Revolutionary Components based on High-Performance Materials

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DARPA/MTO

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **05 MAR 2007**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Revolutionary Components based on High-Performance Materials**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **DARPA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
DARPA Microsystems Technology Symposium held in San Jose, California on March 5-7, 2007. Presentations, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**13**	

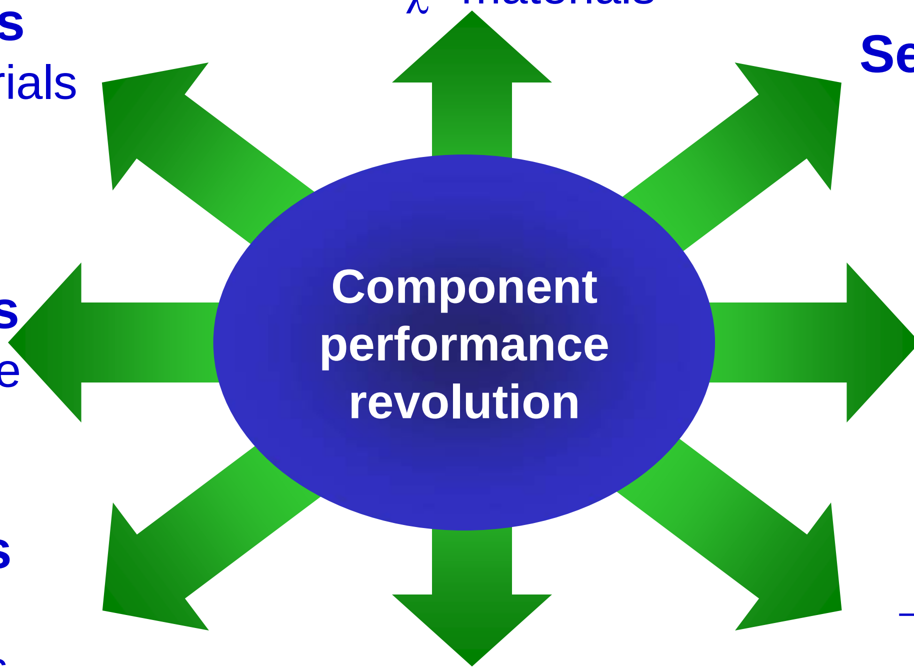
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Components and Devices for the Future Military

EO Modulators
→ χ^2 materials

Superlens
→ Metamaterials

Sensor protection
→ χ^3 materials



Magnetic Sensors
→ Magneto-Resistive materials

High Power Lasers
→ High-efficiency NLO materials

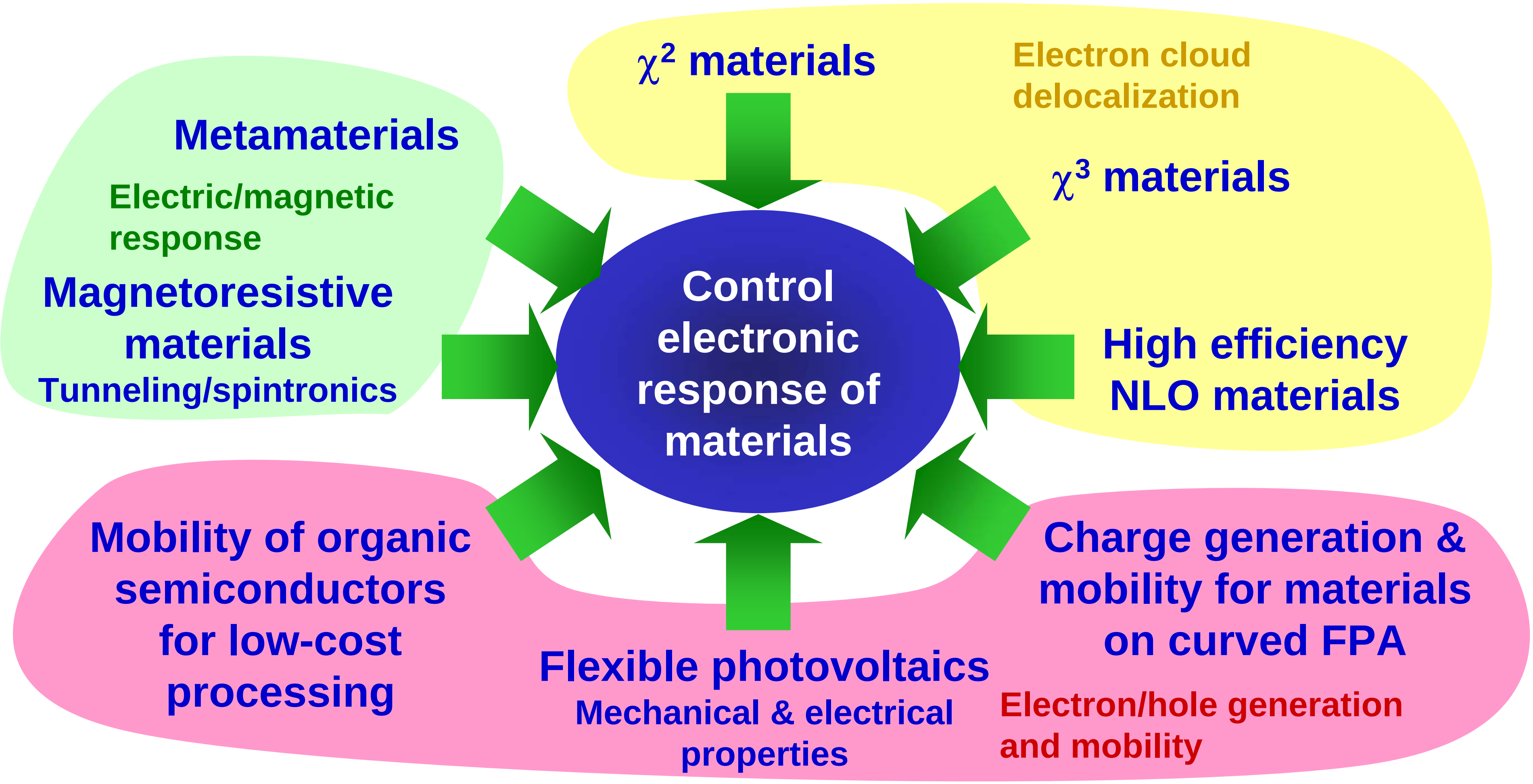
Organic TFTs
→ Organic semiconductors

Compact Camera
→ High-efficiency photo-sensitive materials

Efficient Energy-Harvesting Devices
→ Flexible photovoltaics

Leverage High-Performance Materials for Revolutionary Photonic, Electronic, & Magnetic Components

Engineering at the Nanoscale

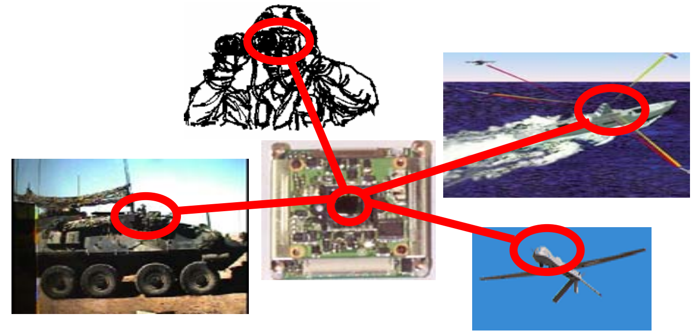


Control of electronic and photonic properties at the nanoscale to drive material and device performance

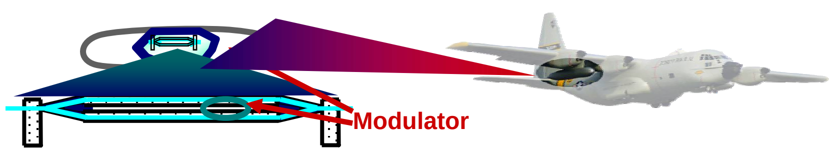
MORPH PROGRAM

Objectives:

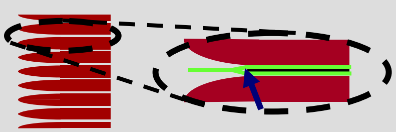
- Develop highly non-linear optical materials for applications in RF photonics and sensor protection
- Develop high-bandwidth, low drive-voltage EO modulators

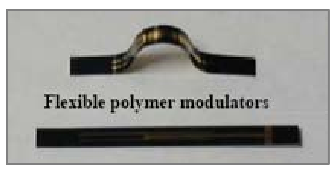


Protect from ultra-short pulsed and broadband tunable lasers



Antenna Integrated Modulator for Photonic Beamforming





Flexible polymer modulator

Military Impact:

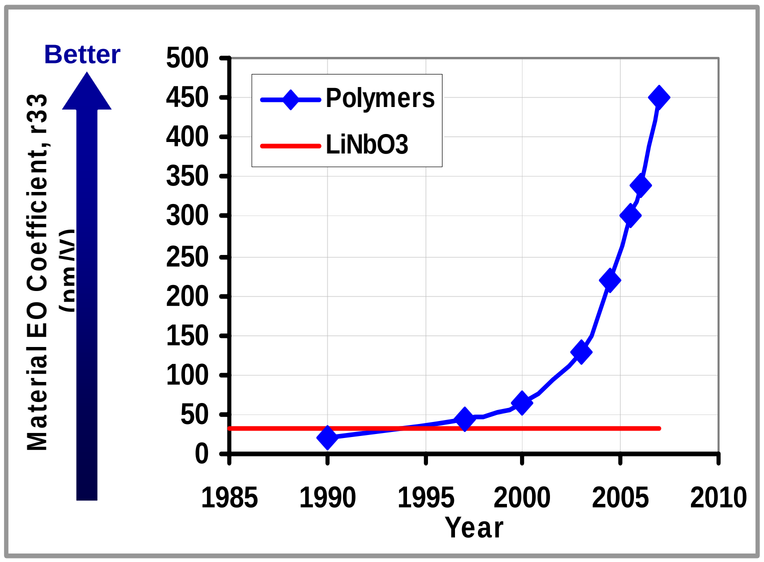
- Enhanced Performance of Phased Array Radar
- Protection for DoD personnel and sensor systems from laser threats

EO Modulators
$\chi^{(2)}$ Materials and Components

Program Goals

NLO coefficient r_{33} @1.5 µm	>1200 pm/V
Absorption loss	<1 dB/cm
Polymer T_g	>200 C
Fiber coupling	<0.75 dB
Bandwidth	100 GHz

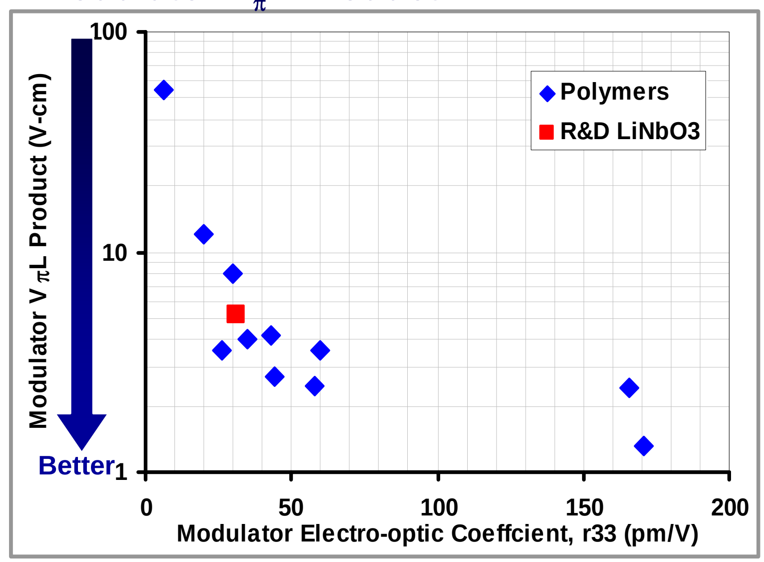
Material EO Coefficients



Exploit exceptional polymer r_{33} for better modulator performance

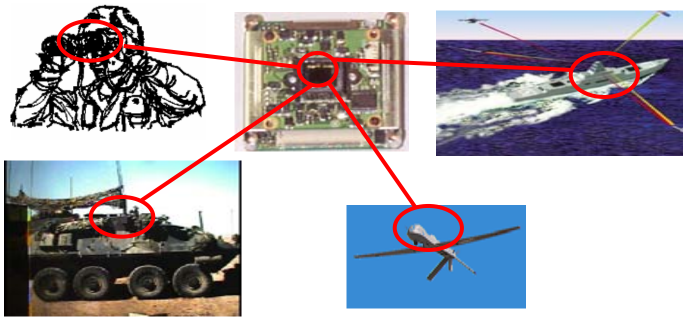
$$V_\pi L = \frac{\lambda d}{n^3 r_{33}}$$

Modulator $V_\pi L$ Product



New $\chi^{(2)}$ Optical Materials are Enabling Revolutionary Electro-Optic Modulators

Sensor Protection
$\chi^{(3)}$ Materials and Components

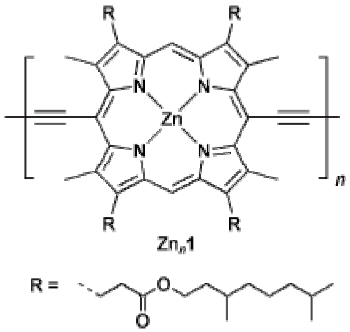


Protection from ultra-short pulsed and broadband tunable lasers

Program Goals

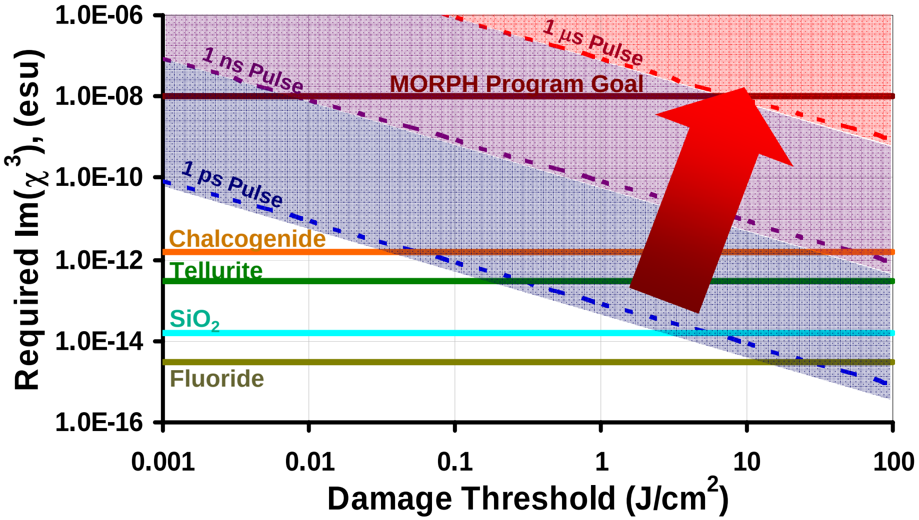
Transmission @ 700-900 nm	>80%
Transmission @ 1530-1640 nm	>70%
Suppression	30 dB

femto→pico→micro-second pulses



HLApol-Zn

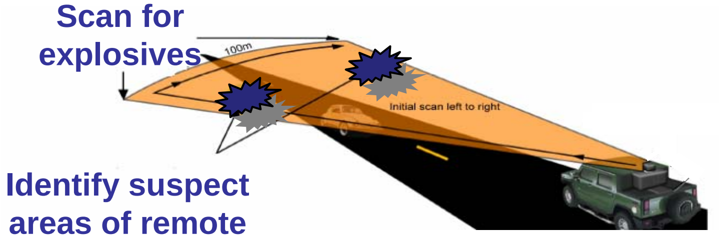
$\chi^{(3)}$ versus Sensor Damage Threshold



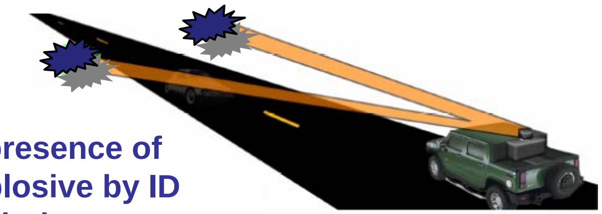
New $\chi^{(3)}$ Optical Materials will Enable Sensor Protection Systems

High-Power Lasers
High-efficiency NLO materials

Scan for explosives

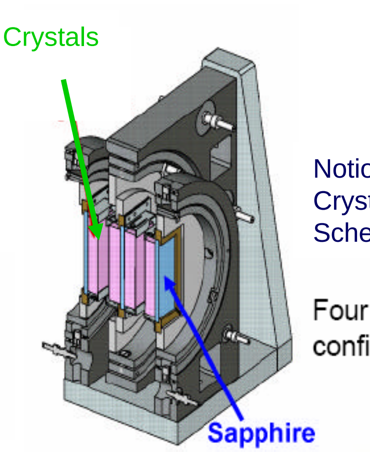


Identify suspect areas of remote explosives



Confirm presence of remote explosive by ID technique

Explosives detection at a distance using compact short- wavelength high power lasers and orthogonal optical spectroscopy techniques



Notional NLO Crystal Cooling Scheme

Four DKDP plate configuration

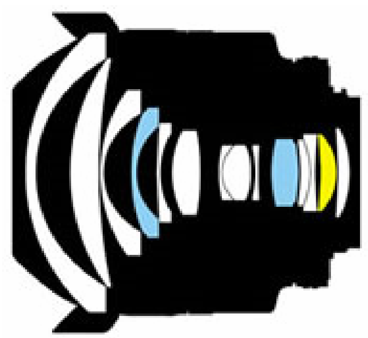
Exploit compact high-power lasers at long wavelengths and use NLO crystals to convert to desired wavelength

- **Thermal and defect damage resistance**
- **High-efficiency NLO materials for high-fluence applications**

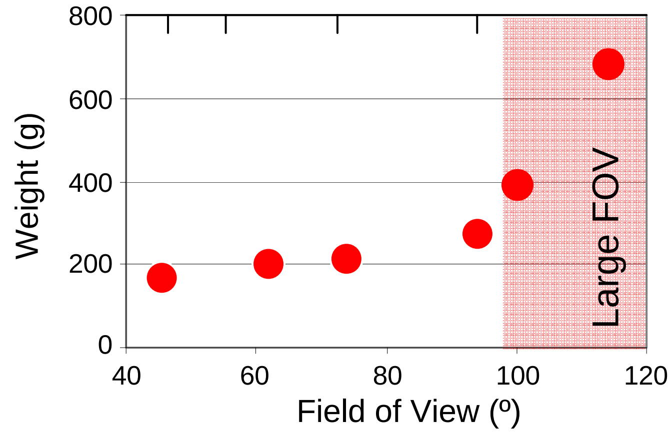
High-efficiency NLO materials will enable remote explosives detection

Compact Camera

New Materials & Processes

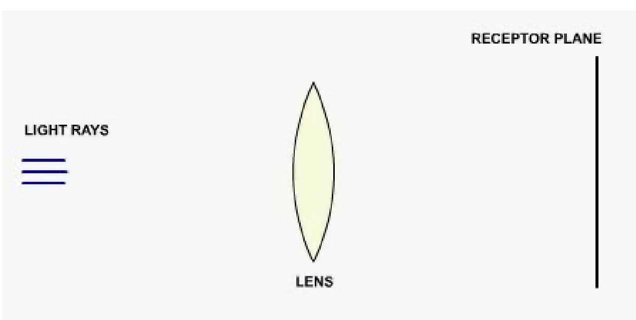


14 lenses, 2 aspherics

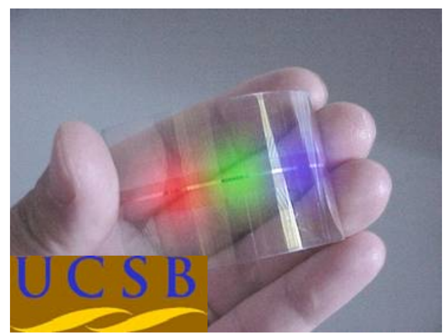


Source: Nikon

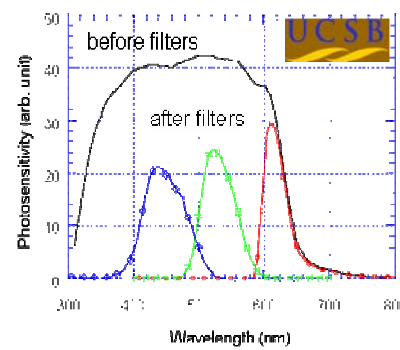
Large field-of-view cameras need multiple lenses to correct for aberrations due to a flat focal plane



Enabled by recent results



Organic photo-detector in VIS



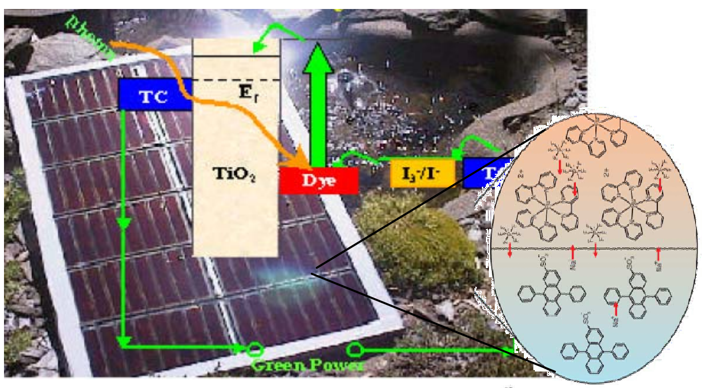
Exploit process able photo-diodes to manufacture curved focal planes for the VIS, NIR and SWIR bands

Efficient Energy-Harvesting Devices
Flexible Photovoltaics

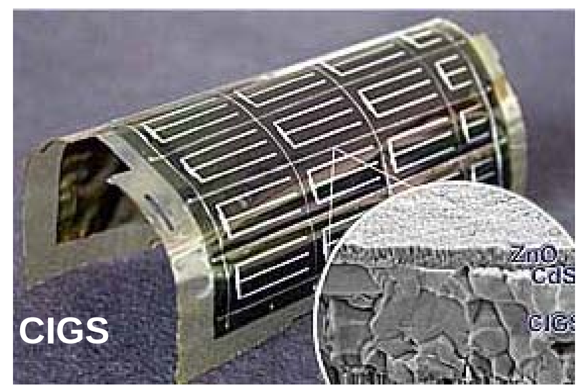
- Low efficiency
- Heavy
- Poor flexibility
- High cost

- New Organic/bioinspired materials

- Thin film inorganics (CIGS)



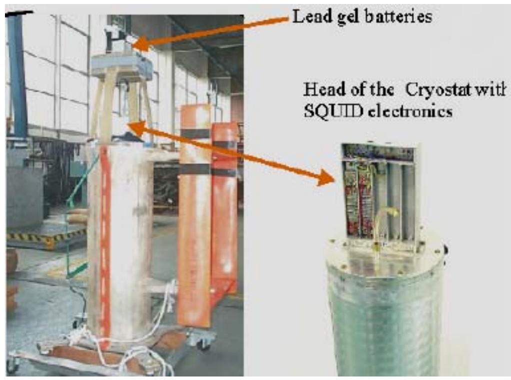
3rd generation technologies with Increased stability and efficiency

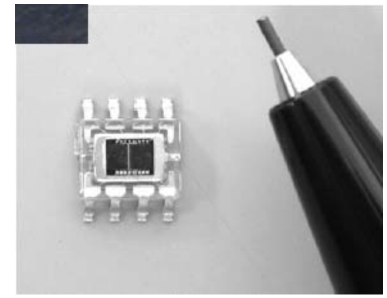


Enabling low-cost, versatile photovoltaics for large-scale power generation

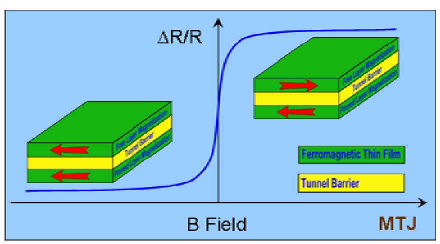
Magnetic Sensors
New Magneto-resistive Materials

Current high-sensitivity magnetic sensors are bulky



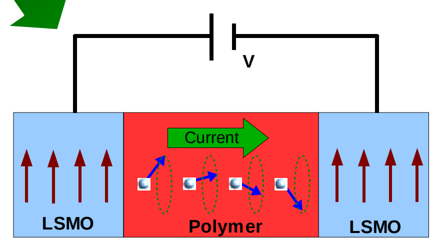


Novel Materials enable MR in excess of 400%!



MTJ Devices

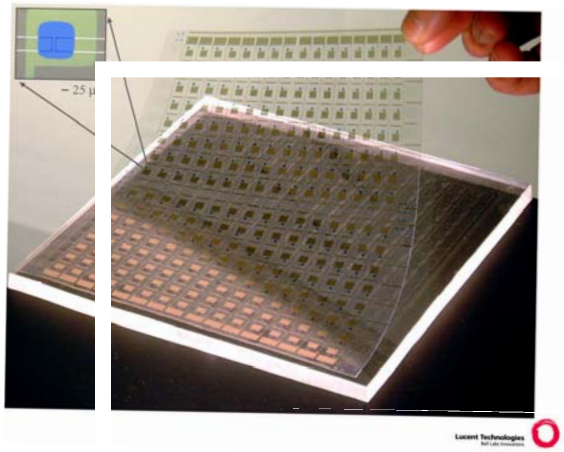
Novel polymer-based devices



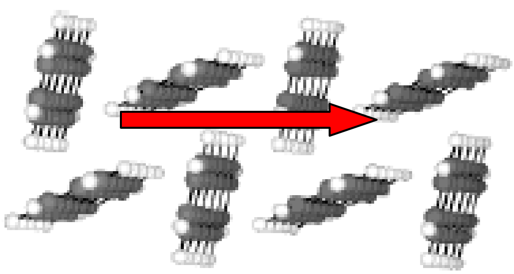
Spin Injection Based Devices

Miniature room-temperature, low-frequency magnetic sensors

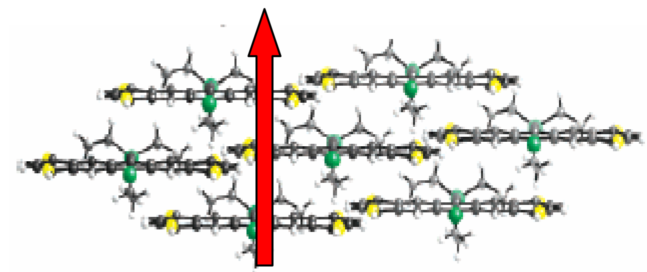
Organic TFTs
Organic Semiconductors



Organic transistors are process able at low-cost but have poor performance



Crystal engineering

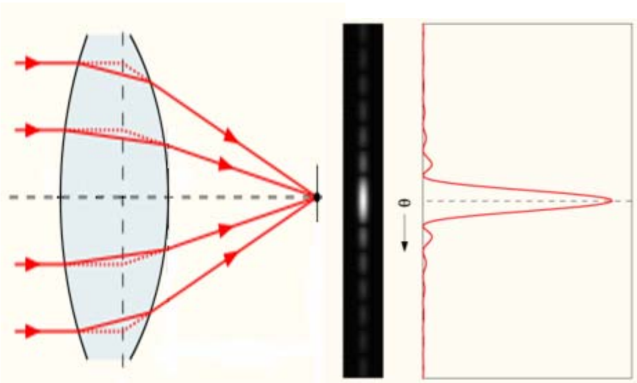


$$\mu \propto t_{ij}^{2} \sqrt{\frac{\pi}{\hbar k_B T \lambda}}\, e^{-\frac{(\Delta E - \lambda)^2}{4\lambda k_B T}}$$

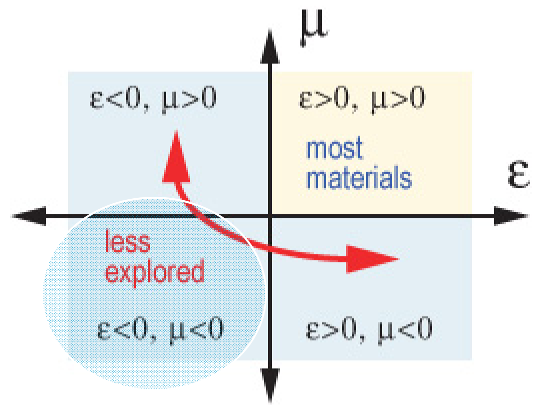
Control of the relative arrangement of the molecules in a solid coupled to theoretical semiconductor performance

Ordered organic semiconductors for higher-end performance and flexible distributed electronics

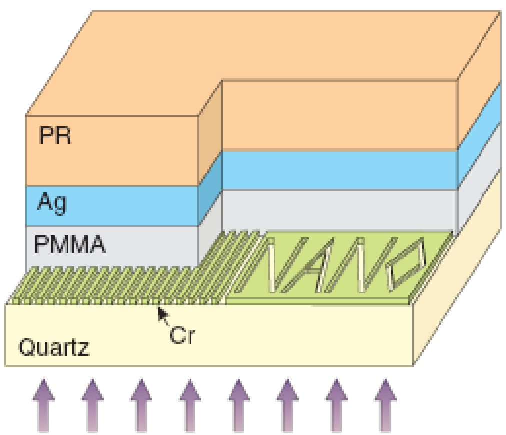
Superlens
Negative Index Materials

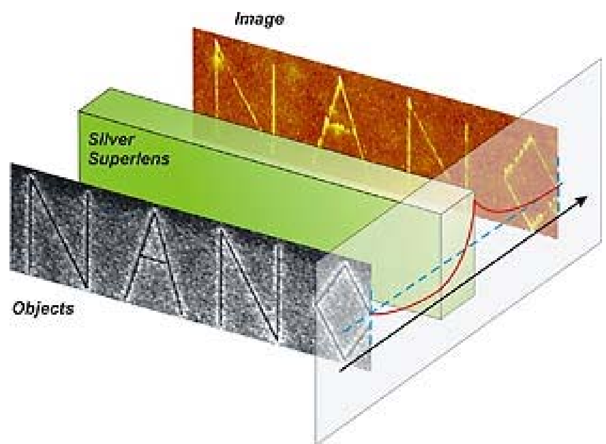


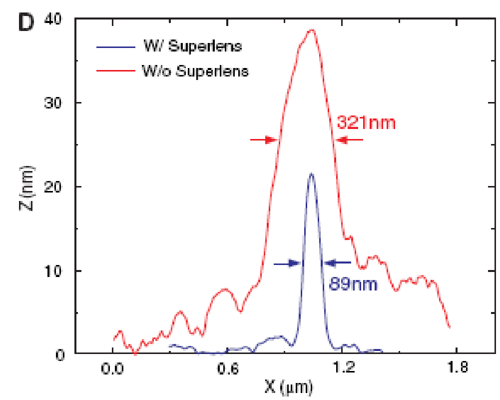
Diffraction limits the performance of current optical elements



Metamaterials for sub-diffraction limited imaging







Sub-diffraction optical imaging

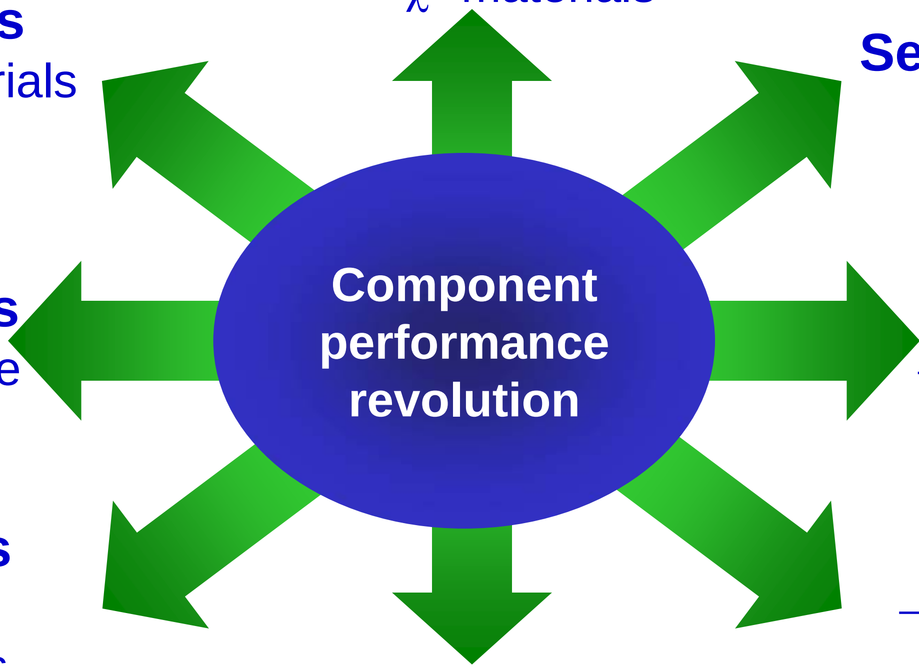
Fang et al, p534, v 308, 2005 (Science)

Components and Devices for New Military Capabilities

EO Modulators
→ χ^2 materials

Superlens
→ Metamaterials

Sensor protection
→ χ^3 materials



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