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# Rockwell Science Center (RSC) Technologies for WDM Components

DARPA WDM Workshop  
April 18-19, 2000

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**Rockwell Science Center  
Thousand Oaks, CA**

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                            | Form Approved<br>OMB No. 0704-0188          |                                    |
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# Introduction

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- RSC has been a center of excellence for more than 20 years, performing R&D on components applicable to telecomm, e.g., sources, detectors, high speed microelectronics, and other components
- Technology transition to former Rockwell businesses (e.g., Conexant Systems, ROK/NTSD to Alcatel), and spin-offs (e.g., Vitesse )
- New RSC initiatives target R&D and business opportunities, including those related to WDM and telecomm, for military and commercial applications

# WDM Offers Significant Benefits to the Military

## Examples of Applications

- Communication
  - Fiber Optic
  - Free Space Optical
  - Fiber & Free Space
  - Multi-Mode (RF & Optical)
- Replacing Wires on Military Platforms (Advantages: Weight, Size, Cost, Low/No EMI)
  - Sensors
  - Data
  - Control
- Others

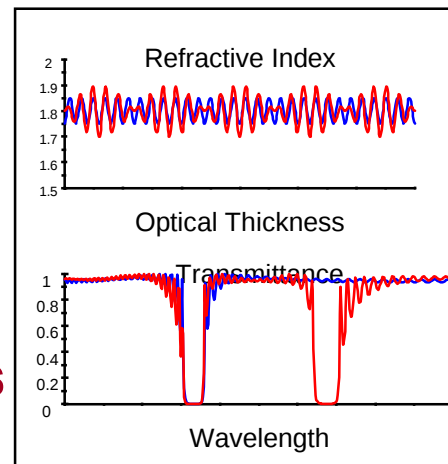
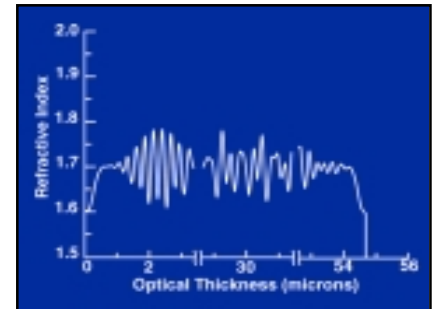
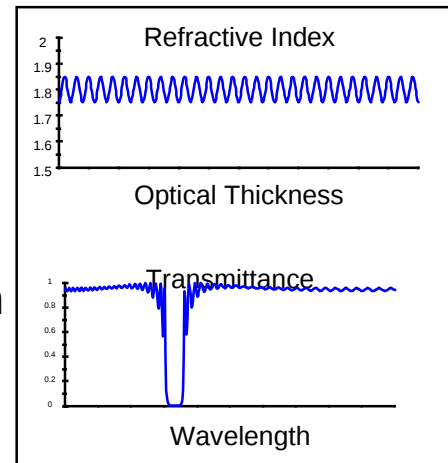
## Technology Requirements

- DWDM
- Switching / Routing
- Infrastructure for Higher Speeds (e.g., 40 Gb/s)
- Fiber Dispersion Compensation
- Wide Band / Multi-Band WDM
- Beam Steering
- Eye Protection
- High Performance Vs Cost
- Robust & Affordable Components
- .....

# “Rugate” Technology for Spectral Control

## • Rugate Technology

- Sinusoidal index profile(s)
  - Allows exquisite control of reflectivity and bandwidths for single or multi-line filters
  - Multi lines are integrated, not stacked
  - Graded index “Quintic” profile provides optimum index match to surrounding media
  - Apodization reduces sidebands near reflection peaks
  - Fabrication requires extreme control on index profile
  - Suitable for non-conventional WDM
- **An AFRL concept that has proven to be a powerful method for spectral control**
  - **RSC is the technology leader in rugates and related developments**
  - **Physics of rugates is related to (1-D) photonic bandgap materials**



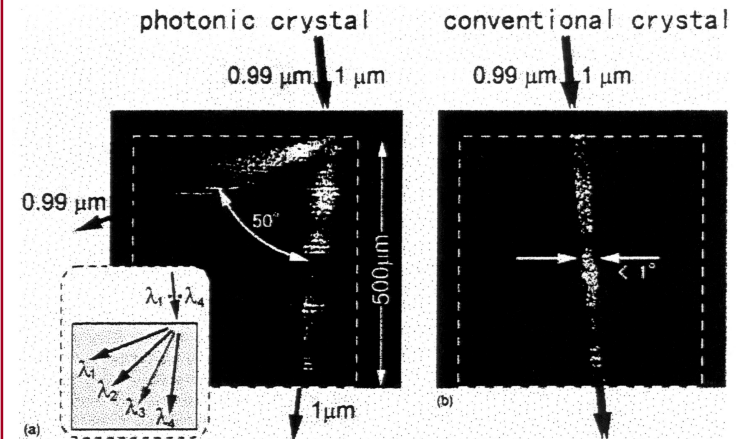
**Rugates + many  
other thin film &  
optical components  
are now RSC  
“products”**

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# Photonic Crystals Offer New Capabilities for WDM

## Photonic Crystal “Super-prisms”

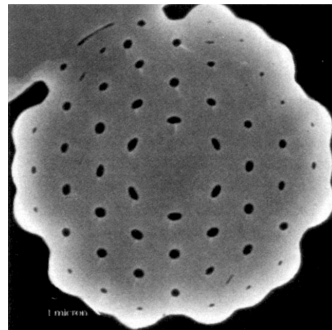
- Periodic structures with special properties
- Much larger (10-100X) dispersion than ordinary materials
- Super-refraction ( $\sim 10X$ ) allows construction of new optical devices
- Offer promise for new WDM & related applications



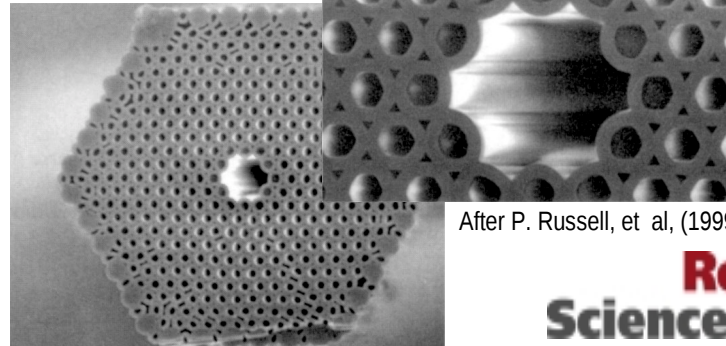
After H. Kosaka, et al, (1999) JP

## Photonic Crystal Fibers

- Can confine light with or without photonic bandgap
- Single mode over much larger wavelength range
- Larger volume allows higher optical powers



After P.J. Bennett, et al (1999)

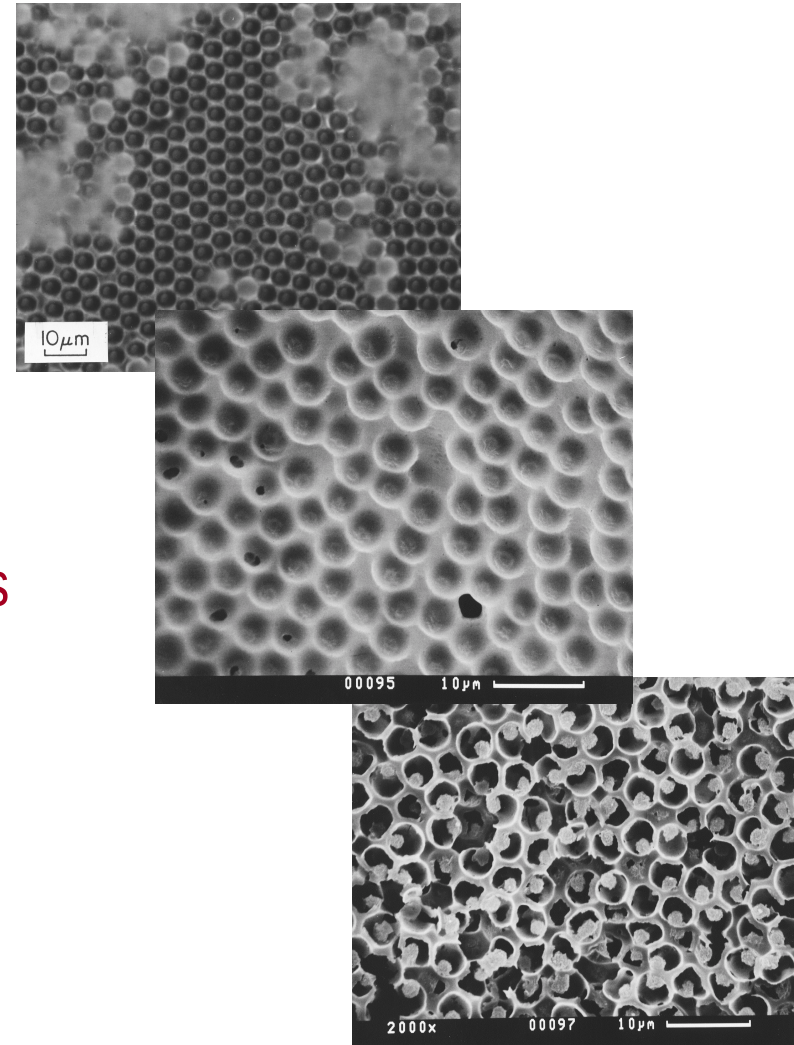


After P. Russell, et al, (1999)

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# RSC Interests in Photonic Crystals

- Substantial history of RSC efforts in photonic bandgap materials and devices for microwave regime
- Recent focus on IR/Visible
- Collaborating with universities in structure design (UCLA, MIT)
- RSC material development approach is focused on self-organized materials
  - Dielectric
  - Metallized dielectrics
  - Tunable
- Applications (including WDM) drive RSC materials efforts



# WDM and optical Switching Technologies

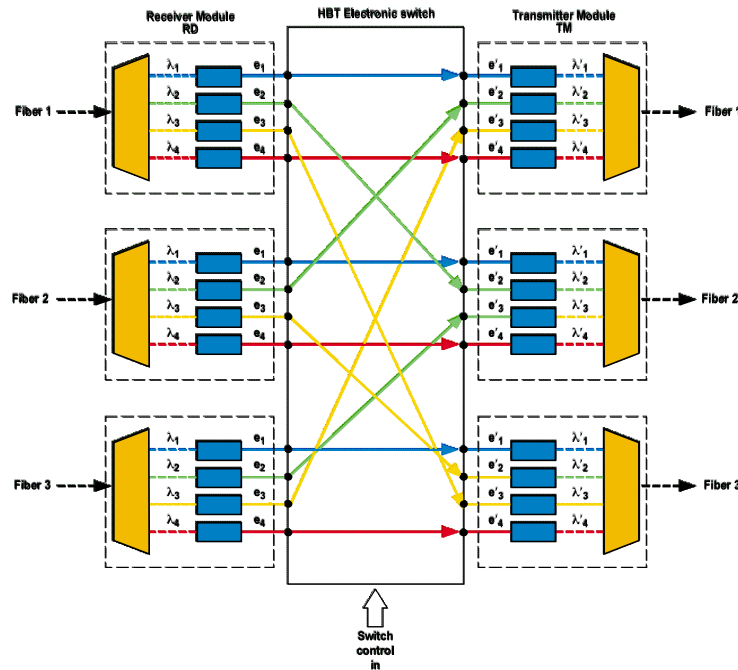
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## Some RSC Contributions:

- OFCS 1986-1989
  - 16x16 Optical fiber crossconnect
- ONTC 1993-1995
  - All Optical WDM Network Consortium
  - Developed all optical switching and components for WDM
- NTONC 1996-Present
  - National Transparent Optical Network
  - Exploratory High bandwidth WDM network
- WEST 1995-1998
  - WDM network switching using electronics

# WEST Program (120 Gb/s Optical WDM Cross Connect Switch)

## WDM with Electronic Switching Technology



### Cross Connect Configuration

- 3x3 fiber switch
- 4 channels/fiber
- 10 Gb/s/channel

### Electronic Switch Core

- OC192/OC48 compatible

### Optical MUX/DEMUX

- ITU WDM channels

### Key Technology

- Rockwell GaAs HBT
- Ortel DFB Laser/PIN

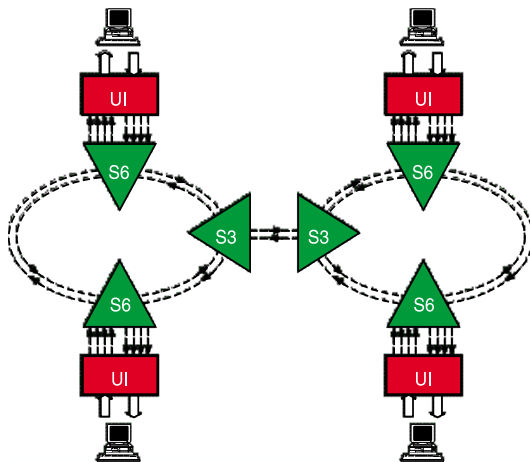
### Advantages of an Electronic Core

- Data regeneration/retiming
- Wavelength translation
- Low crosstalk
- OC192/OC48 compatible
- Realizable with current state-of-the-art production technology
- Potential for additional processing of input signal (smart switch)

# Advantages of WEST Switching Approach & Challenges for All-optical Approaches

## Advantages:

- Easier to monitor
- Inherent Fault Localization
- Fast Switching
- Quasi-Optical Layer Protection
- Enhanced Compatibility



## Applications:

- **WDM Network cross-connect**
  - OC-48 or OC-192 systems
  - Cross-connect switch
  - Wavelength translation
- **Bi-directional SONET ring**
  - Add/drop (S6)
  - Ring interconnection (S3)
- **Distributed Computing**
  - 40 Gb/s/fiber
  - 40 Km distance
  - Connect Caltech/JP
  - Supercomputers

# Summary of WEST Accomplishments

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- **3x3 WDM cross-connect system based on electronic switching**
- **ICs, optical devices, and modules for 4x10 Gb/s and 4x2.5 Gb/s lightwave transmission**
  - **ICs are currently in production**
- **120 Gb/s 12x12 cross-connect switch IC, packaging, and module**
  - **Switch ICs and design innovations are now embodied in Commercially available products**
- **WDM link models and simulation tools**
  - **Simulation software now a successful product**

# Concluding Remarks

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- **Multi-disciplinary RSC technologies for WDM components and applications:**
  - Optics, Photonics, Rugates, Cavity Filters, Micro-optics, Liquid Crystal Components & Devices, MOEMS
  - High Speed Microelectronics, Switch ICs, WDM Cross-connects, High speed Opto-electronics, MEMS
  - Key technology partnerships (e.g., Conexant, Boeing, Universities)
- **RSC activities range from basic R&D to (selected) low volume production ---- <http://www.rsc.rockwell.com>**
  - Interested in WDM with both fiber optic and free space comm
  - Interested in a number of other dual use applications of WDM
  - RSC efforts emphasize state-of-the-art and new approaches (e.g., WEST, “super-prism” effects)
- **IR/visible Photonic Crystals offer important new capabilities for potential WDM and other applications**