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FIBER OPTICS WAVELENGTH DIVISION MULTIPLEXING(COMPONENTS)

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Long Term Objectives:	Develop optical multiplexers/demultiplexers, different wavelength and modulation stable semiconductor lasers, high data rate transceivers and test and evaluate in fiber optic networks applicable to Space Station
Importance of Problem:	Information networks for space data systems require high data rate and high data capacity which can be expandable and fault tolerant. Fiber optics wavelength division multiplexing provides all of these options through the multiplicity of wavelengths available.

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Related R & D: Comments related to other R & D in this area has been obtained from AGED "C" reviews, Tri-Service Working Group on Fiber Optics, Published Literature and Private Communications.

Optical Multiplexer/ Demultiplexer Technology: DOD/RADC through contract to ITT has demonstrated a twelve channel point to point mux/demux with an insertion loss of 8 dB and a cross talk of 17 dB. LaRC evaluated device for RADC independently of contractor. Current status-design being improved. This device works in 1.3 micrometer region and has 15 nanometer spacing between channels.

Boeing/Martin Marietta have laboratory experiments with six channel mux/demux systems. PTR supplied device to Boeing with approximately 5 dB insertion loss and cross talk in 15 dB range and a channel spacing of 20 nanometers. JDS (Canadian Co.) supplied Martin Marietta with a six channel device with a 2.5 db insertion , approximately 20 dB crosstalk and 25 nanometer channel spacing. All channels in 1.3 micrometer region.

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Related Technology:

Optical Multiplexer/ Demultiplexer Technology:

BTL performed a "hero" demonstration of a point to point 10 channel system operating at 2 nanometer channel spacing (possibly 20-30 dB cross talk), no insertion loss given, while operating the data system at 2 GBits. System used 1.5 micrometer DFB semiconductor lasers.

Instruments S.A. (Metuchen, NJ), a subsidary of a French company(Jovin), reported a 49 channel device at the SPIE(8/85) in San Diego. Discussions with the author revealed a device cross talk of 15 dB, channel spacing of 1.2 nanometer but only with a matched mux/demux pair in point to point data systems. Data Rate was 50 kBits in the 0.8 micrometer region of the spectrum.

Quante Corporation used a NEC filter type mux/demux with 3-4 dB insertion loss and 15 dB cross talk in a four wavelength system in 0.8 micrometer region of the spectra. Channel spacing was 30 nanometers. Quante also announced a system in the 1.3 micrometer region using single mode fibers. The original work was done for the German post-office.

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Related Technology:

Semiconductor Lasers:

Distributed Feedback Semiconductor Laser Technology has mainly centered around R & D in Japan and BTL in terms of demonstration of utility. Modulation rates up to 4 GBits were demonstrated in the laboratory with a 1.5 micrometer device by BTL. Japanese accomplishnments have been just as significant with an addition plus of a demonstrated lifetime of at least 10,000 hours without any wavelength shift.

Current R & D is being funded at RCA by NASA for Ridge Guide Device in the 1.3 & 1.5 micrometer region of the spectra.

DOD has funded a SBIR effort with General Optronics but no device announced.

Other Semi-Conductor Lasers:

RCA, General Optronics, Lasertron, & Laser Diode Laboratory are the main known suppliers of different wavelength lasers in the 0.8, 1.3 & 1.5 micrometer region. GTE, Ortel and Spectra Diode Labs. have been involved to a lesser extent. Twelve different wavelengths have been the maximum number supplied in any one wavelength region to date.

Related
Technology:

Transceivers: The DOD has a number of military qualified transceivers demonstrated up through 50 Mbits. Current RADC/NASA activity is addressing devices Military/Space qualified up through 200 MBits and available within a year. Transceivers are being breadboarded with military qualified components up through 1 GBit (NASA/RADC).

Commerical transceivers are available in various configurations and wavelength regions up to the 500-700 Mbit/sec(NRZ) range. BTL is planning on installing 1728 MBit transceivers/systems beginning in 1986.

DARPA is funding monolithic transceiver technology in GaAs material system with Honeywell and R. I. The Japanese have reported a number of integrated transmitter and receiver front ends(i.e. the integration of a laser or photodetector with a GaAs FET technology.

At least four companies offer foundry services for high speed front end circuit design for hybrid systems which is currently the most advanced and practical intermediate system.

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Related Technology:

Fiber Optics Networks:

Many point to point WDM systems have been demonstrated. Greatest number has been 12 by ITT in a RADC demonstration contract. Data rate only 40 MBits and no BER data(1.3 micrometer spectral region). Quante has a four channel point to point WDM data system running at 140 MBits (A commerical system). BTL demonstrated in the lab. the highest data rate, 4 MBits, in a 10 channel point to point single receiver set up.

A number of companies are looking at the "Star" bus approach but mainly in the labs. Noteably Harris, Martin Marietta, Lockheed and Boeing

Many companies have studies of the WDM technology looking at network approaches. Noteably GTE, Honeywell, Xerox, Mitre, RCA, TRW, ITT, etc.

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Technical Approach:	The technical approach has been a many faceted approach drawing from a combination of contract, military efforts, in-house and demonstration and application of the component technology.
Mux/Demux:	A combination of contracts for grating demux technology, direct procurements of best effort prism gratings, in-house interference filter demultiplexer design and participation in and evaluation of RADC & ERADCOM contract designs. Assessment of advances of technology from available literature and published reports. Objectives of all of the approaches has been to reduce the device insertion loss, decrease the optical spacing between channels and improving the cross talk isolation.
Semiconductor Laser:	A combination of contractural efforts, coordination with DOD efforts, and evaluation of contracturally developed devices and commerically available devices. Published literature and conference reported advances serve to assess progress and limitation. Insertion of devices into actual prototype applications also serves as a method of determining and assessing device properties and specific utility.

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Technical Approach:

Transceivers: Active transmitter and receiver designs have been a regular in-house activity to implement a variety of demonstration data networks. Coordination of work in this area has been with the Tri-Service Committee on fiber optics and industrial sources which have advanced the state of the art. Joint efforts have been with RADC to supplement NASA programs in this area.

Fiber Optics Networks: Components have been built into a variety of networks ranging from point to point, star and mesh types to demonstrate the performance of the devices. A central theme has been maintained in demonstration of the networks. That theme is to utilize the passive coupling nature of fiber optics and eliminate the need for repeaters. The idea of modularity and repeatibility of the network configuration with gateway type communications has also been implemented. Numerous discussions on the methodology to implement the technology have been held with DOD, industry, universities and NASA researchers.

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Technical Results and Accomplishments

Multiplexer/Demultiplexer Technology

Tested and evaluated three prism grating demulti- designs, one Rowland Grating design and one Littrow Grating design(RADC/ITT).

Semiconductor Lasers

Continued in-house evaluation and insertion program in transmitter design. Funded InGaAsP DFB laser development in 506 58 23 area.

Transceivers

Demonstrated in-house designed fiber optic transceiver operating at 500 MBits. Designed 0.5-2 GBit front end transceiver based on GaAs FET technology. Implemented 200 MBit transceiver program with RADC to develop military/space qualified version. Implemented 1 GBit military qualified bread board design program.(482 58 13)

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Technical Results and Accomplishments

Fiber Optics WDM Networks

Demonstrated components in an 8 channel star bus configuration using 810, 820, 830, 840, 1250, 1300, 1350 and 1500 nanometer wavelengths.

Achieved less than 10^{-10} bit error rate in 8 channel star bus with 0.8 and 1.3 micrometer wavelength system operating at 20 MBits and 500 MBits.

Demonstrated 32 node multi-mode fiber optics network operating at 500 MBits worse case condition with 10 dB excess dynamic range.

Designed 60 node single mode fiber optics mesh network based on 3 x 3 star couplers.

Initalized network within a network using WDM.

Progress towards planned milestones have exceeded estimations.

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HOW CURRENT RESULTS AND ACCOMPLISHMENTS WILL ENHANCE NASA CAPABILITY IN COMPUTER SCIENCE AND DATA SYSTEMS.

Current results demonstrate the WDM concept. Through its implementation more parallel channels of data can be transported with less interference, at higher data rates, with implementable fault tolerance approaches for self repairing. That networks can operate within networks that have a common physical connection. This thus provides a more powerful parallelism for network inconnection for an expandable and evolutionary data systems approach for Space Station

An example of this technology expansion capability using just 12 wavelengths and the 32 node fully connected star bus can be demonstrated. Twelve(12) mux/demux systems can be connected at each of 32 ports giving 384 transmitter/receiver pairs running at 500 MBits. Reducing data capacity due to some type of time sharing of the 12 individual networks within a network the data rate could easily be a composite total of 6 Gbits/sec. If the 500 MBit transmitter/receivers are electronic multiplexed and demultiplexed at the highest VHSIC data rate reported, 30 MBits, 17 VHSIC microprocessors could be accommodated at each of the 384 transmitter receiver pairs. This would provide an interconnect between 6528 VHSIC type processors capable of processing 6 Gits/sec of data.

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MAJOR MILESTONES

Demonstrate improved demultiplexer design with reduced insertion loss, increased channel spacing and reduced cross talk - 9/85

Continue to demonstrate components in networks both multi-mode and single mode optical fiber systems directed toward 2 MBits-2GBit/sec systems - 9/86

Demonstrate high performance WDM components (2 GBits) -9/86

Demonstrate DFB laser transmitter - 3/87

RESOURCE REQUIREMENTS	85	86	87	88	89
($k)	175	350	450	450	450
(MY)	0.5(2)	1.5(2)	1.5(2)	1.5(2)	1.5(2)

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Issues: Funding level, Space Station Qualification Requirement, Space Station Systems Requirements

Comments: All programs coordinated with DOD-Tri-Service Committee on fiber optics and AGED Working Group "C"

Publications/Presentations of Record - Invited Talk and invited paper onn WDM, 3 Conference Publications on WDM components/networks