DARPA Workshop
WDM for Military Platforms
April 18, 2000

Robust WDM Components, Packaging, and Integration

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<u>Outline</u>

- **Application/System Level Motivation**
  - **military**
  - **commercial**
- **Requirements**
- **Technology Enablers**

Applications and System Motivation

- Multi-sensor networks
  - Military: flight control
  - Commercial: controlling critical environments

- Security: use multiple wavelengths to ensure channel separation

- Interconnects
  - Military: increased reliability via reduced number of connectors
  - Commercial: 10 Gbps Ethernet and beyond

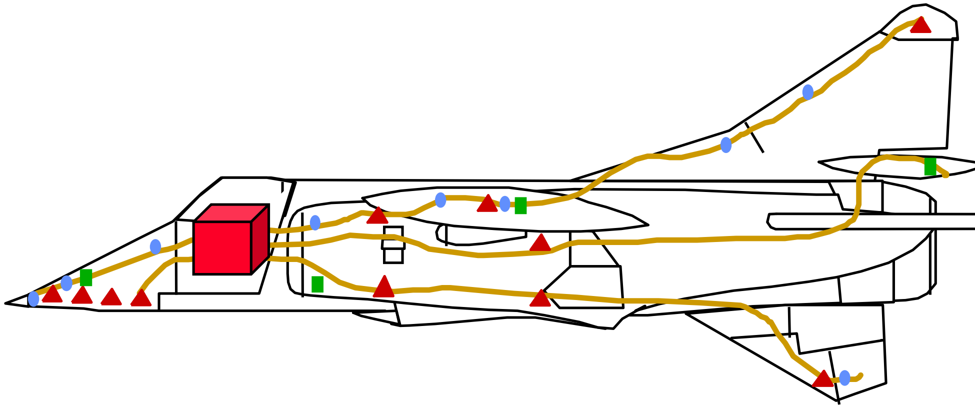
Likelihood of Commercial Volumes for WDM

Coarse WDM proposed to IEEE 802.3ae committee for 10 Gbps Ethernet

- **multimode fiber to minimize cost over short distances (100 - 300m)**
- **both 850nm and 1300nm proposals**
- **4 channels at 3.125 Gbps**

Optically Addressed Sensor Networks

- **The need:**
  - Vehicle management systems/condition based maintenance systems require many sensors, with hundreds of pounds of associated wiring
  - Sensors need to tolerate high temperatures, electrically noisy environments
  - Sensing multiple parameters (temperature, strain, vibration, etc.), widely distributed across vehicle
- **Mission benefits of optically addressed sensor networks**
  - Condition based maintenance-improved maintenance efficiency, reduced downtime, increased safety
  - Reduced weight means increased range/fly time for UAVs
  - Improved vehicle performance and maneuverability with improved flight control



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Optically Addressed Sensor Networks

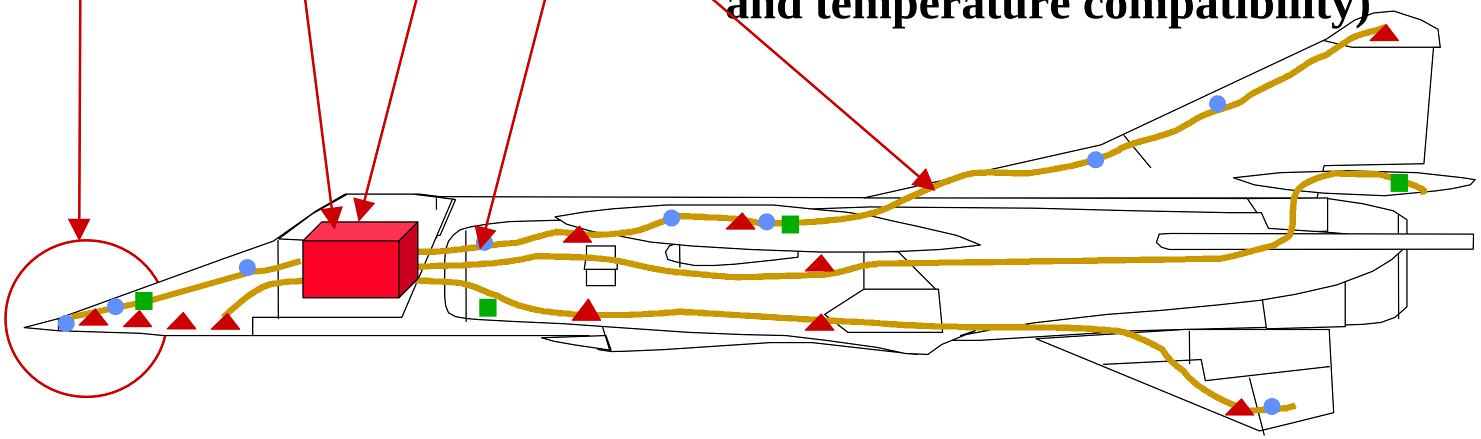
1. ORIMS for wide temperature range operation

2. Optical fiber networks allow remoting of temperature sensitive optoelectronics and electronics

3. WDM allows reduction in number of cables

4. Optical couplers for interfacing with sensors and for networking (diffractive and/or integrated optics)

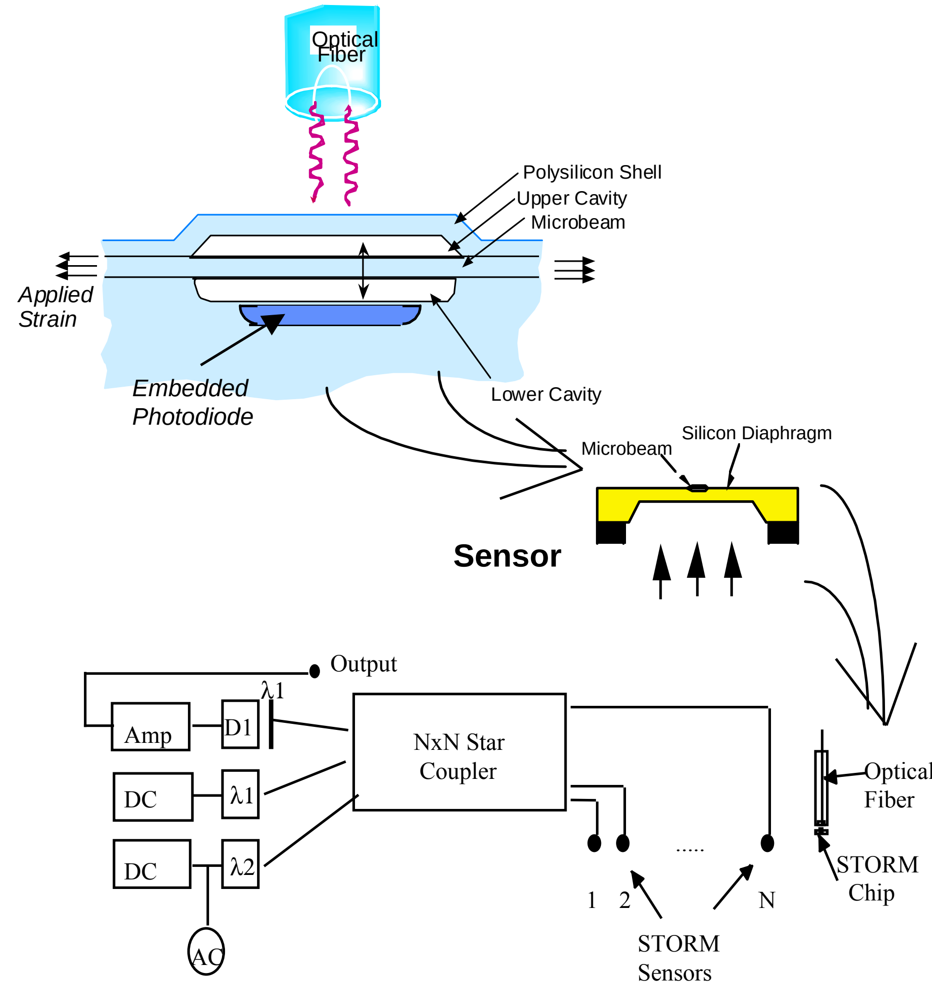
5. Fiber network design (built-in redundancy and temperature compatibility)



MEMS and WDM Photonics Technology Enable Optically Addressed Sensor Networks

MEMS: Optical Resonant Microsensors

- Flexibility
  - multiple sensor types
  - plug-and-play potential
  - expandable
- No electronics or power at sensor node
  - non-incendiary
  - compatible to harsh environments
  - EMI immunity at sensor
  - reduced sensor node cost



Optical Network

Optical WDM networks

- Reduced cabling weight and volume
- Wavelength routes to a node, frequency domain used to distinguish different at node

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Networked Photonic Sensing

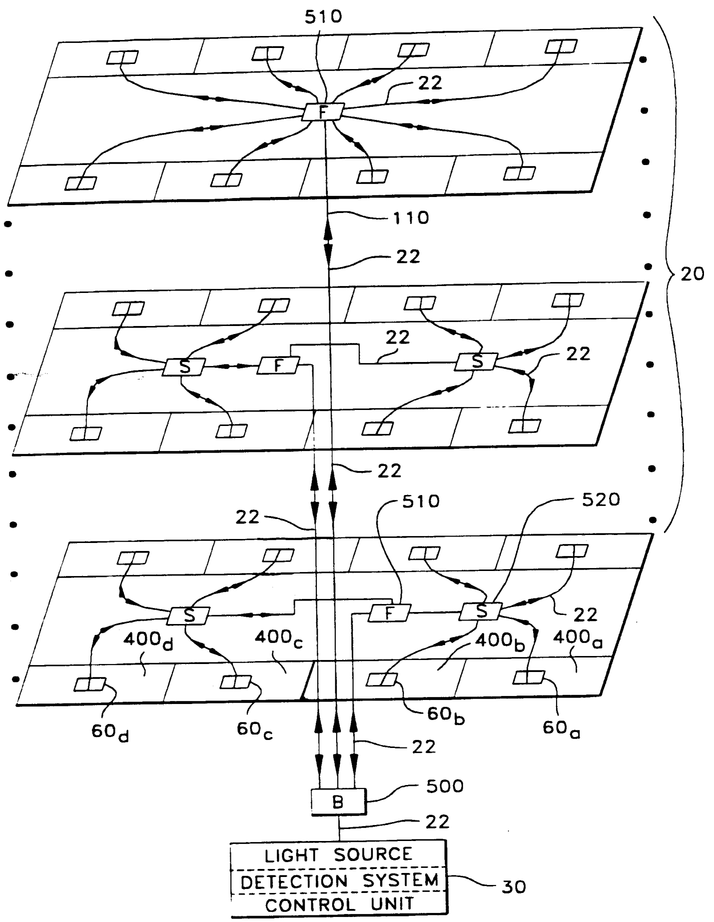

FIG. 2

- **Uses network topology and routing concepts**
- **More powerful concept than multiplexing yet simpler to apply and more flexible.**
- **Usable with virtually all optical sensor types**
- **Expandable design with ability to lower cost of sensing by a factor of 10 to a 100!**
- **Takes advantage of emerging "all optical" network technology and components**

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Critical Spaces Applications

- **Laboratories and General Spaces**
  - Hazardous gas, VOC, bacteria detection
  - Demand controlled ventilation
  - Automatic (and repeatable) fume hood containment testing
  - Room occupancy detection (CO_2)
  - Room and duct static pressure measurement
- **Animal Research Facilities**
  - Detection of allergens (ammonia)
- **Clean Rooms**
  - On-line particulate monitoring

Requirements and Implications

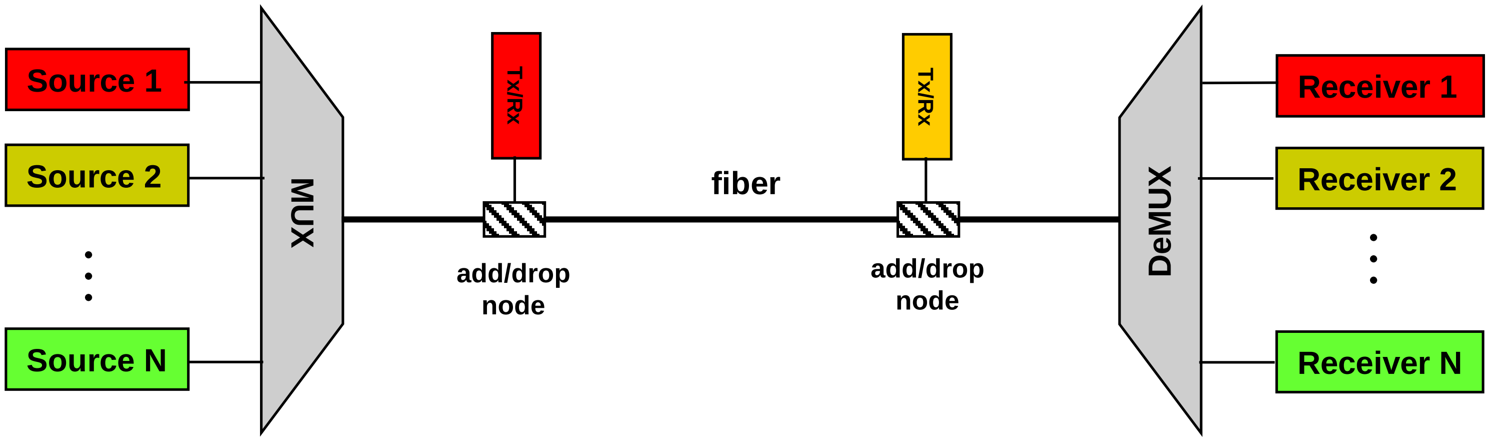
Requirements

- Low cost
- Large temperature range
- Temperature insensitivity
- <100 meter link lengths
- Compact
- Standard supply voltage, <3.3, 5V
- Switching times
  - msec for sensors
  - nsec for data

Implications

- Multi-mode alignment tolerances, integration
- Coarse WDM
- VCSEL wavelength shifts 4X slower
- Active, tunable compensation
- Multi-mode fiber, 850nm sufficient
- Monolithic and heterogeneous integration
- Limits MEMS applications, or requires new approaches to MEMs
- MEMs will work
- Need non-mechanical approach

Candidate Enabling Technologies for WDM



MUX/DeMUX/Add-Drop

- diffractive elements/gratings
- photonic bandgap devices
- MEMS

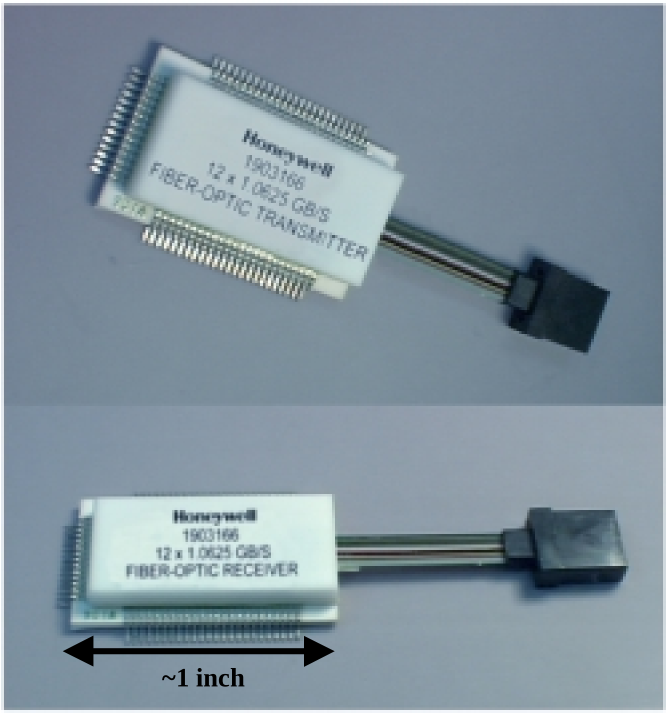
Sources

- VCSEL
- PBG μ-cavity laser
- resonant reflective filter
- heterogeneous integration

Receivers

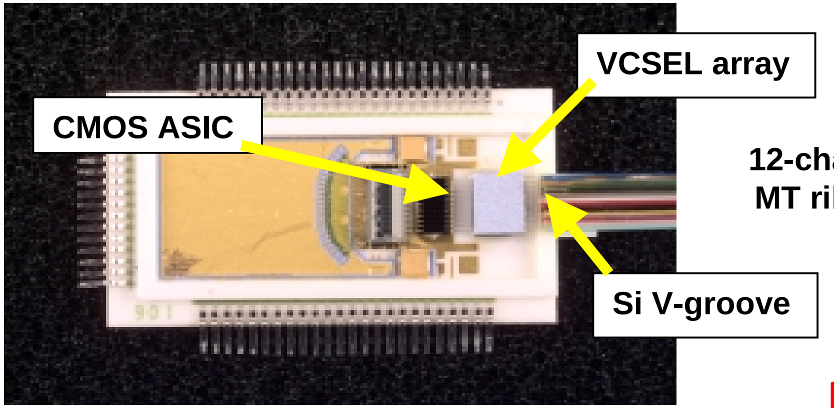
- dielectric filters
- resonant reflective filter
- photonic bandgap devices
- heterogeneous integration

OMNet-Derivative Parallel Optical Data Links



Overview

- Internally Developed at HTC for Ruggedized Applications
- Engineering Prototypes Delivered to Potential Users for Evaluation
- TX Module: 1x12 array of standard MicroSwitch 850 nm VCSELs with Helix HXT 2000 ASIC
- RX Module: 1x12 array of MicroSwitch GaAs PIN detectors with Helix HXR 2012B ASIC
- Silicon V-groove Fiber Interface with Metallized-angle Polish
- Low Profile Package
- Standard MT Connectors, Fiber Ribbon (250 μm pitch)
- Tested up to 2 GHz per Channel



12-channel
MT ribbon

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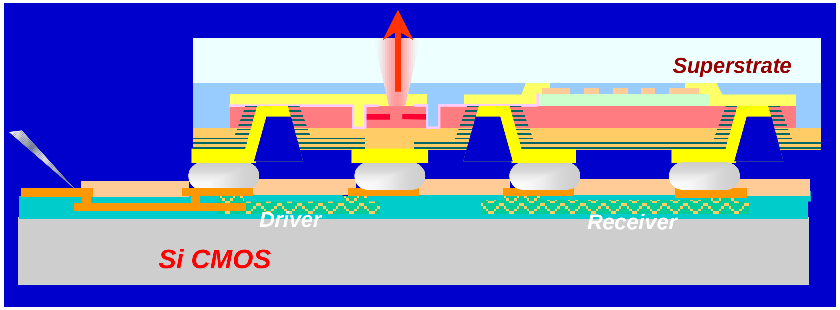
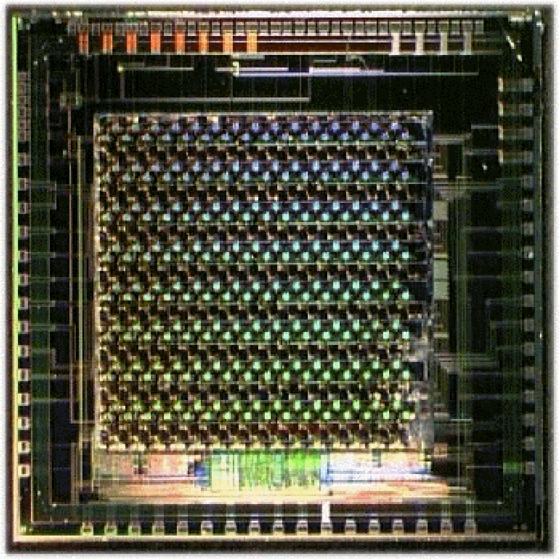
Smart Pixel Array with Heterogeneous Integration



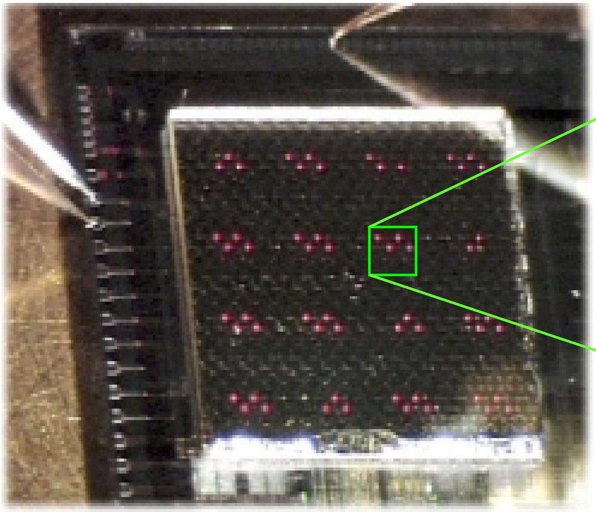
2D OE array bump-bonded directly on top of a Si-CMOS ASIC chip

4 mm

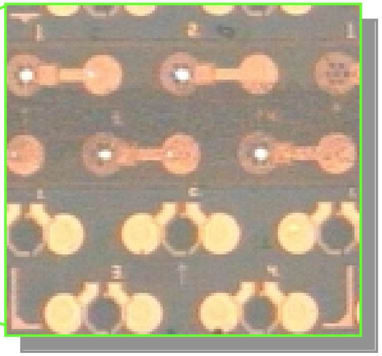


An 256 VCSEL and 256 PD array integrated with a Si-CMOS ASIC.

4x4 clusters (64 VCSELs) <u>powered</u> through the AISC



850nm VCSEL lights are perceived as red on a 3-chip CCD camera.



Four active VCSELs in a unit cell light up, captured by a single-chip CCD camera.

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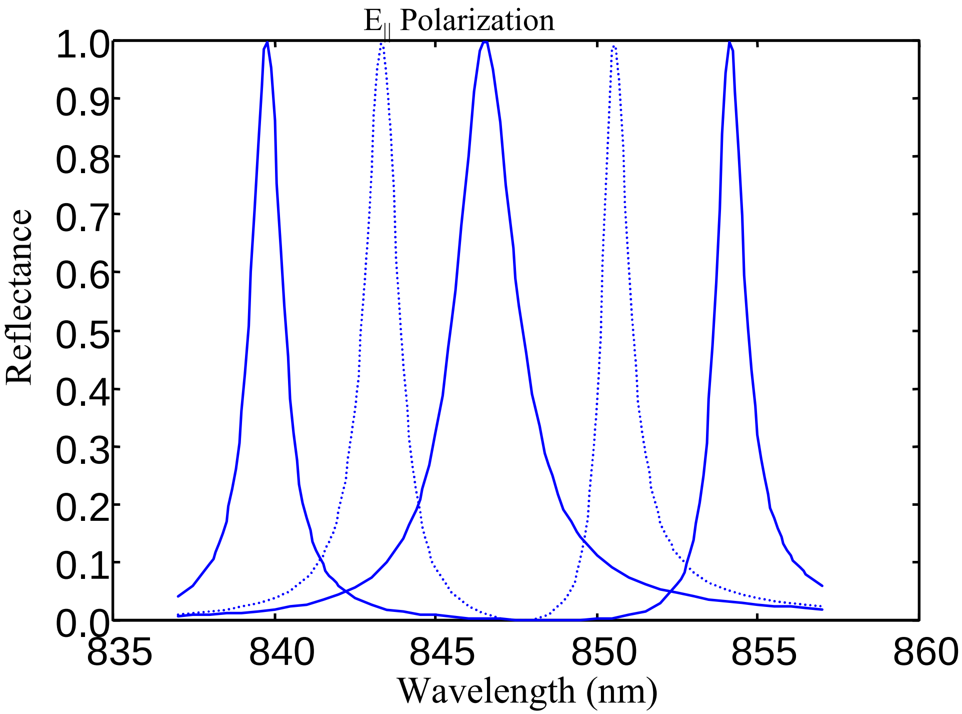
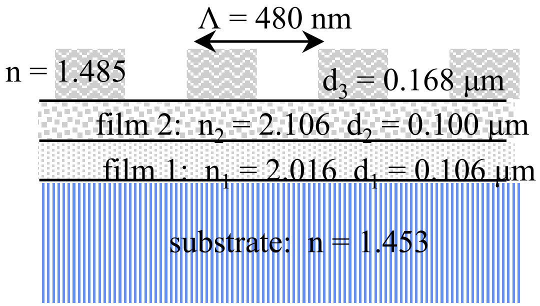
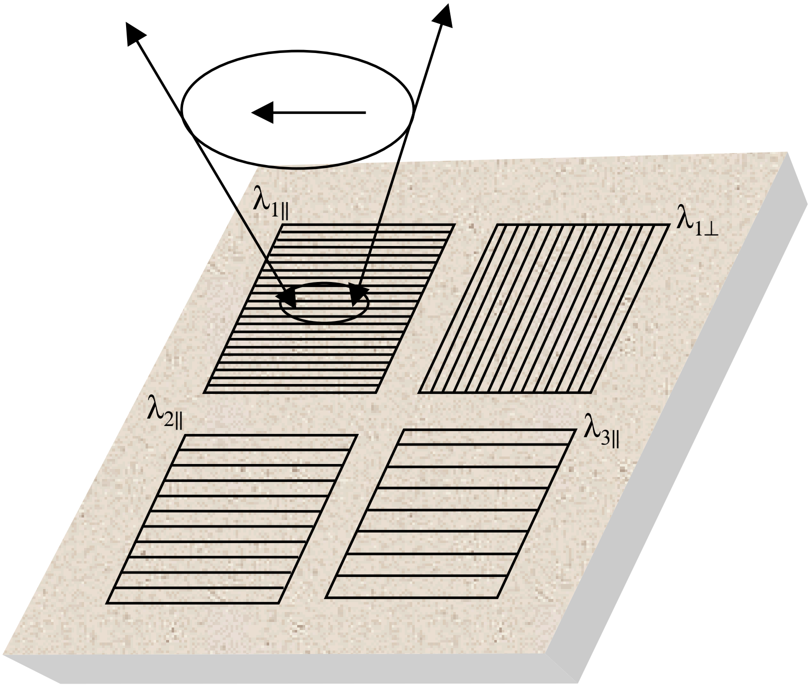
Guided-Mode Resonant Filters for Optoelectronic Devices
Wavelength/Polarization Division Multiplexing







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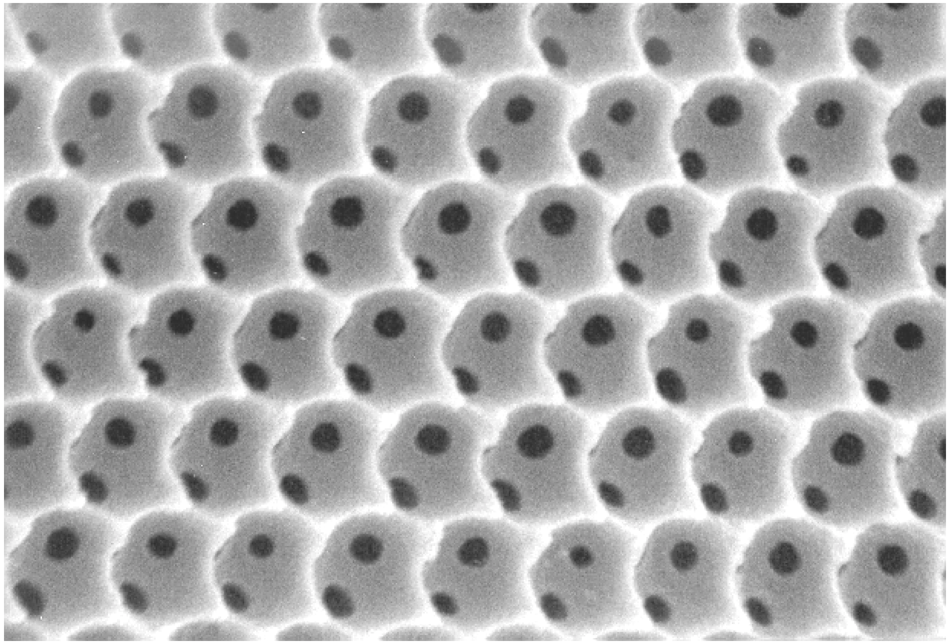
Opal Structures with 3D Photonic Bandgap



SEM micrograph showing inverse opal structure fabricated by self-assembly

Visible Regime

- Optical Switches
- Low threshold laser

Funded under NEDO Grant on tunable photonic crystals

Infrared Regime

- Mirrors and filters
- IR camouflage
- IR Electrochromics

Funded under MURI Grant on IR Camouflage

Microwave Regime

- Tunable phase shifters
- Adjustable antennas
- Phased-array antennas
- Attenuators

Funded under Honeywell program on phased-array antennas

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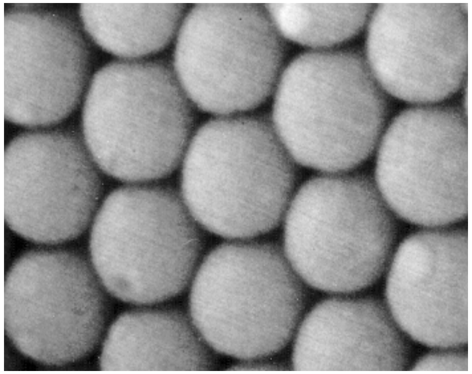
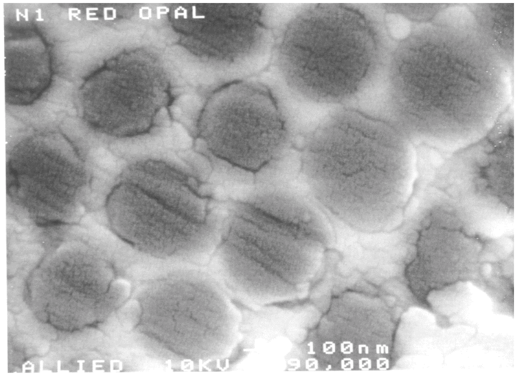
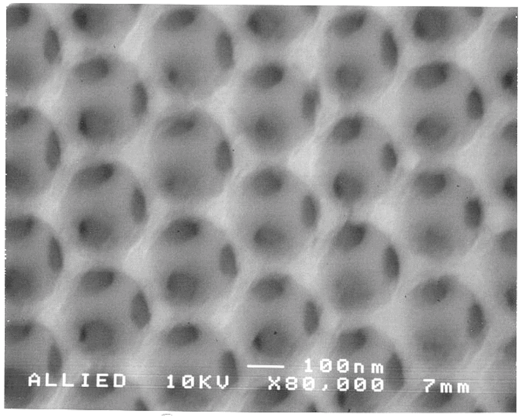
Opal Structures: Fabrication & Features



Porous silica FCC Opal



2-component nanocomposite



Inverse opal photonic crystal

Materials

- Semiconductors
- Polymers
- Metals
- Magnetic materials
- Thermoelectrics

Features

- Tunable 3D lasing
- Tunable photonic crystals
- Metallicity gap in IR
- Anomalous coherent backscattering

Collaborators

- Eli Yablonovitch (UCLA)
- Sajeev John (U. Toronto)
- V. Vardeny (U. Utah)
- J. Whiley (DARPA)

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Summary

- Transition of optoelectronics from telecom to datacom required technology development

- The same will be true for WDM for LANs and SANs

- Military applications may leverage commercial CWDM but will have special reliability and ruggedization req'ts

- Widespread Acceptance Requires both Cost Reduction and Volume $\rightarrow$ technology development