**Report Documentation Page**

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
WDM uses multiple wavelengths of light to increase the *bandwidth* and architectural *flexibility* of a fiber optic networking system.

Commercial products available today:

- 2 to 100+ wavelengths (DWDM/CWDM)
- > 400 Gb/s capacity

*BACKGROUND*

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Evolution of IP Photonic Networks

**BACKGROUND**

Along with Ethernet technology, WDM technology will become prominent in Metro Area Networking (MAN) and Local Area Networking (LAN) topologies.

Military platform networking most resembles the MAN environment with high priority on Quality of Service (QoS).

Trend towards less network management

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<thead>
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<th>2001</th>
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<tbody>
<tr>
<td>IP</td>
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<td>SONET</td>
<td>10Gb Ethernet</td>
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<td>SONET</td>
<td>WDM</td>
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Level 3 and below
Research and Development
– Components
– Applications, e.g., CWDM Ethernet; optical packet switching

Narrow band laser transmitters / VCSELs
Optical multiplexers / demultiplexer
Fiber Bragg gratings
Narrow band optical filters
External modulators
MEMS devices

Photodiode receivers
Optical amplifiers
Add-drop filters
Wavelength converters
Optical switches
Integrated optical circuits

Commercial implementations
– mature technology for long haul high bandwidth networks (DWDM)
– recent commercial implementation in MANs and SCM access
– many system implementation competitors (Lucent, Nortel, Ciena, AT&T,..)
– many component suppliers (JDSU, Corning, Lucent, Nortel, Alcatel, Agere, …)

Military can leverage on commercial WDM investment
– future bandwidth requirements
– additional Navy/DOD requirements and applications

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Military WDM Technology

A few areas of military WDM interest:

- Network ruggedization
- Mixed signal antenna networking
- Optical signal processing
- Optical domain microwave filtering

Need to differentiate required technology from ongoing commercial activities

Need to differentiate required technology from DARPA AOSP Program requirements
Need for Advanced Mixed Signal Optical Networking

Current Optical Networking Technology

High-speed digital networks
- 10 Gb ethernet
- WDM with >100 channel throughput

High-speed RF networks
- Low loss microwave fiber optic links
- High dynamic range links
- >40 GHz bandwidth available
- Sub-Carrier Multiplexing (SCM) [CATV, MAN]

Future Military Optical Networking Vision

High-capacity mixed signal SCM/WDM fiber-optic networks satisfying Military Vision 2020 platform requirements.
SIGINT/RADAR/COMMS: >80 dB SFDR typical with close to thermal limited RF detection

Wideband military requirements much more demanding than commercial applications that require either Fidelity at high input RF powers (CATV) OR Sensitivity with lower dynamic range (Wireless Remoting)

Can military RF signals share a common WDM backbone network with digital signals???

RF Network Components
- Modulators (efficiency, linearity, bandwidth)
- Lasers (DFB; FP; VCSEL) (power, efficiency; amplitude noise, linearity, bandwidth)
- Receivers (efficiency, power handling)
- Fibers (MMF; SMF) (modal, polarization, and chromatic dispersion)
- EDFAs (noise figure, optical bandwidth)
- MUX/DEMUX/ADD/DROP/COUPLERS (loss, isolation, polarization sensitivity)
- Switch Arrays (loss, isolation, polarization sensitivity)
Network accommodates ANALOG and DIGITAL signaling
Useful for Vision 2020 military networks and multifunction antennas
Sensor and network information available in real-time on demand
WDM provides increased flexibility, reduced installation & servicing time

Remaining R&D Challenges:
1. Improved **Analog WDM** fiber optic link performance
2. **Integration & Packaging** of SCM/WDM link components
Future Shipboard Networking
Connections via WDM backbone

ETHERNET
- S - Switch
- R - Router
- H - Hub
- N - Node

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Microwave Photonic Signal Processing
System Capabilities

- Optical Domain RF Frequency Conversion & Filtering
- Optical True-Time-Delay (TTD) RF Beamforming
- Fiber Optic Delay Line RF Signal Processing

Military RF System Insertion Targets

Communications, Radar, Navigation, & Electronic Warfare Systems

Airborne & Space Platforms
Army, Navy & Air Force

Maritime Platforms
Navy

Ground Platforms & Facilities
Army, Navy & Air Force
Optical Domain Microwave Filtering
(All Optical Superheterodyne Receiver)

- Eliminates need for electronic mixer (reduced front-end complexity)
- Incorporates pre-selector filtering in optical domain
- Builds upon commercial DWDM telecommunications and millimeter-wave fiber-radio system technologies
Microwave Photonic Signal Processing
Example

WDM Based Signal Processors

- RF PHOTONIC FRONT-END TRANSVERSAL FILTER
- WIDEBAND OPTICALLY MULTIPLEXED TTD BEAMFORMING ARCHITECTURE

- Wavelength dispersive signal processing architectures
  - Fast tunable lasers
  - Broadband optical sources

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Enabling WDM Component Technologies

WDM-Based Building Block Examples:

- High channel isolation (>40 dBo), polarization independent passive components
- Fiber Bragg Grating (FBG) arrays
- High-speed (<1 µsec) tunable optical filters
- Optical domain tunable microwave filters
- High-performance digital/analog WDM transmitter arrays
- High power, low noise, wavelength selectable laser diodes
- High-speed tunable lasers (continuous and discrete)
- High power, spectrally equalized supercontinuum optical sources
- Optically broadband E-O modulators/switches
- Low loss WDM optical switching arrays
- Ruggedized Erbium Doped Fiber Amplifiers (EDFAs)

Proposed Program Goal: Integrated WDM Modules & Functionality

Grand Challenges

Low cost
Size, weight and power
Environmental stability

Advanced Fabrication, Integration & Packaging