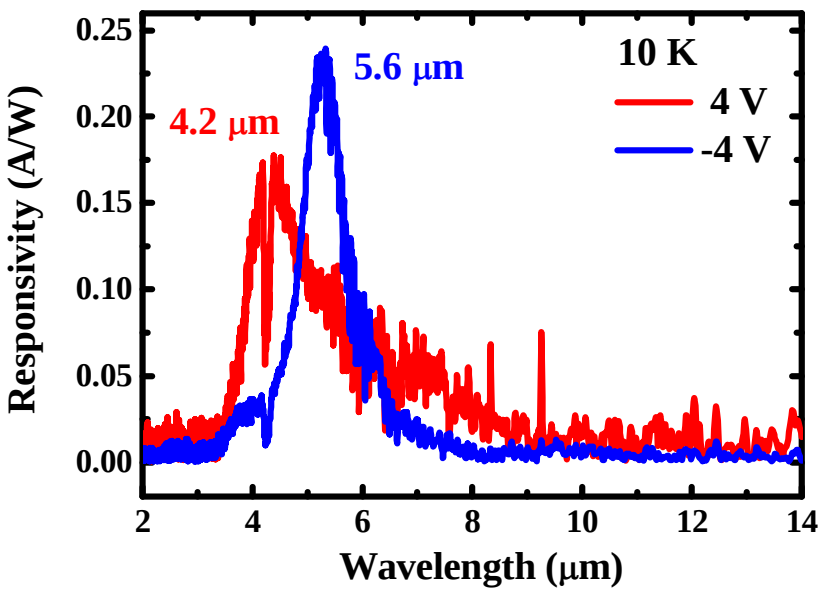
Why QD/QW MMIPs?

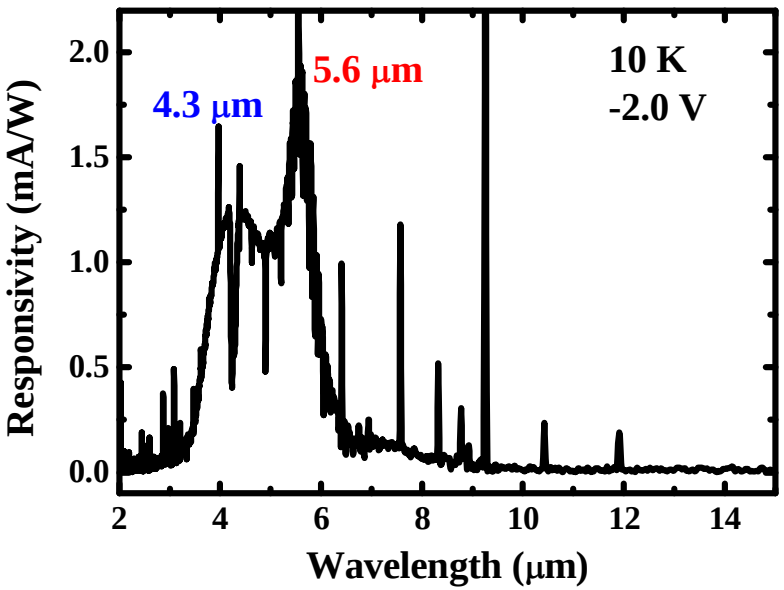
- **Achieve MWIR and LWIR Detections within A Single Structure**
- **Maintain the High-Temperature Property of QDIPs**
- **Enhance Normal Incident Absorption for Both MWIR and LWIR Absorptions**

The QD/QW MMIP Device Structure

	Top Contact	300 nm GaAs $n=2x10^{18}cm^{-3}$
	25 nm $Al_{0.2}Ga_{0.8}As$	undoped
10x	8 nm GaAs (Doping=)	$n=5x10^{17}$ cm^{-3}
10x	2.4 ML InAs QDs	undoped
10x	1 nm GaAs	undoped
10x	25 nm $Al_{0.2}Ga_{0.8}As$	undoped
	Bottom Contact	600 nm GaAs $n=2x10^{18}cm^{-3}$
	Substrate	350 mm (100) Semi-Insulating GaAs

Spectral Responses of the MMIP





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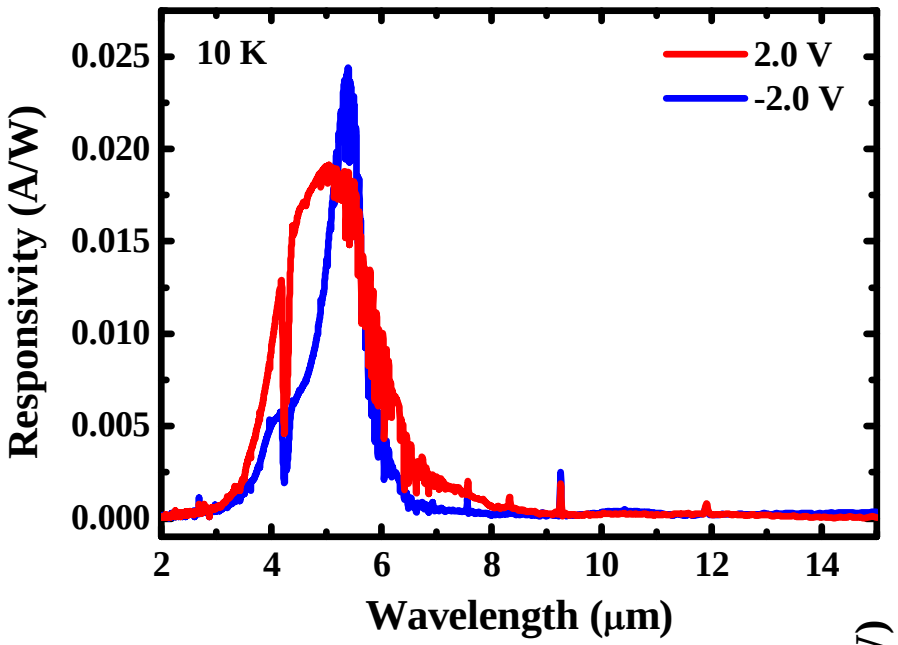
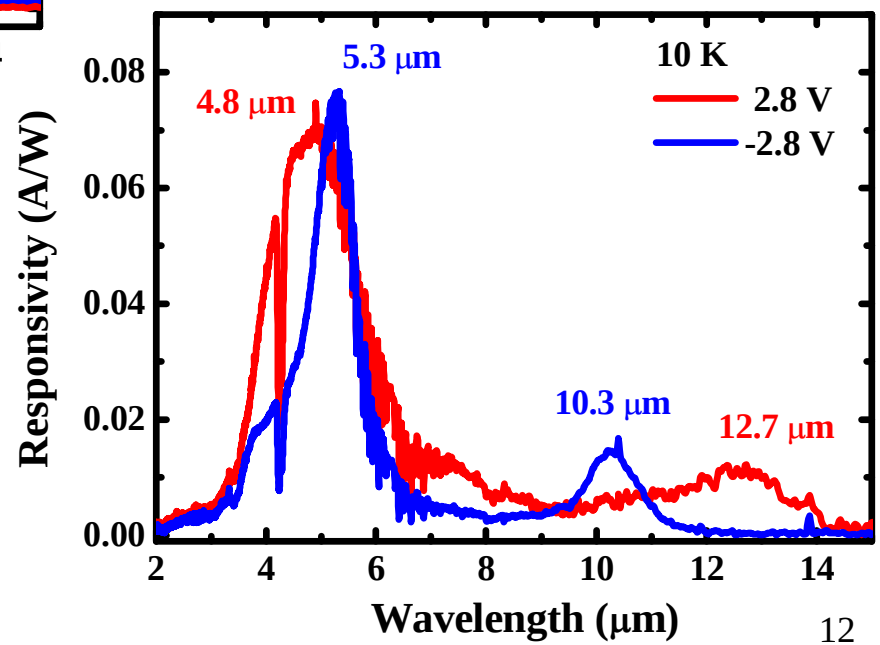
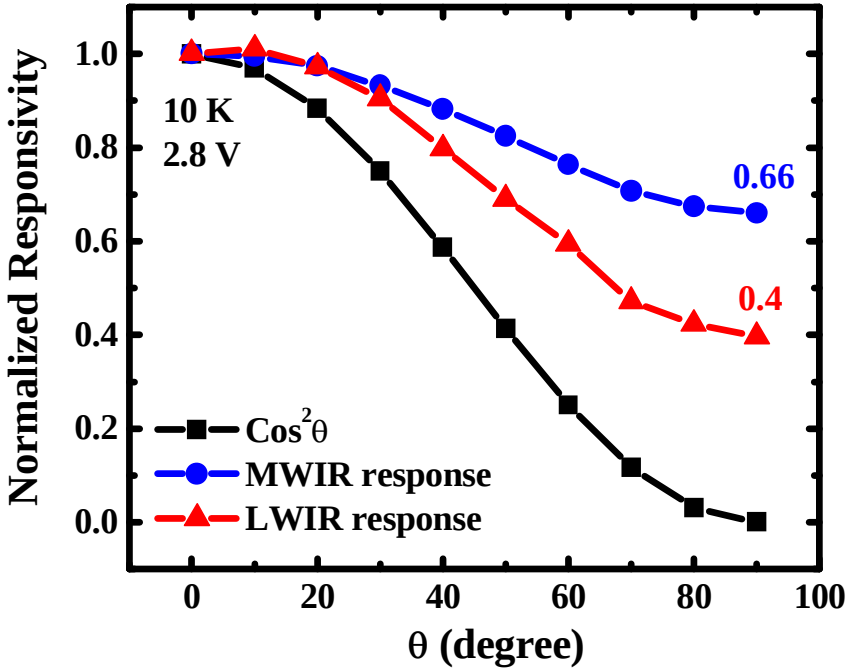
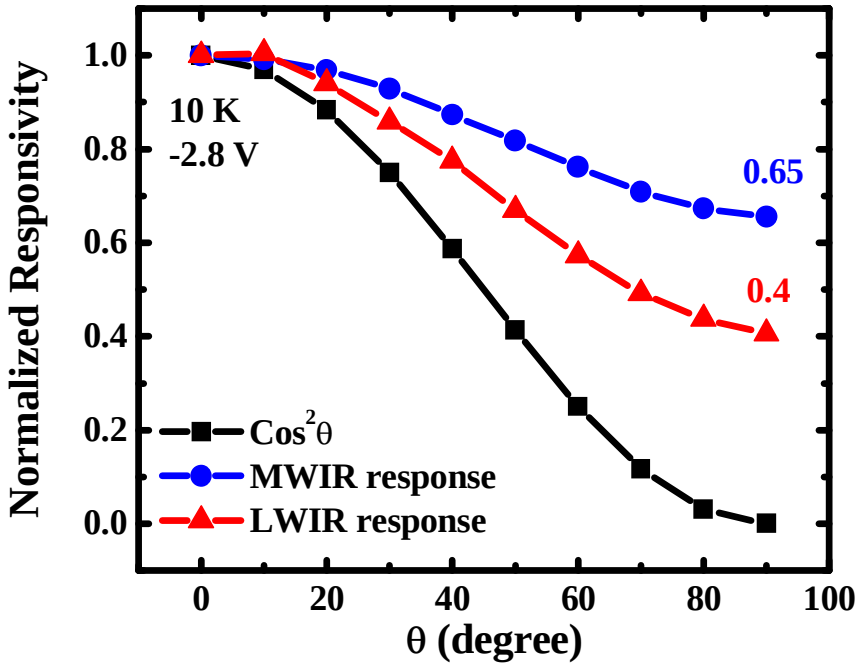
The Spectral Responses of The MMIP



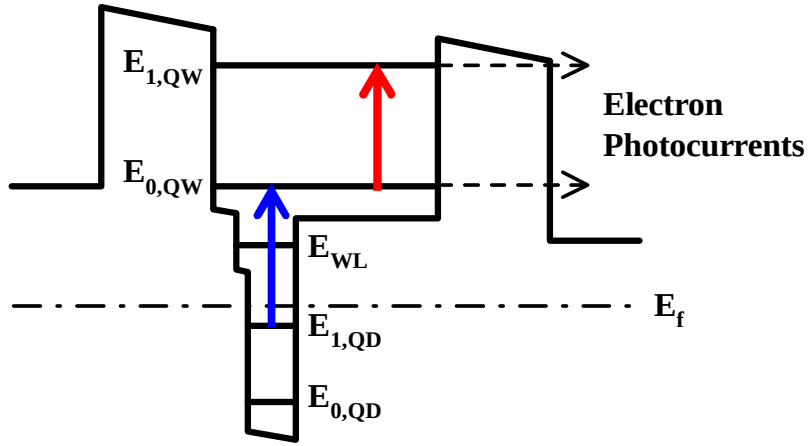


Normalized Responsivities over Different Polarized Lights

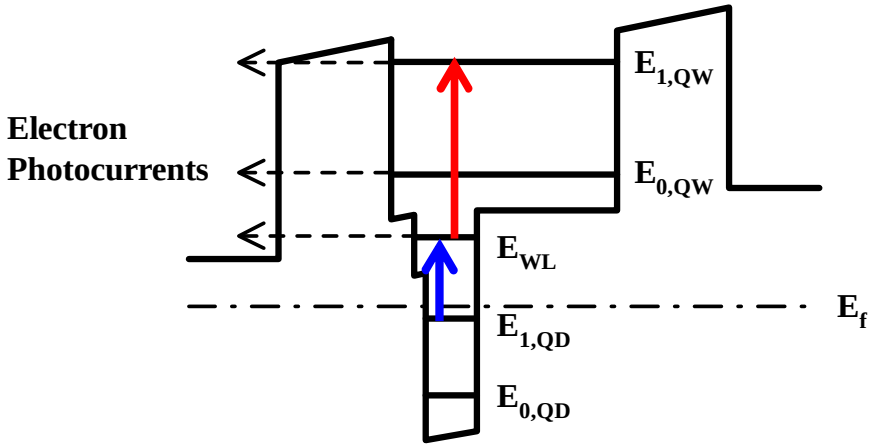




The Device Model of The MMIP

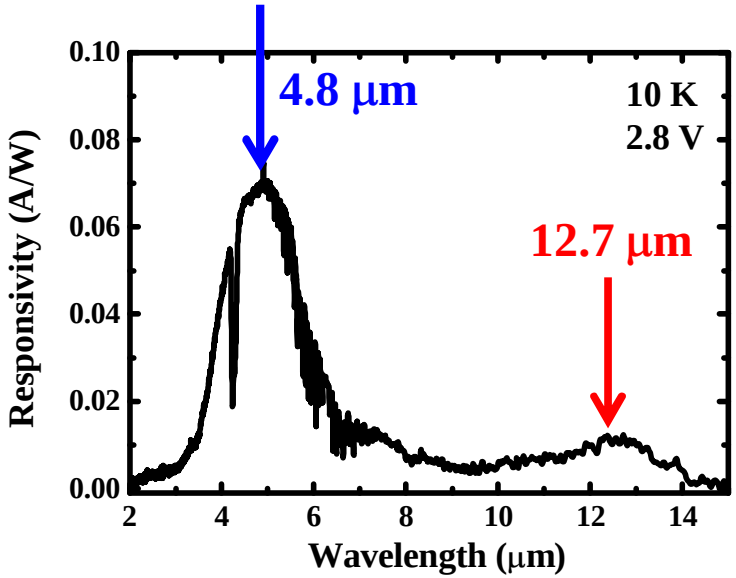


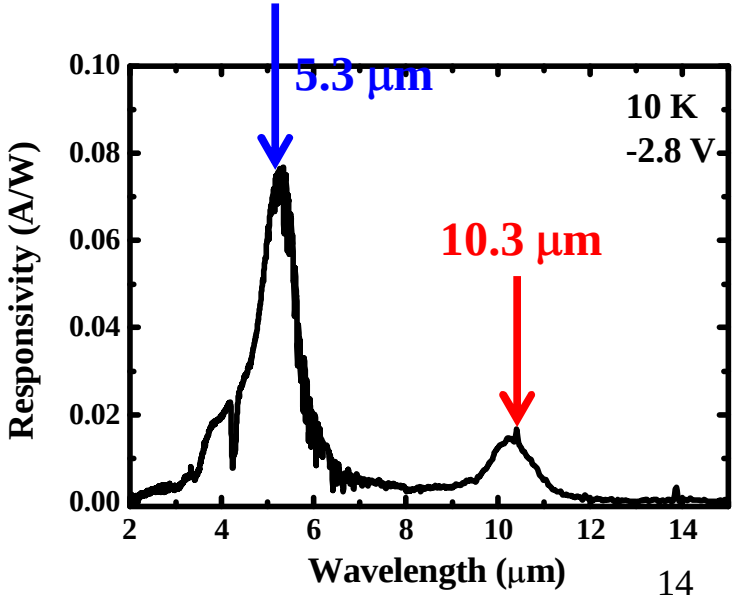
Positive Bias



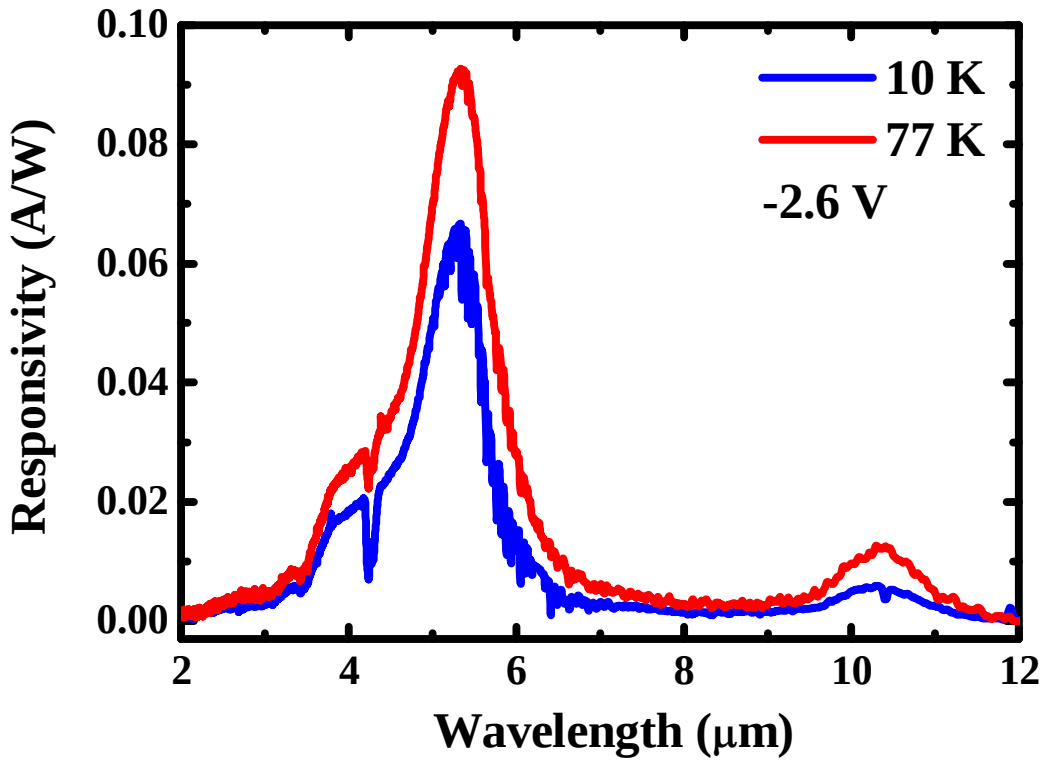
Negative Bias

Growth Direction





High-Temperature Operation of the MMIP



Conclusions

- **MWIR and LWIR Detections Are Observed within A Single Structure**
  - Multi-color detections at both MWIR and LWIR regions within a single device structure at the same applied voltage

- **The Increase of Photo-responses at LWIR with Increasing Temperatures**
  - High-temperature operation at both MWIR and LWIR regions

- **No Significant Normal Incident Absorption Observed at LWIR Region**
  - The responses at QD and QW regions are seperate

Future Work

- **Wavelength Tunning at The LWIR Range**
  - The influence of barrier height on the detection wavelengths

- **The Effect of The (AlGa)As Barrier Width on The Device Performances**
  - The enhancement of LWIR responses for high-temperature operation