Control and measurement of carrier dynamics in InSb QWs

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I. Introduction

Narrow Gap Semiconductors (NGSs) such as InSb have

Strong spin-orbit coupling, large Rashba effect,

and high carrier mobilities.

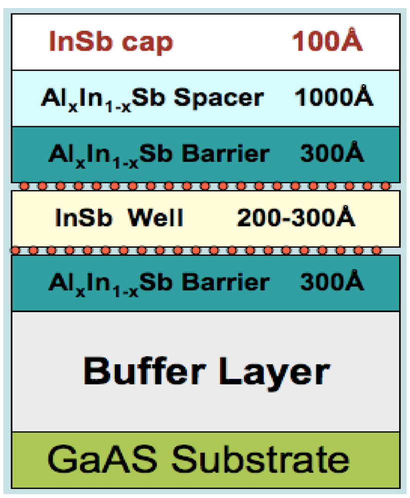
- One of the prime candidate for fast switching and carrier transport application
- Exploring carrier dynamics provides a better understanding of many phenomena such as scattering, quasi-equilibrium carrier distribution, and carrier cooling.

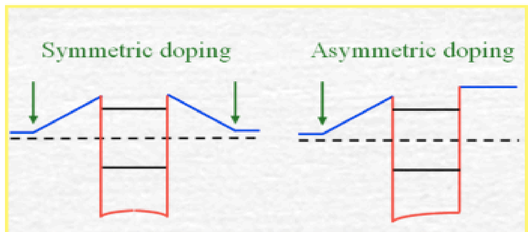
Why InSb?

bulk III-V	m^*/m_0	g-factor	E(k)	Band Gap (eV)
GaAs	0.067	-0.5	Least non-parabolic	1.4
InAs	0.023	-15	More non-parabolic	0.42
InSb	0.014	-51	Most non-parabolic	0.24

InSb has the smallest effective mass, largest g-factor, smallest energy gap,and strongest spin-orbit interaction.

InSb QWs Strucures



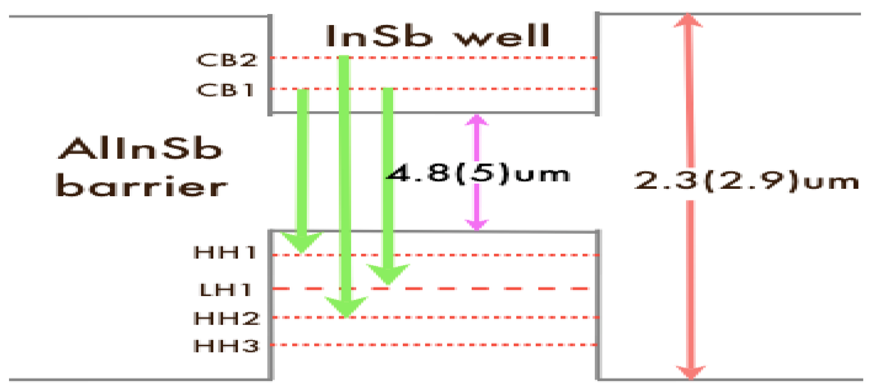


Density: 1-4x10[11] cm[-2]
Mobility: 100,000-200,000 cm²/Vs
Alloy concentration: 9%-15%

Sample	Density (cm^-2)	Mobility (cm^2/Vs)	QW width (nm)	Al concentration
S360 "A"	2.2x10^11	73,000	30	9%
S499 "S"	1.8x10^11	135,000	30	9%
S769 "S"	2 x10^11	97,000	30	9%
S939 "S"	4.4x10^11	96,000	11.5	15%
S591(24QWs)	undoped	N/A	30	9%

"A"=Asymetric QW, "S"=Symmetric QW

Energy levels and possible transitions for 15(9)% Al samples

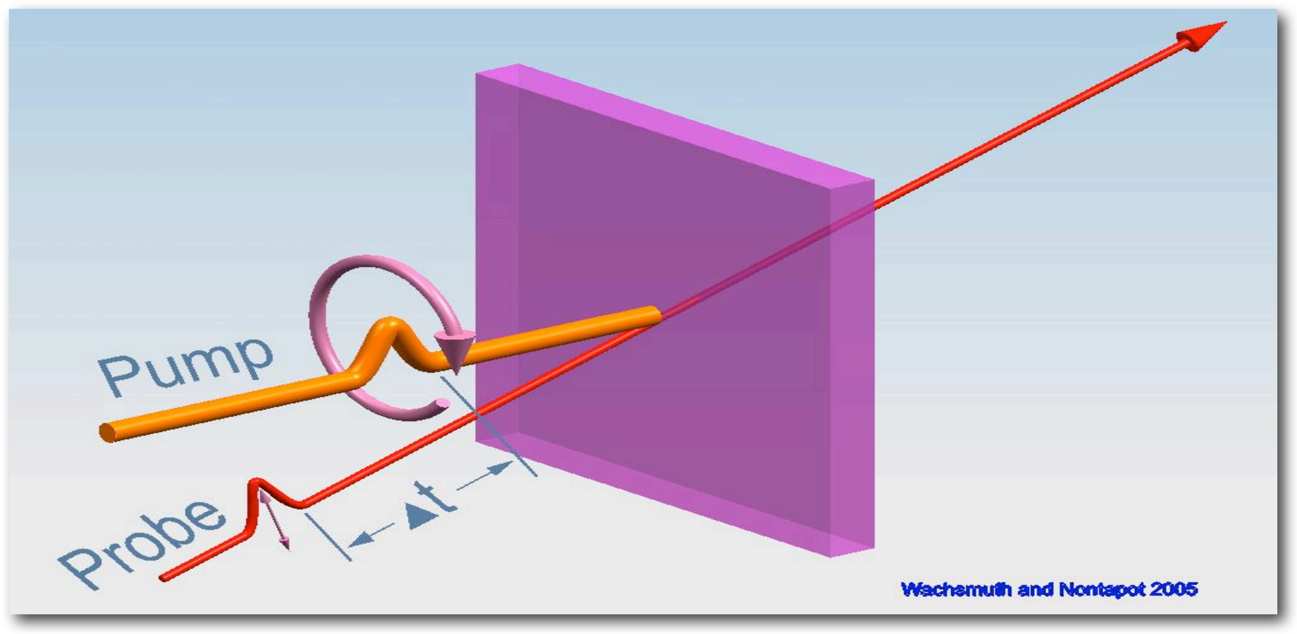


Energy separation at different levels and their corresponding wavelengths

	CB1-HH1	CB2-HH1	CB1-HH2	CB2-HH2	CB1-HH3	CB2-HH3	CB1-LH1	CB2-LH1
15%	318mev 3.9um	425mev 2.9 um	342 mev 3.6 um	449mev 2.7 um	386mev 3.2 um	493mev 2.5 um	386mev 3.2 um	493 mev 2.5 um
9%	264mev 4.7um	302mev 4.1um	266mev 4.66um	304mev 4.07um	N/A	N/A	320mev 3.87um	N/A

* possible transitions are shown in red

II. Experimental Technique



Time-resolved measurement

Degenerate pump-probe spectroscopy(One-color)

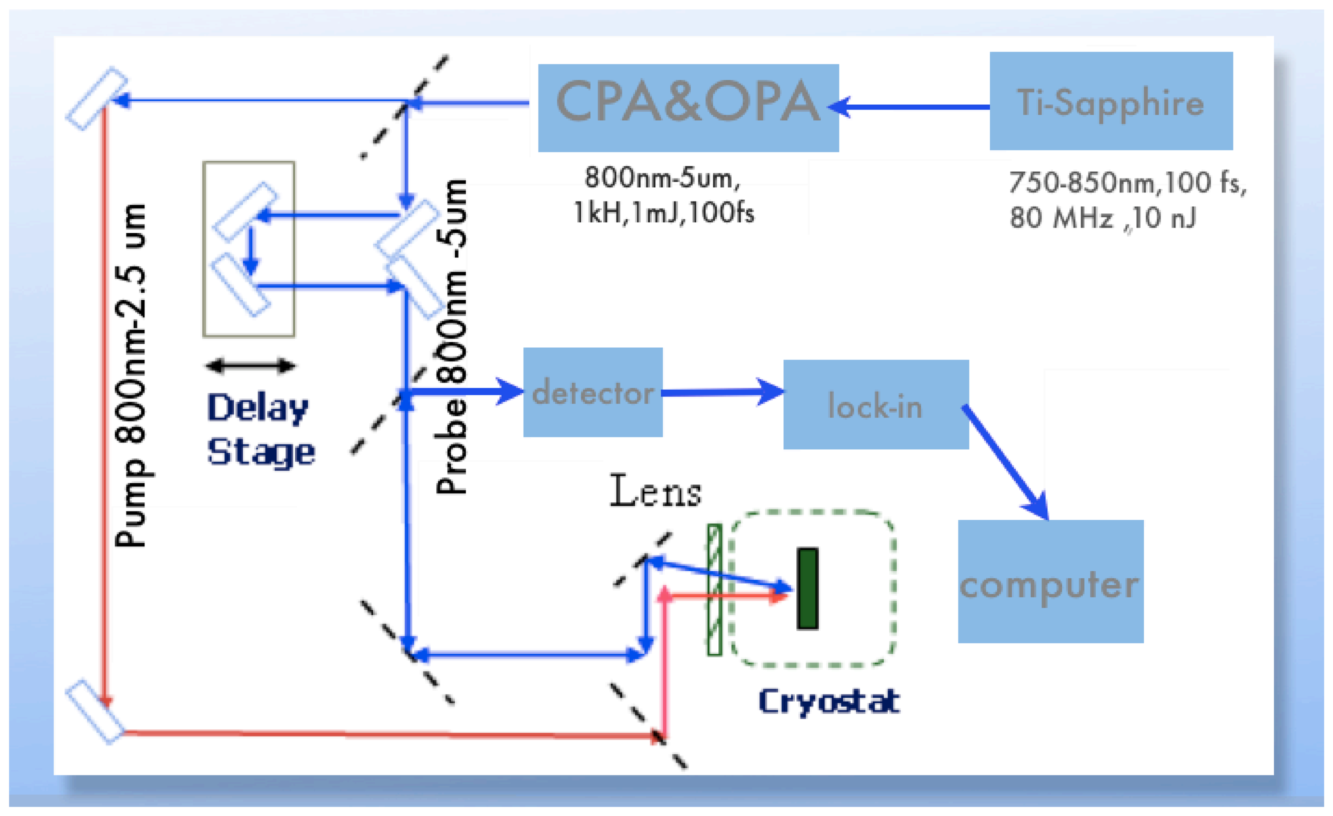
Non-degenerate pump-probe spectroscopy (Two-color)

Interband absorption of polarized light

Non-equilibrium carrier density

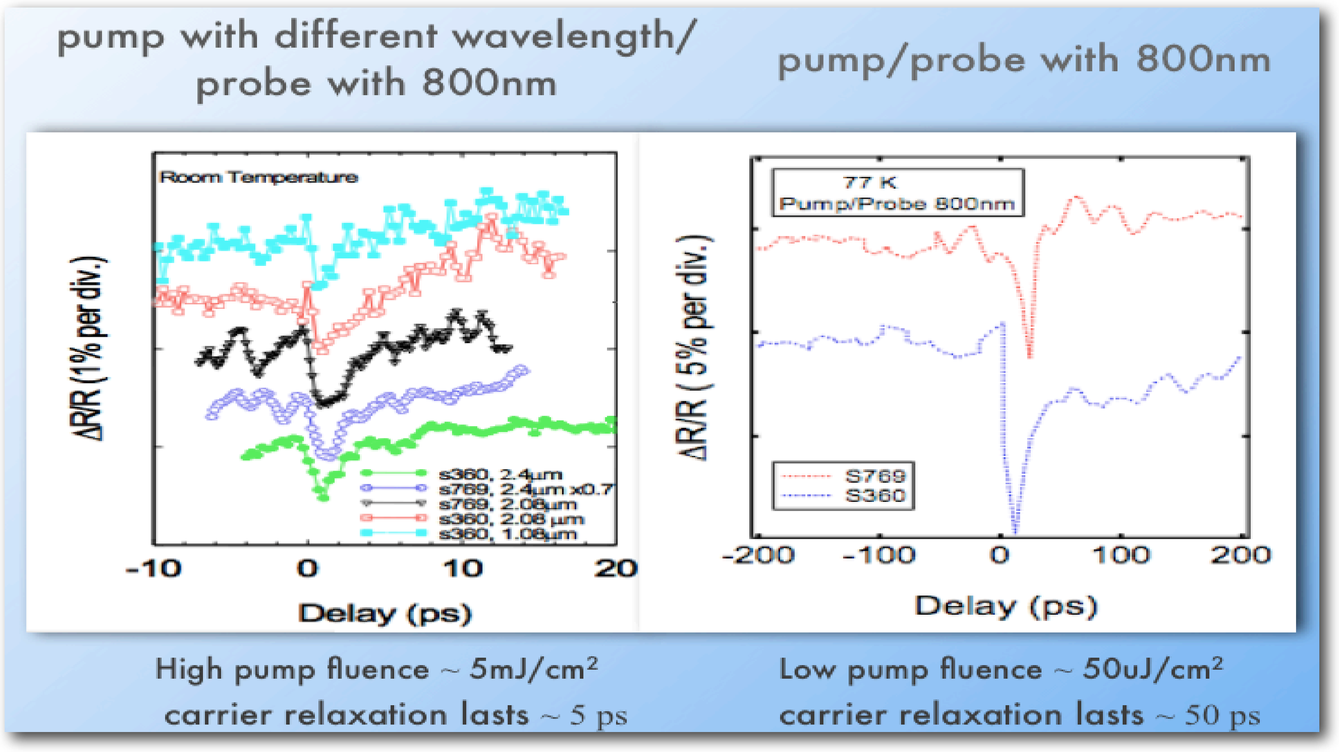
probe carrier relaxation time by time resolved measurement

Experimental Setup



III. Results

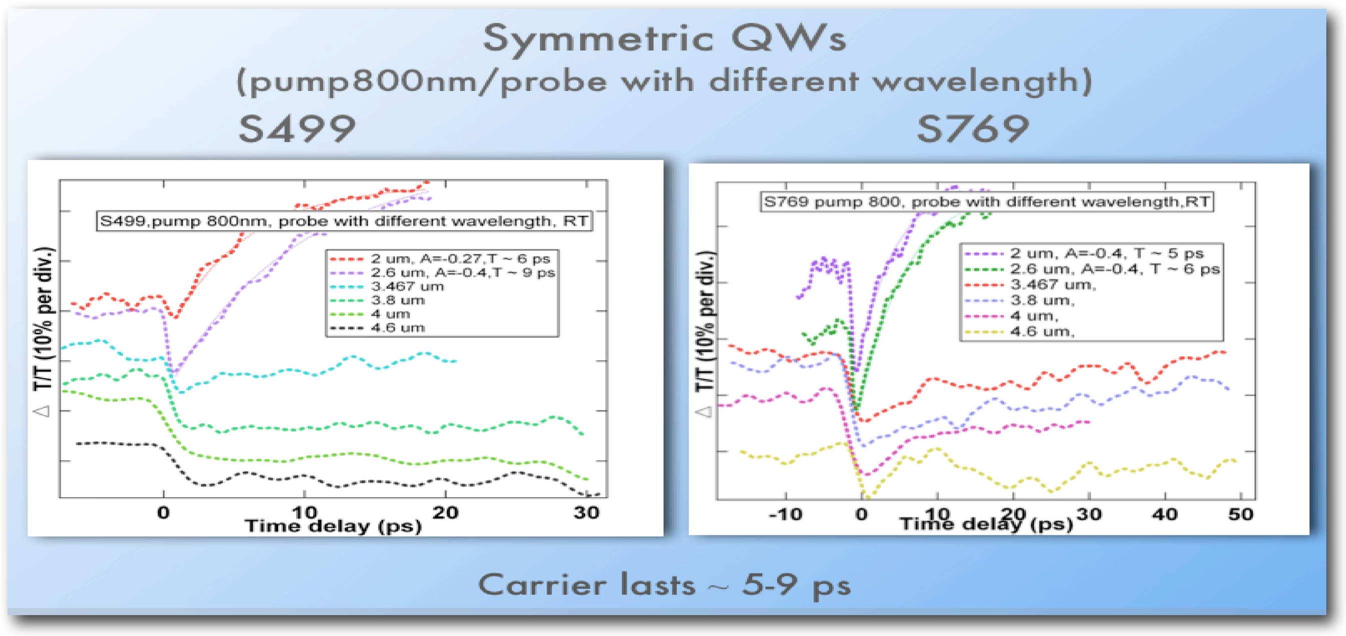
Reflection geometry(one/two color)



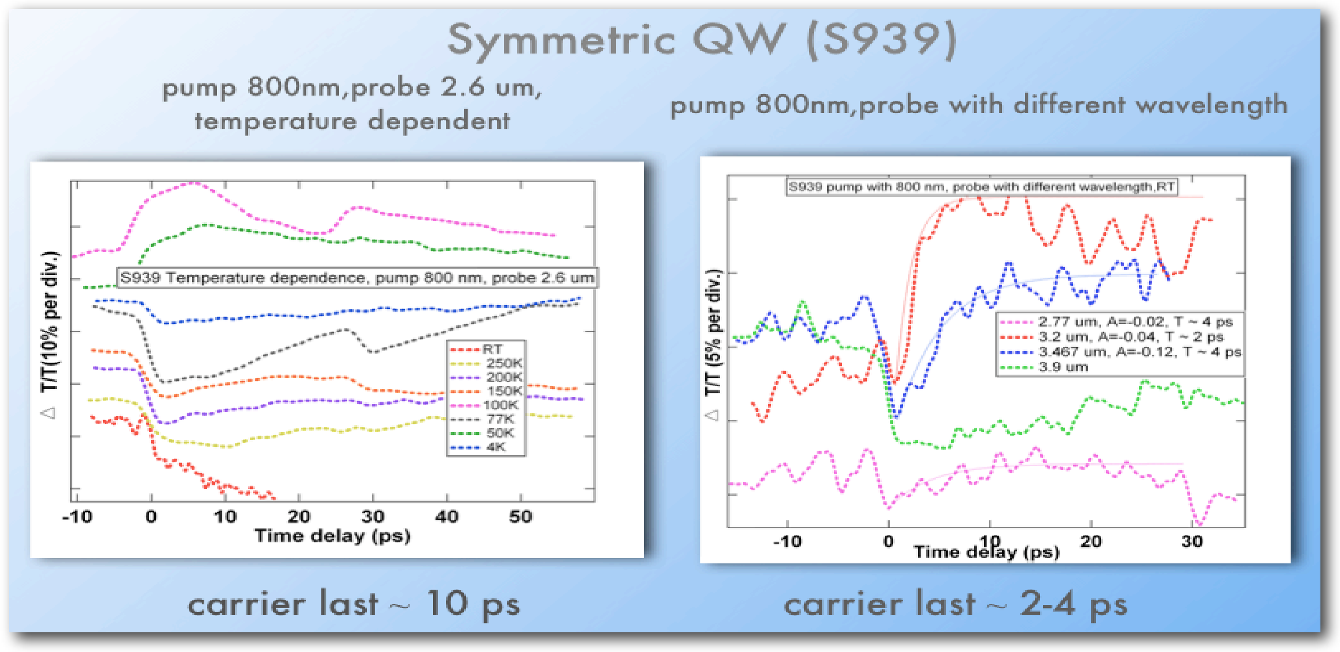
High pump fluence ~ 5mJ/cm²
carrier relaxation lasts ~ 5 ps

Low pump fluence ~ 50uJ/cm²
carrier relaxation lasts ~ 50 ps

Transmission geometry, pump fluence ~ 5mJ/cm²

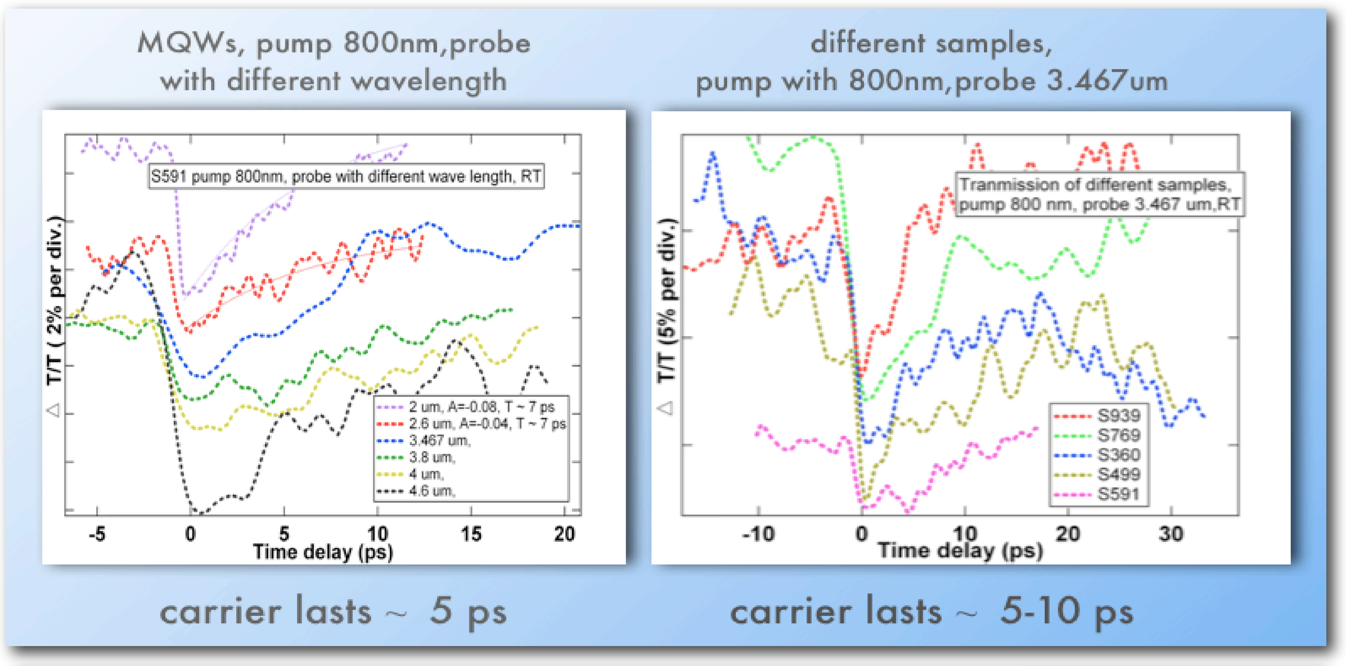


Carrier lasts ~ 5-9 ps



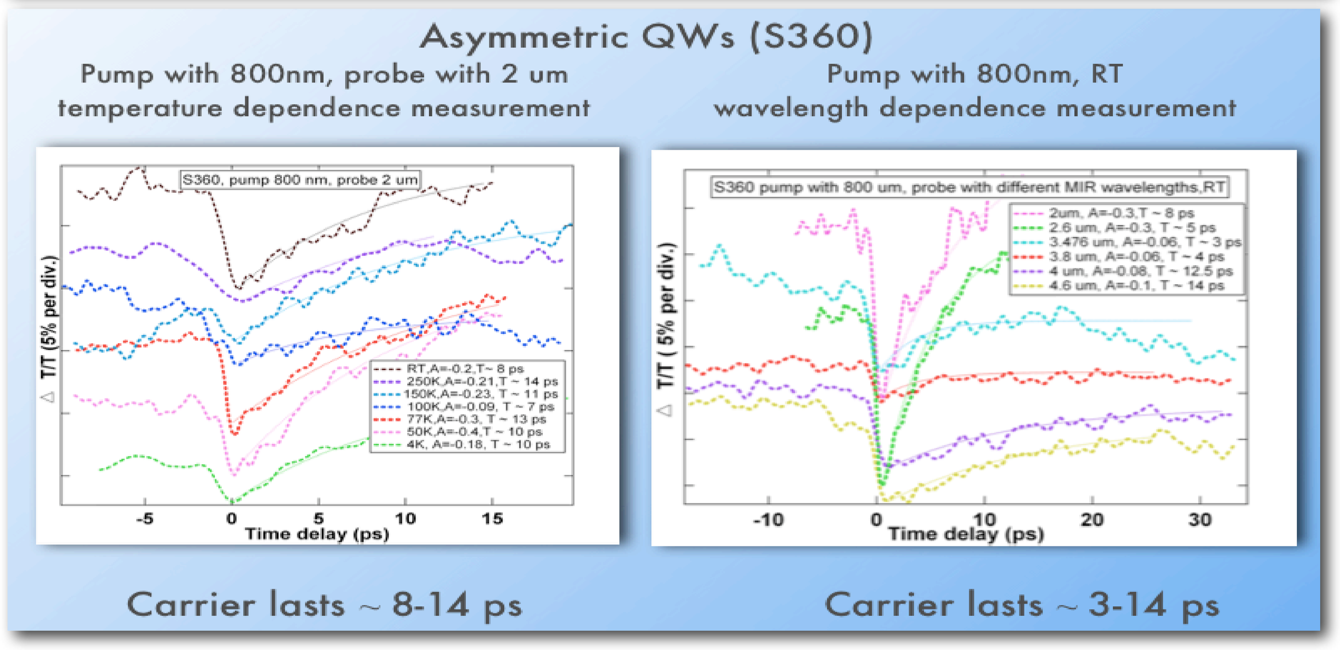
carrier last ~ 10 ps

carrier last ~ 2-4 ps



carrier lasts ~ 5 ps

carrier lasts ~ 5-10 ps



Carrier lasts ~ 8-14 ps

Carrier lasts ~ 3-14 ps

IV. Conclusion

Carrier relaxation time of different transition levels

sample	CB1-HH1	HH2-CB2	CB1-LH1	outside the well
15% Al	20 ps	10 ps	2ps	10 ps
9% Al	14 ps	10-12ps	4-10 ps	5-14 ps

- The observed carrier relaxation time from CB1-HH1>HH2-CB2>CB1-LH1.
- Carrier relaxations are different in low fluence (~50 ps) and high fluence regimes (~4-14 ps).
- Momentum relaxation can be a dominate relaxation mechanism in these structures
- Strong temperature dependence is observed in sample with high Al concentration

Supported by : NSF-DMR-0507866, DMR-0618235, and DMR-0520550, Jeffress-Trust Fund-J748, Advance VT

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