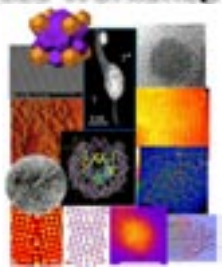
RFA: Optics and Photonics in Nanostructures

Nanophase Materials Sciences Workshop



1. Breakthrough needs

- **Scientific challenges to be addressed: Understanding photon interactions with matter on the nanoscale**
  - **Optical coupling to nanoscale structures**
    - Optical coupling between quantum dots and a matrix, and quantum confinement phenomena
    - Femptosecond electron and relaxation dynamics in nanostructures
    - Optically-driven spin and defect transport
    - Optically-induced coupling of nanoparticales
    - Dynamics of optically switched phase transitions
    - Near-field effects, including plasmonics and near-field photon transport; local nanoprobes
    - Light localization on the nanoscale and in nanostructures
  - **Fabrication and understanding of diffractive nanostructures**
    - Growth of high-index, high Pockels coefficient materials for waveguides
    - Fabrication of photonic crystal structures in a variety of materials
    - Optical effects of surface, interface, and edge effects in complex nanostructures
    - Interferometric and quantum nanolithography
    - Laser-focused atomic deposition
    - Effects of the nanoscale on the optical properties of complex oxides such as ferroelectrics
  - **Novel nanophotonic materials**
    - Potenial lasing media (n-Si in SiO_2, ZnO)
    - Potential E-O switching materials (organic chromophores, VO_2, semiconducting polymers)

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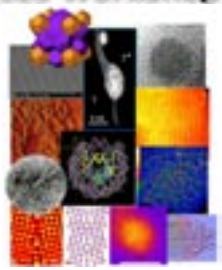

1. Breakthrough needs

- **Technological opportunities to be addressed: Controlling Photons using nanoscale structures**
  - **Transport and Processing Applications**
    - Optical or photonic switching and modulation using diffractive nanostructures in waveguides
    - Active and passive photonic crystal devices
    - Photonic transport to photodetectors
    - Optical computing, optical gates
    - Molecular scale opto-electronics and computing
    - Active and passive photonic crystal manipulation of reflected light (super diffraction gratings
  - **Ultrafast Precise Optical Instrumentation**
    - Frequency- and phase-locked laser arrays for ultrashort-pulse and CW operation
    - Coherent combination and multiple-beam interference
    - Ultrafast time domain optical probes
  - **Sensors**
    - Quantum dot fluorescence tags
    - Quantum dot x-ray digital sensors
    - Integrated bio-detection
    - Nanostructured sensitizers for optical devices

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2. Collaborative strengths

- **People**
  - **ORNL SSD: C. W. White, S. P. Withrow, T. E. Haynes, L. A. Boatner, C. M. Rouleau, H. M. Christen**
  - **ORNL ESTD: P. Datskos, S. Rajic, J. T. Simpson**
  - **ORNL CSD: Bob Shaw, J. M. Ramsey**
  - **ORNL LSD: T. G. Thundat**
  - **N. Dietz (Ga. State)**
  - **I. Perakis, R. A. Wheeler (Vanderbilt)**
  - **R. Singh (Univ. of Fla.)**
  - **R. Whetten, Z-L Wang (Ga. Tech)**
  - Phil Rack, (Univ. of TN)
  - Anne Lazarides (Northwestern)
  - Hans-Peter Wagner (Univ. Cinn.)
  - Jan Yarrison-Rice (Miami of Ohio)

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2. Collaborative strengths

- **Equipment**
  - **Laser facilities (Vanderbilt, Ga. State, Univ. Cin., ORNL)**
  - **Nanofabrication facilities (ORNL, Vanderbilt, Ala-Huntsville)**
  - **Ion beam synthesis and characterization (ORNL)**
  - **Film growth capabilities (ORNL, Ga State, Univ. Fla, Univ. Cin.)**
    - **PLD, MO-CVD, MJ-CVD, PE-CVD, HP-CVD, oxide MBE, organic MBD, solution growth, Sputtering and evaporation**
    - **Cluster tool for silicon processing**
  - **Chemical synthesis (ORNL, Ga. Tech, Vanderbilt)**
  - **Materials characterization (All)**
    - **TEM, AFM, STM, x-ray, ellipsometry, NSOM**
- **Methods/expertise**
  - Ultra-fast laser spectroscopy
  - Nanosynthesis and characterization
  - Nonlinear, quantum, and classical optics\
  - Theory: (many-body, EM) and computational methods

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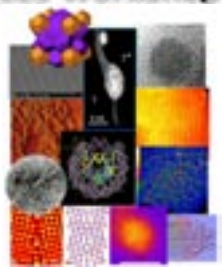
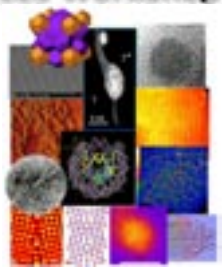


3. Collaborative needs

- **Equipment and infrastructure (buildings, facilities)**
  - Nanophotonics lab with femtosecond laser system and automatic fiber aligner
- **Theory / modeling / simulation support**
  - This will be done by principal investigators; need access to ORNL supercomputer
- **Special nanofabrication support**
  - ICP etcher (materials other than Si)
  - Dual-column FIB; Interferometric stage
  - Cathodoluminescence
  - Interferometric microscopy
- **Special neutron environments**
  - None



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4. University / other external "champions" for the RFA

- Richard Haglund (Vanderbilt)
- David Norton (Univ. of Fla.)
- Greg Nordin (Univ. of Alabama, Huntsville)
- Marc Stockman (Ga. State)
- Mostafa El-Sayed (Ga. Tech)
- Peter Delfyett (CREOL)
- H. John Caulfield (Fisk)

5. ORNL champions for the RFA

- Gerald E. (Jay) Jellison SSD
- Yehuda Braiman CSMD
- Mike Barnes CSD
- Marc Simpson ESTD

6. Possible interactions with other national or regional centers

- Georgia Tech Nanoscience Center
- Advanced Light/Photon Source
- CREOL

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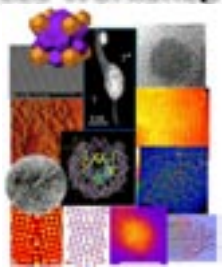

7. Collaborative research proposals to "jump start" CNMS' scientific program

- Presently negotiating a CRADA with a start-up company on sub-wavelength structures
- DOE NSET funded projects at Georgia St. and Vanderbilt