



STA 2.1 Materials and Devices for All-Optical Signal Processing

Joseph W. Perry

School of Chemistry and Biochemistry

Center for Organic Photonics and Electronics

Georgia Institute of Technology



Organic Materials for All-Optical Devices



substituents for tuning solubility and film-forming

possible extension of end-group conjugation to control relative energies of 1-photon and 2-photon states

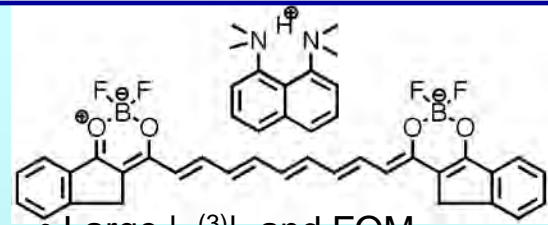
Y = S, Se, CR₂, H₂ etc. choice affects 1- and 2-photon absorption, γ , stability

possible ring-locking of polymethine chain to:
• improve thermal and photochem. stability
• reduce aggregation
• provide points of attachment for solubilizing groups, tethered counterions etc.

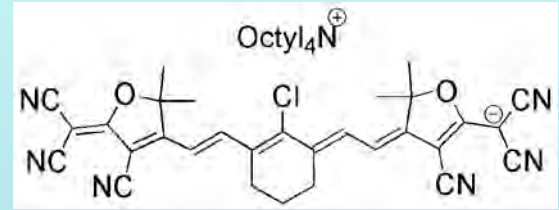
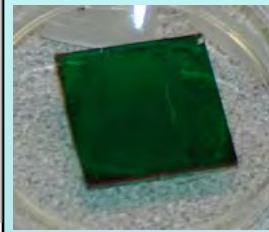
chain length allows control of absorption edge and γ

Molecular engineering for optical response and processability

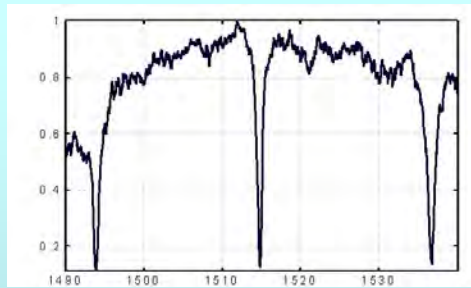
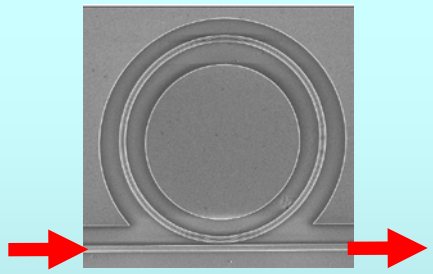
Organic All-Optical NLO Materials



- Large $|\chi^{(3)}|$ and FOM
- Ultrafast response

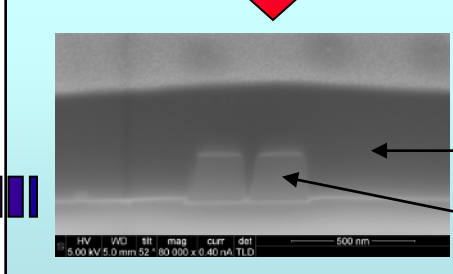


- Processable into good quality films for device integration
- Sizable $|\chi^{(3)}|$ ($\sim 6 \times 10^{-11}$ esu)



Optically Switchable Photonic Devices

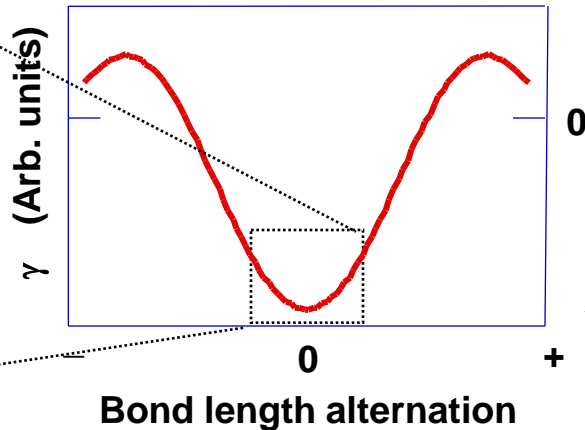
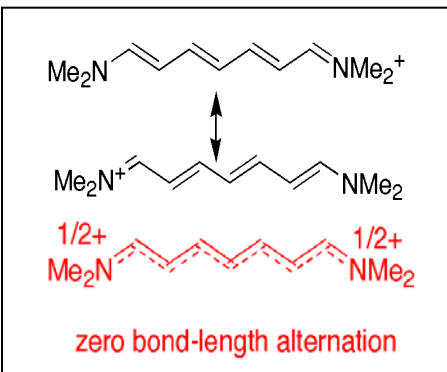
Integration with Si Photonics



Organic NLO layer
Si slotted waveguide



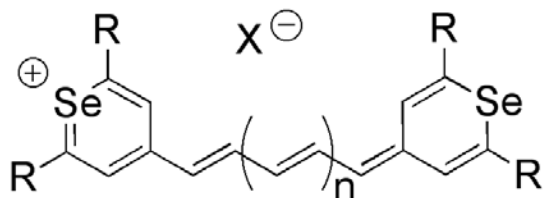
Optimizing Chromophores for All-Optical Switching



Marder, S. R. et al., *Science* **265**, 632 (1994)

- Cyanine-limit: max $|\gamma|$
- High order dependence on length:
 $\gamma \sim N^7$ or higher

Increased length, delocalized terminal groups

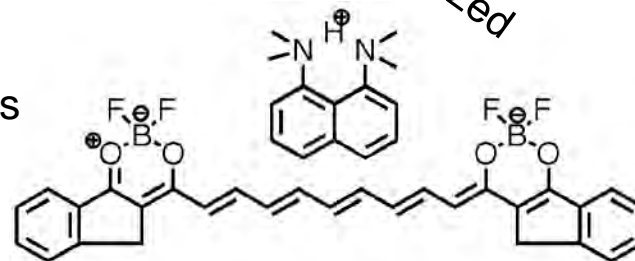


Optimizing terminal groups



- Selenopyryllium cyanine with very large large γ
- FOM = $\text{Re } \gamma / \text{Im } \gamma \sim 100$ in telecom band!

Hales et al., *Science* (2010) in press



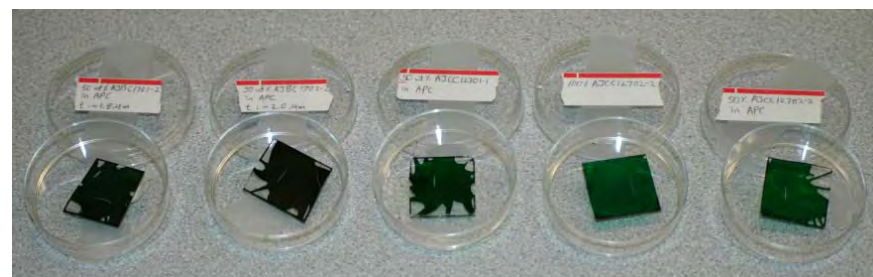
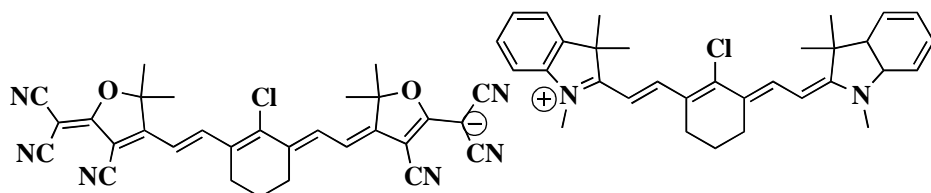
- Extended DOB cyanine with large γ and $|\chi^{(3)}|$ (3.6×10^{-10} esu)
- FOM = $\text{Re } \chi^{(3)} / \text{Im } \chi^{(3)} = 10$
- >200 GHz bandwidth



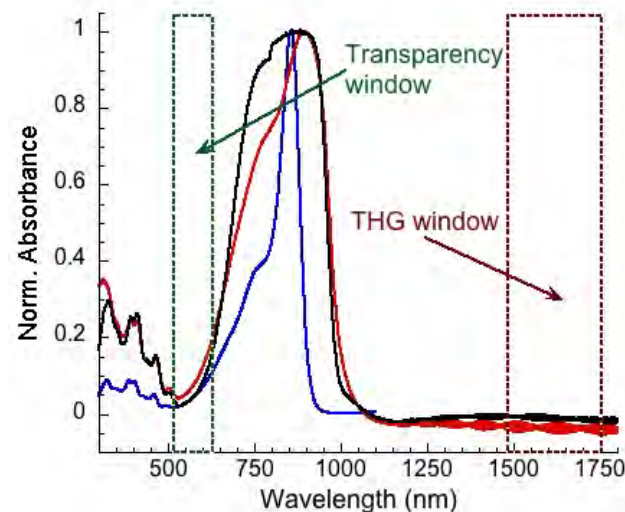
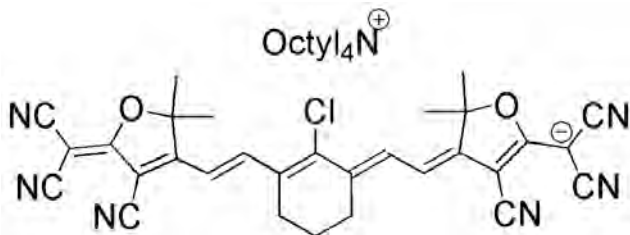
TCF Cyanines: Processable Materials



- Cyanines with complementary charges showed improved optical quality of resulting films



- TCF-terminated cyanines with TOA cations for good solubility, processability, and low NIR absorption.

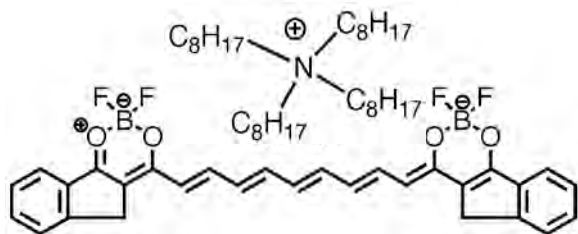


Jen, Marder, Perry Groups

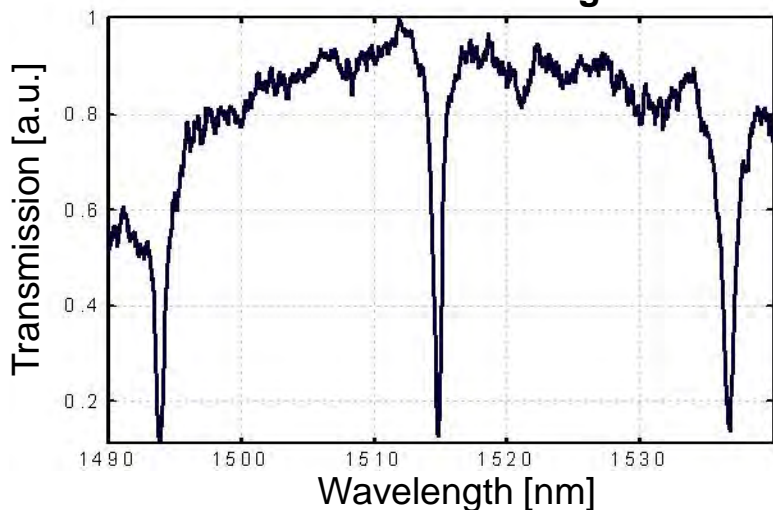
Center on Materials & Devices for Information Technology Research

An NSF Science & Technology Center

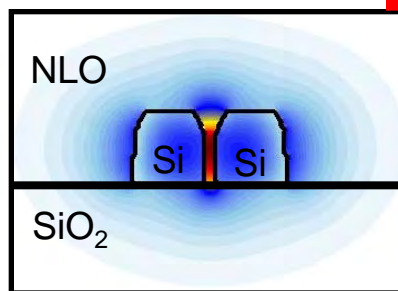
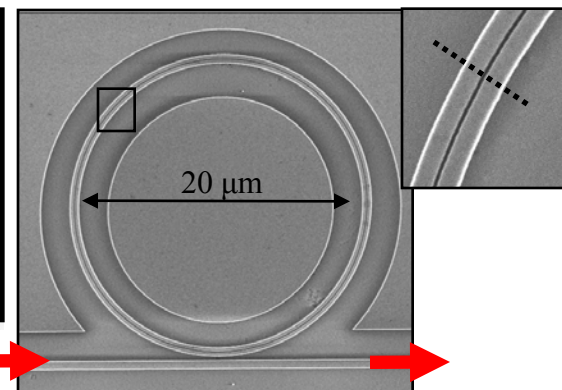
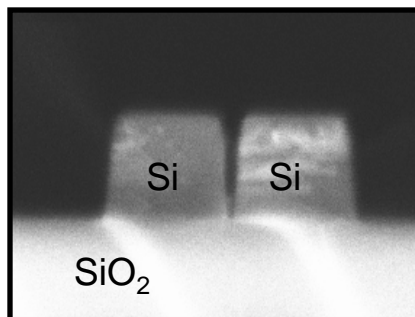
CMDITR Retreat, February 2010, Seattle, Washington



Measured resonances in coated slotted-ring



Keys: Large ratio of $\text{Re}(\chi^{(3)})/\text{Im}(\chi^{(3)})$
Low loss spin-coated films



Simulated Mode Profile

- 0.6 THz intrinsic bandwidth for coated slotted ring
- ~100 mW pump power to achieve 3dB modulation

- 1000x size reduction in device size due to field enhancement in a slot resonator

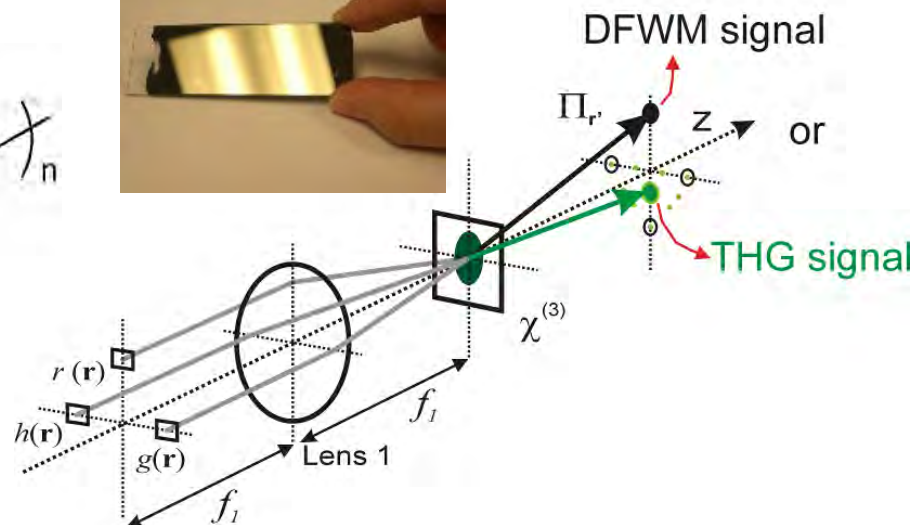
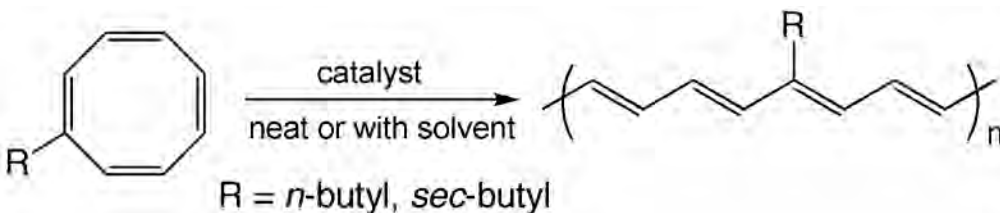
Perry, Marder, Lipson, Hochberg Groups



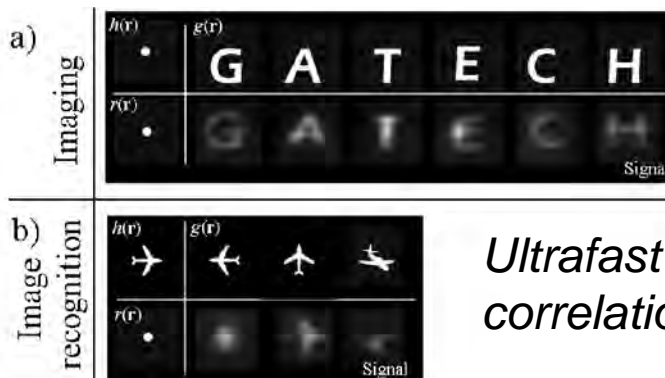
Processable Polyacetylene for All-Optical Image Processing



in-situ polymerization



- Large $|\chi^{(3)}|$ (2.0×10^{-10} esu) for optimized polymerization conditions
- >10 THz temporal bandwidth
- Moderate NIR loss (~ 30 dB/cm)
- Processable into good optical quality thick or thin films



Ultrafast DFWM image correlation

S. Chi, et al., *Adv. Mat.* **20**, 3199 (2008)