Recovery rate and optical anisotropy in the metal-to-insulator transition in VO_2 thin films

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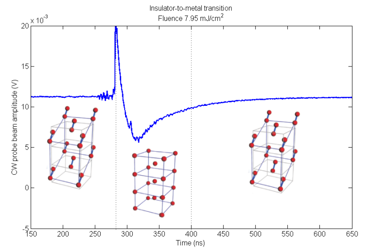
APS March Meeting

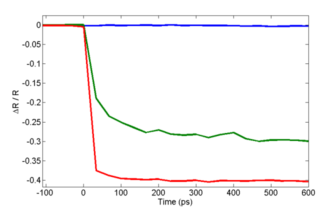
4 March 2014

VO_2: vanadium dioxide

Metal-insulator transition

- optically-induced
- sub-ps transition
- strain from substrate

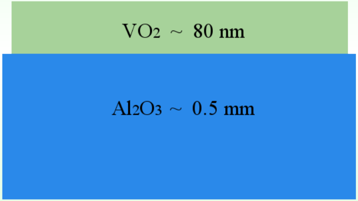


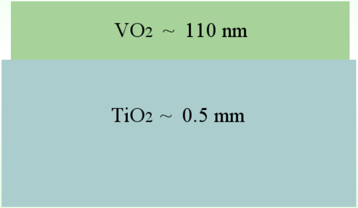


Applications

- ultrafast optical switches
- temporary circuits

VO_2 thin-films

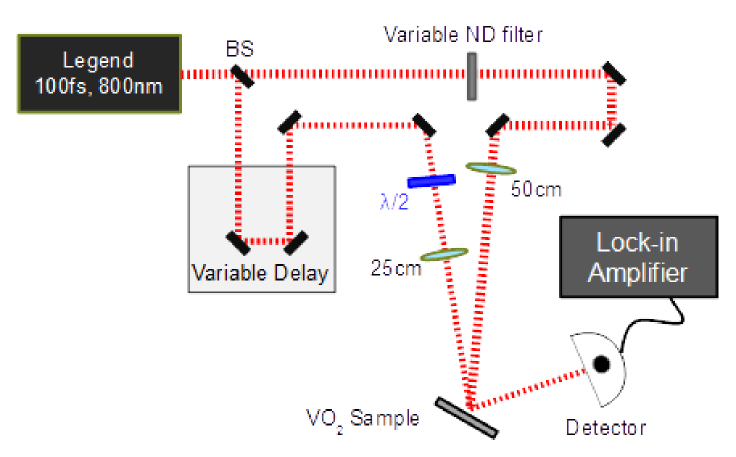




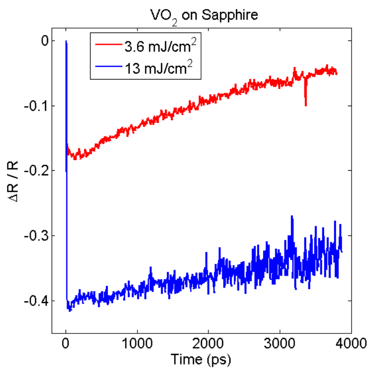
- sapphire substrate
- hexagonal
- $T_c = 341$ K

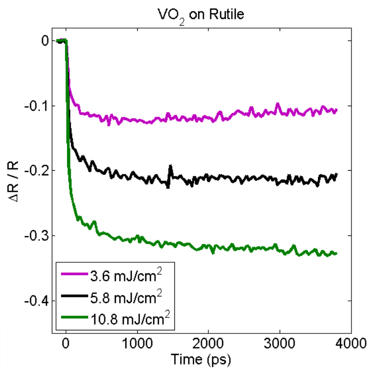
- rutile substrate
- tetragonal (011)
- $T_c = 306$ K

Pulsed pump-probe experiment

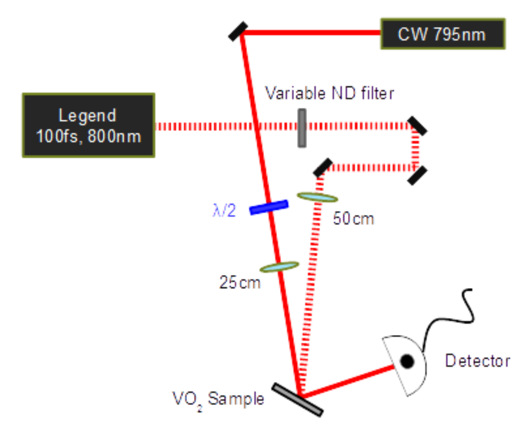


Pulsed probe data

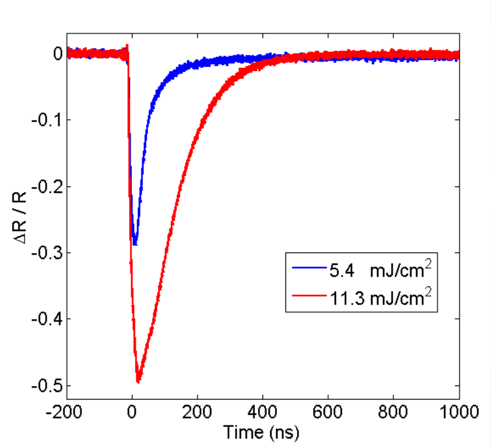




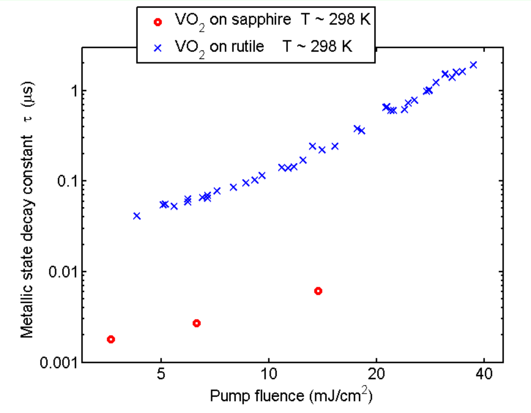
CW probe experiment



Decay time for VO_2 on rutile



Metallic state decay vs. Pump fluence



Heat transport across boundary

PHYSICAL REVIEW B VOLUME 48, NUMBER 22 1 DECEMBER 1993-II

Kapitza conductance and heat flow between solids at temperatures from 50 to 300 K

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(Received 24 May 1993)

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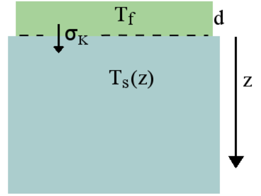
Structural and electronic recovery pathways of a photoexcited ultrathin VO_2 film

Haidan Wen,[1,*] Lu Guo,[2] Eftihia Barnes,[2] June Hyuk Lee,[1] Donald A. Walko,[1] Richard D. Schaller,[3,4] Jarrett A. Moyer,[5] Rajiv Misra,[6] Yuelin Li,[1] Eric M. Dufresne,[1] Darrell G. Schlom,[7,8] Venkatraman Gopalan,[2,†] and John W. Freeland[1,‡]

$$C_f d \frac{\partial T_f}{\partial t} = -\sigma_K [T_f - T_S(0,t)] \qquad (1)$$

$$C_S \frac{\partial T_S(z)}{\partial t} = \kappa_S \frac{\partial^2 T_S(z)}{\partial z^2} \qquad (2)$$



σ_K – Kapitza conductance between VO_2 and TiO_2

Applied Physics Express 4 (2011) 091104
DOI: 10.1143/APEX.4.091104

Transport Anisotropy of Epitaxial VO_2 Films near the Metal–Semiconductor Transition

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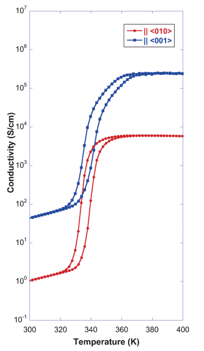
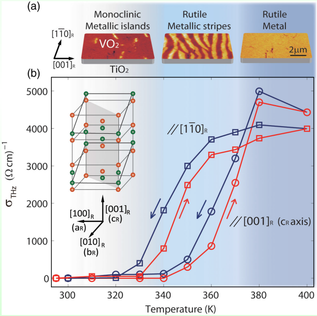
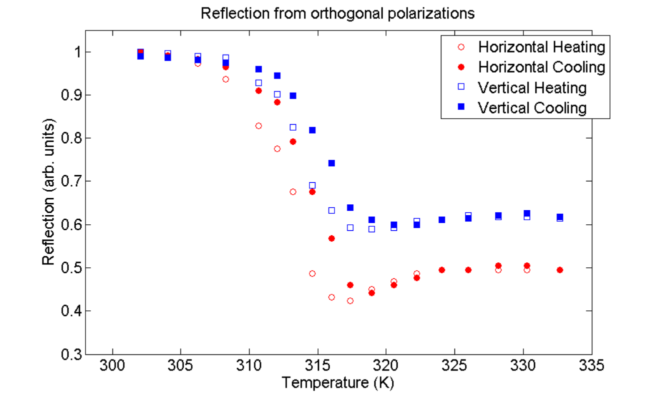
Anisotropic Electronic State via Spontaneous Phase Separation in Strained Vanadium Dioxide Films

M. K. Liu,[1] M. Wagner,[1] E. Abreu,[2] S. Kittiwatanakul,[3] A. McLeod,[1] Z. Fei,[1] M. Goldflam,[1] S. Dai,[1] M. M. Fogler,[1] J. Lu,[4] S. A. Wolf,[3,4] R. D. Averitt,[2] and D. N. Basov[1,*]



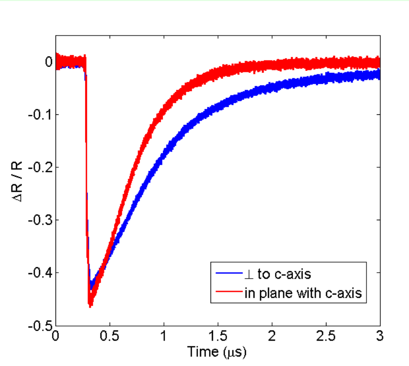


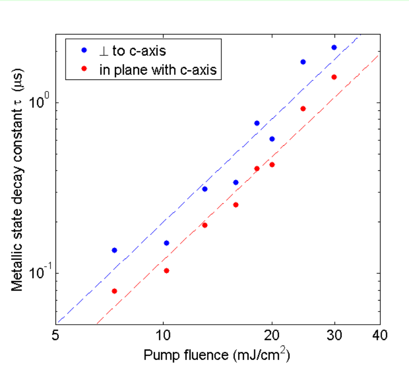
Optical anisotropy



VO_2 on rutile substrate

Anisotropy in decay constant





VO_2 on rutile substrate

Conclusions

VO_2 transition characteristics depends on substrate

- Substrate dramatically affects decay rate
- Optical pump fluence affects decay rate
- Rutile sample – optical anisotropy

Thank you!

College of William & Mary

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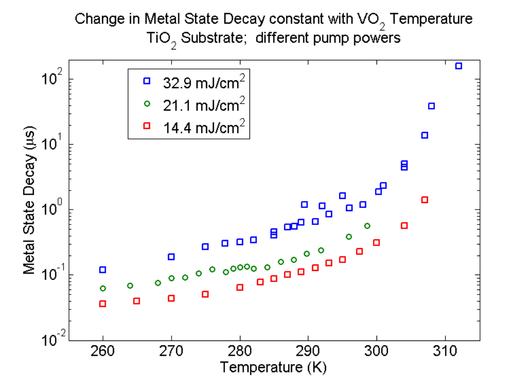
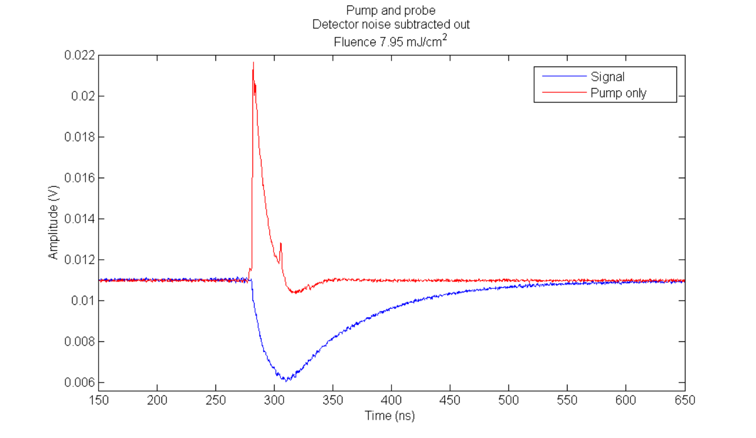
Begin Extra Slides

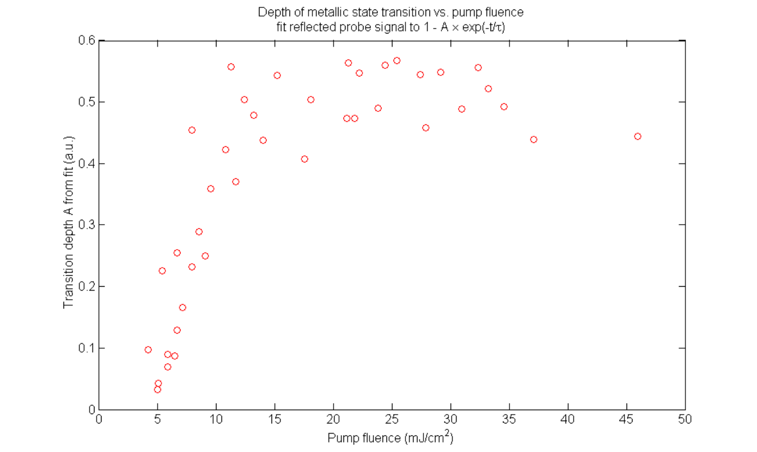
Decay vs. Temp



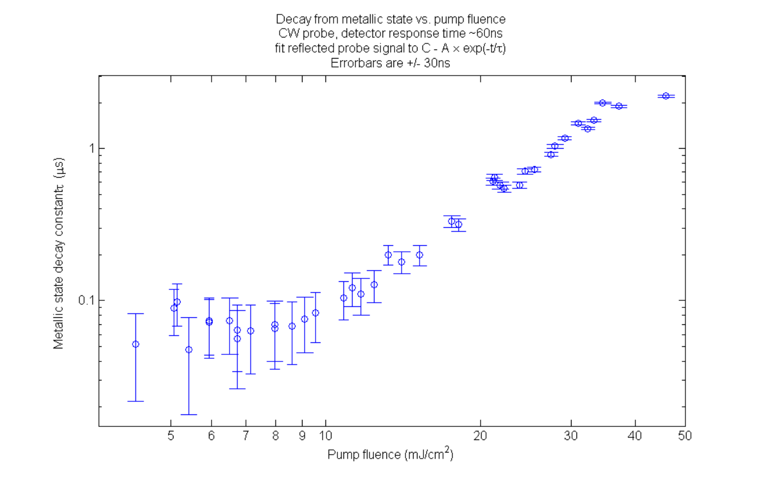
Normalized data



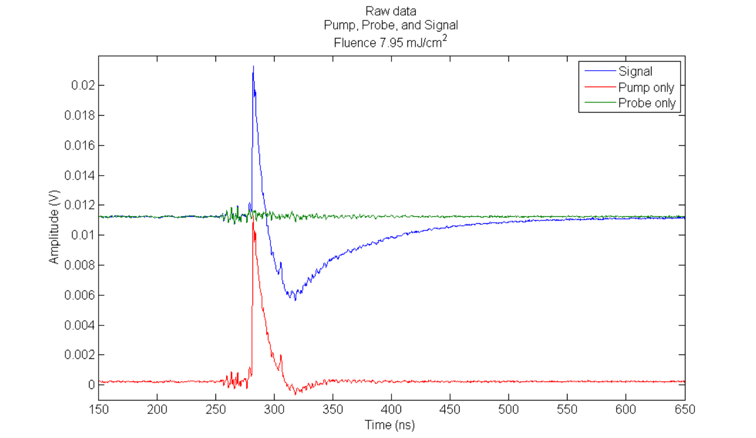
Max reflection change vs. pump fluence



Decay time varies with pump fluence

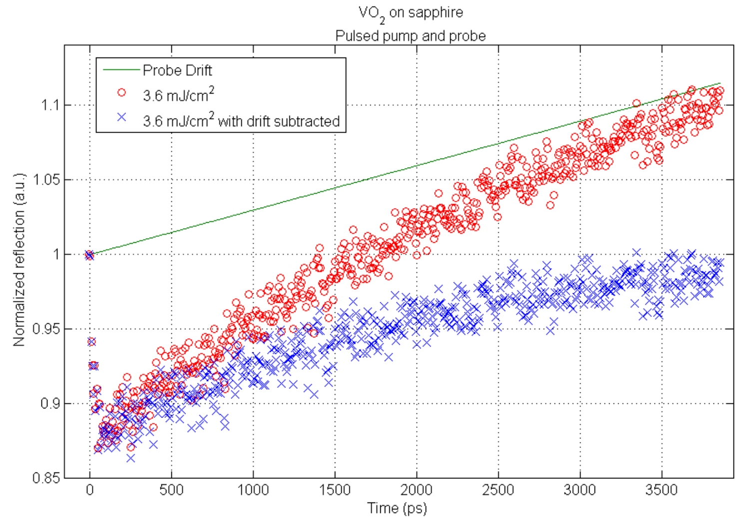


Raw data



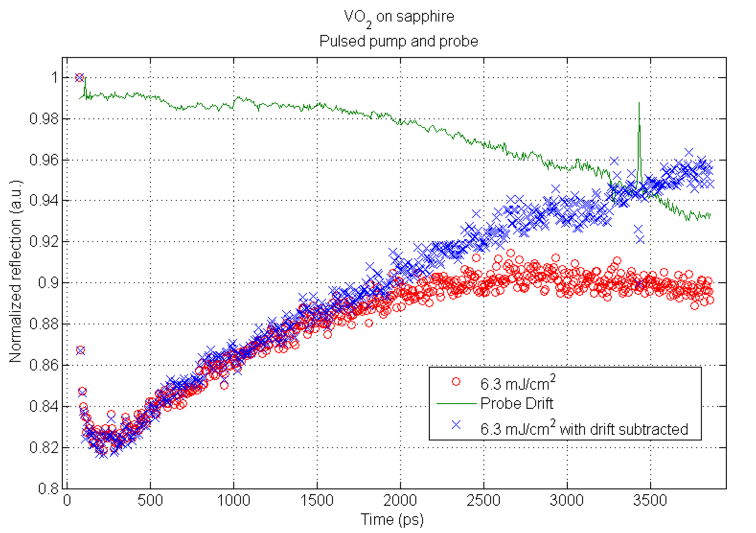
Raw data
Pump, Probe, and Signal
Fluence 7.95 mJ/cm2
Signal
Pump only
Probe only
Amplitude (V)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
150
200
250
300
350
400
450
500
550
600
650
Time (ns)

Al_2O_3 data



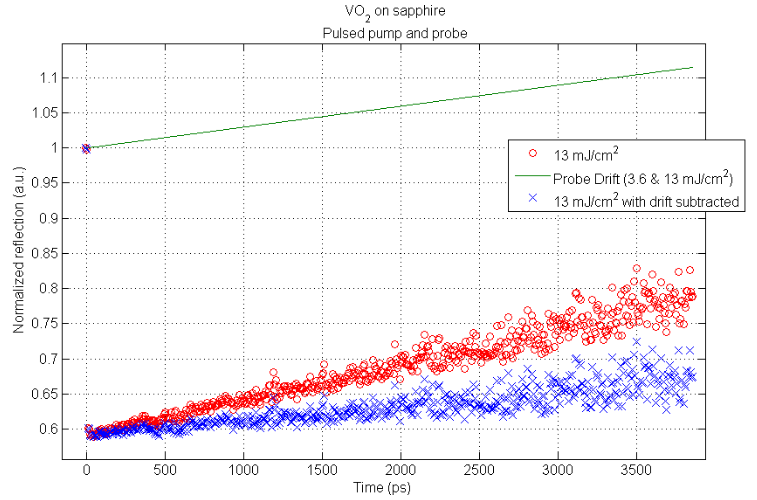
VO2 on sapphire
Pulsed pump and probe
Probe Drift
3.6 mJ/cm2
3.6 mJ/cm2 with drift subtracted
Normalized reflection (a.u.)
Time (ps)
1.1
1.05
1
0.95
0.9
0.85
0
500
1000
1500
2000
2500
3000
3500

Al_2O_3 data



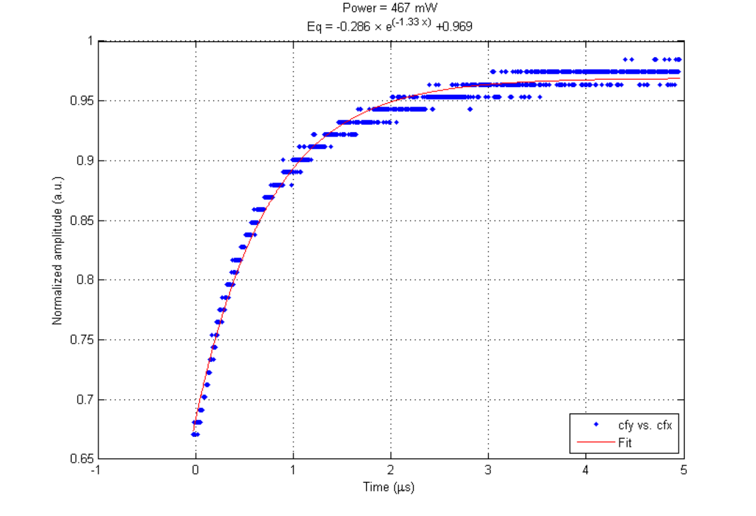
VO2 on sapphire
Pulsed pump and probe
Normalized reflection (a.u.)
Time (ps)
6.3 mJ/cm2
Probe Drift
6.3 mJ/cm2 with drift subtracted
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
0.8
0
500
1000
1500
2000
2500
3000
3500

Al_2O_3 data



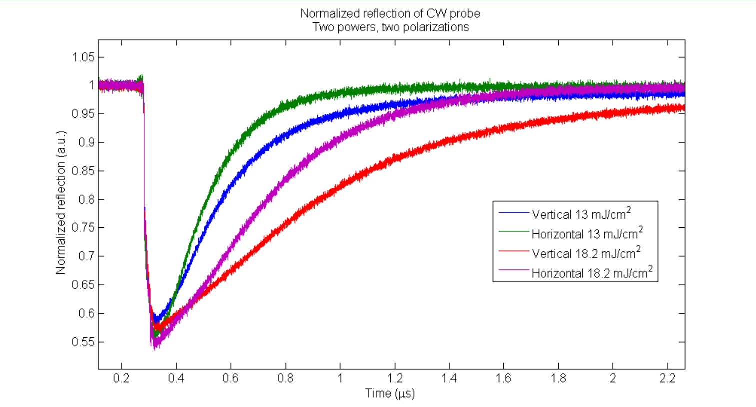
VO2 on sapphire
Pulsed pump and probe
Normalized reflection (a.u.)
Time (ps)
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0
500
1000
1500
2000
2500
3000
3500
13 mJ/cm2
Probe Drift (3.6 & 13 mJ/cm2)
13 mJ/cm2 with drift subtracted

Example fit

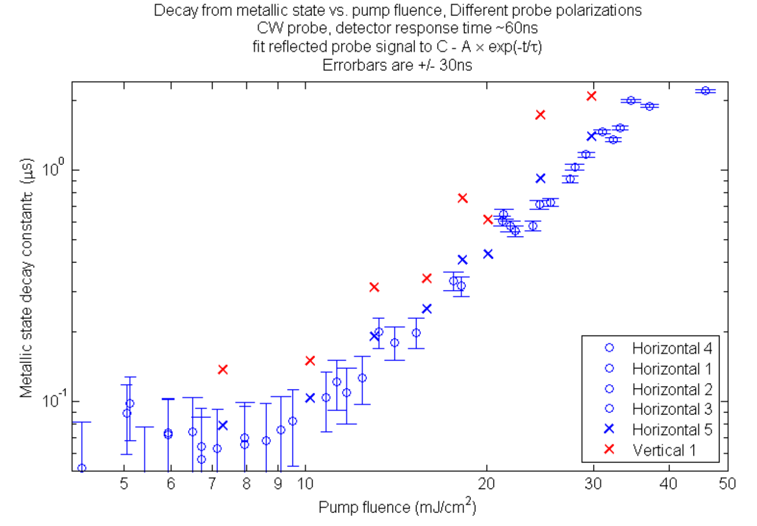


Power = 467 mW
Eq = -0.286 × e^(-1.33 x) +0.969
Normalized amplitude (a.u.)
Time (µs)
cfy vs. cfx
Fit
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
-1
0
1
2
3
4
5

Probe polarization variation



Probe polarization variation



Experimental set-up

photo of lab