Generation of THz Electrical Pulses

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Abstract: Recently it has been shown that optical laser pulses can be used to manipulate the magnetism of various materials. Electrical pulses should be able to play the same role as optical pulses, but for this research to progress, the generation of THz electrical switches must first be studied. Using the epitaxial liftoff method, we transferred a low-temperature grown GaAs photoswitch onto a SiO_2 substrate, demonstrating the feasibility of this transfer method. We measured the carrier lifetime of the LT-GaAs, both before and after transfer onto quartz, and the electrical transient carried by Au conduction lines. We hope to build upon this work by demonstrating ultrafast all-electrical switching by means of the generated electrical pulse.

Eventual Goal

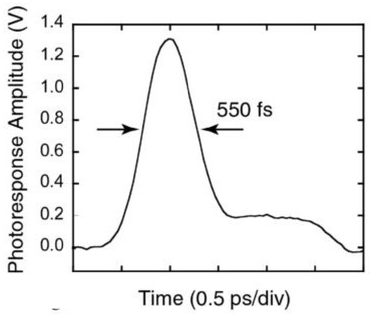
- Optical laser pulses have been shown to manipulate magnetism
- Want to use electricity as it is practical for devices -> need to generate of ultrafast electrical pulses

Objective

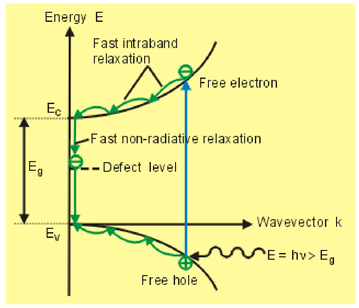
- Demonstrate feasibility of layer transfer and measure carrier lifetime electrical transients in different device geometries

Material: LT-GaAs

- Low temperature gallium arsenide - III-V direct band gap semiconductor
- Grown in the temperature range 200 – 300° C by molecular beam epitaxy
- Defects are introduced -> limits carrier lifetime
- Electric pulse length is determined by carrier lifetime
- LT-GaAs cannot be grown on arbitrary substrates due to lattice mismatch



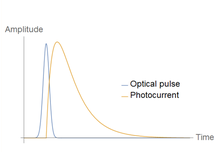
Zheng et. *al*, *Appl. Opt.* **42**, 1726 (2003)



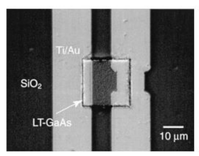
http://www.batop.de/information/pictures/PCA_band_diagramme.png

Auston Switch

- Generates electric pulse when excited by laser
- Transmission lines bridged by semiconductor
- Laser pulse creates electron/hole pairs in film
- DC voltage is applied across switch



https://upload.wikimedia.org/wikipedia/commons/4/4d/Photoconductive_antenna_response.png



Adam et. *al*, *Appl. Phy. Lett.* **81**, 3485 (2002)

Layer Transfer

- Move LT-GaAs from growth substrate to arbitrary substrate using microfabrication techniques
- Allows for exploitation the properties of the new substrate

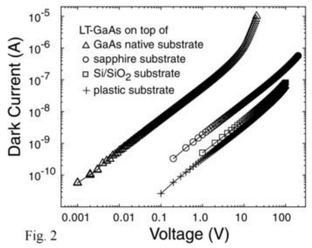


Fig. 2

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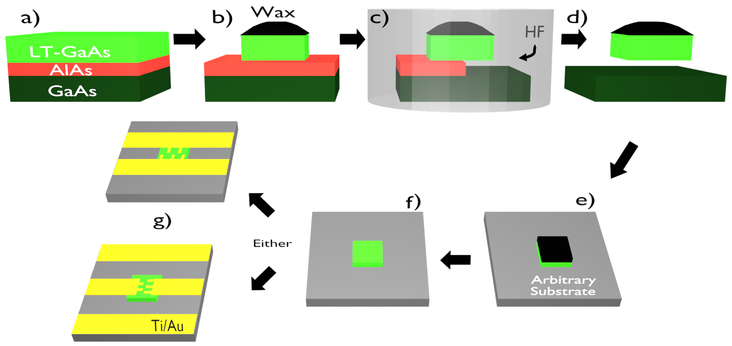
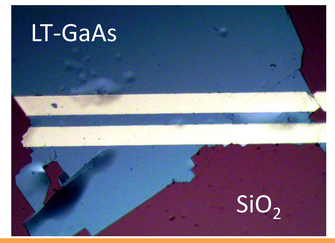
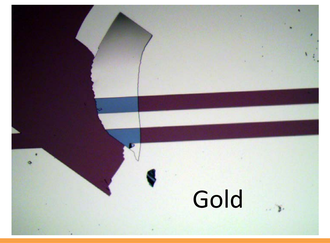
Fabrication

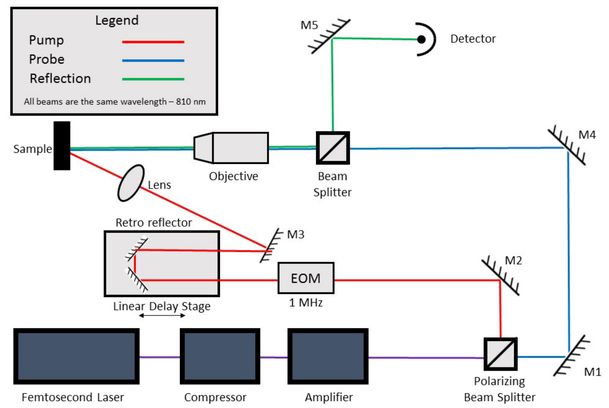


a) GaAs/AlAs (500 nm)/LT-GaAs (2μm)
b) Pattern into small squares; coat with Apiezon W wax
c) Etch AlAs using HF:H_2O (1:9) solution
d) Transfer film using tweezers
e) Bond film to SiO_2 substrate using VDW forces
f) Dissolve wax in trichloroethylene
g) Deposit Ti/Au (50/200 nm) transmission lines



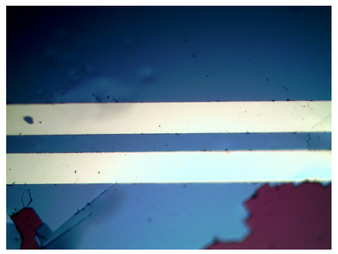


Optical Measurement

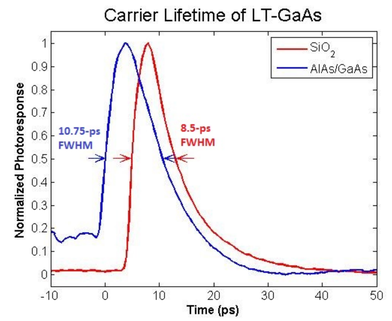


- GaAs detector can be used to measure electrical pulse transmitted by gold conduction lines

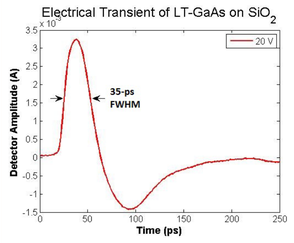
Results

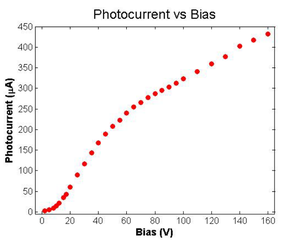


Coplanar strip (CPS) device that was tested; LT-GaAs bridges gap between biased conduction lines



- Carrier Lifetime is 2.25 ps shorter after transfer
- Due to dielectric nature of SiO2, long-term energy dynamics are suppressed
- Dark current negligible for moderate voltages; < 30 nA at high voltages
- Electrical transient is x3 broader than carrier lifetime

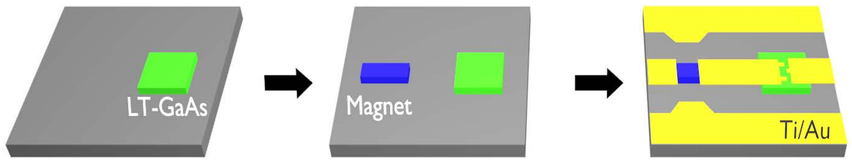




- Breakdown of switch occurred at 170 V
- Nearly linear relationship between photocurrent and voltage

Future Work

- Improve fabrication process – etch wells into SiO_2 to reduce height difference between switch and substrate -> reduce breaks in gold lines; use vacuum pipet to handle film instead of tweezers -> prevent cracks
- Direct electric pulse into magnet to attempt all-electrical switching



Acknowledgements: I would like to thank Yang Yang and Dr. Jon Gorchon for mentoring me throughout the summer and the almost daily trips for coffee; Professor Jeffrey Bokor; Perez, Hoang, Fanny, Lea, and Kedrick, the E³S team who organized and ran this program; and the NSF who funded this research.

Support Information: This work was funded by National Science Foundation Award ECCS-0939514

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Presented on 8/4/2016 at UC Berkeley