Implementation of Multiple FDDI Networks Utilizing High– Density WDM Techniques

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1. ABSTRACT

High-densit y wavelength division multiple.xing offers an immediat e increase in transmission bandwitdh over existing optical fibers, A multiple FDDI backbone network, utilizing a multi-element, DFB laser diode array transmitter, is being developed as part of the Advanced Network Concepts Testbed project at JPL. in this paper, ANCT hardware development and syst em issues are described.

2. INTRODUCTION

Many advances have been made in network communications for integrated voice, video, and data services. As the number of fiber optic comm un ication link users is growing, and with it data traffic and bandwidth requirements, wavelength-division multiplexing (WDM) techniques, which have established themselves in niche applications over the past decade, are now finding wider acceptance. WDM technology offers not only the paralellism required to circumvent single channel electronic and opto-electronic switching speed, but also the implementation of multi—speed, multi -- backbone., networks. in recent years, high — density WDM techniques, which allow the transmission of multiple data channels within a narrow wavelength band, are becoming increasingly popular. in this paper we report on the ongoing Advanced Network Concepts Testbed (ANCT) program, which focuses on implementing multiple FDDI backbones on a single optical fiber. A novel, multi i-element, DFB laser diode array transmitter, developed at JPL, for high-density WDM applications is described.

3. ADVANCED NETWORK CONCEPTS TESTBED

The Advanced Network Concept Testbed (ANCT) program is aimed at providing scalable-- rate network technology for supporting multi – tier tactical bat tlefield backbone networks. The testbed is comprised of several Fiber Optic Tactical Local Area Network (FOTLAN)[1] nodes, interconnected over different wavelength channels, over a single optical fiber. In FOTLAN, developed in an earlier project for the U.S. Army CECOM, a custom 100 Mbit/s FDDI network interface unit (NIU) has been developed that incorporates- in addition to the conventions] host VME interface- a private streams bus to voice (T1, DNVT) and video (NTSC) interfaces. Up to 7 peripheral interface (9U VME) boards can be interfaced to the NIU board, for a total of 56 DNVT voice channels or 28 T1 voice channels, or 7 video channels or some combination thereof. The initial phase of the ANCT is directed toward developing a two -- node 3x100 Mbit/s FDDI experimental testbed, as shown in Figure 1, The various building blocks of the ANCT are described in further detail in the following sections.

WDM Transmitter

Laser Diode Sources: initially, discrete, pigtailed distributed feedback (DFB) laser diodes (LD) are being used as the light sources for the WDM transmitter. In parallel, a stepped

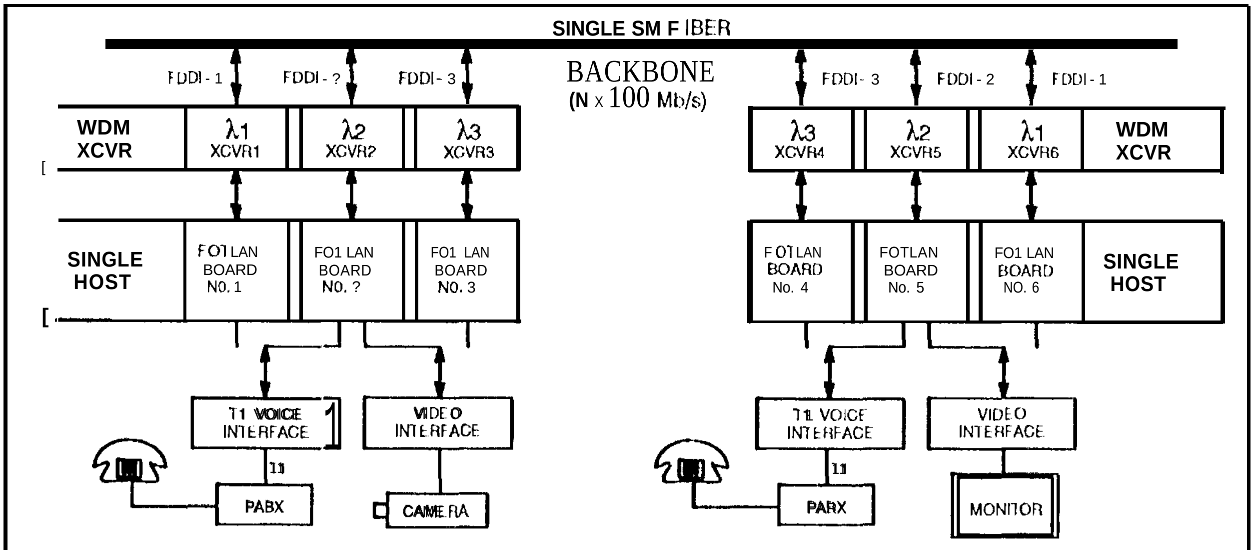

Figure 1: Advanced Network Concepts Testbed

wavelength, multi-element DFB LD array, is being developed by JPL's Micro Devices Laboratory (MDL). Operating at around 1550 nm, the initial array consists of four InGaAsP/InP strained-layer multiple quantum-well DFB LD elements, having a 5 nm wavelength spacing. The devices are grown on a single substrate and their physical separation is 250 pm. The optical power output of each LD is between 10 and 15 mW and their threshold currents and modulation depth are between 50-100 mA. The devices were designed to operate up to at least 1.2 Gbit/s. A second generation LD array will have a vertical grating monolithically integrated on the same substrate, allowing the combination of all output light beams onto a single emerging fiber, as shown in Figure 2. Four flat-polished, single mode fibers in a silicon v-groove assembly are actively aligned with the LD array elements achieving coupling efficiencies between 1% and 4%. Conically polished fibers and micro-lenslet arrays have also been tried to achieve a two-fold increase in coupling efficiency. The LD/fiber array subassembly is attached to a thermo-electric cooler (TEC), used to set and maintain the LD to within 0.01°C, anywhere between 0°C and 50°C. Although normally operating at room temperature, the TEC can also be used to perform temperature tuning of the LD array wavelengths, which can be shifted by 1 nm for each 10°C change in temperature.

LD Drivers: The 125 Mbit/s differential ECL signal, going from the FDDI chipset to the fiber optic transmitter is taken directly off the FOTLAN NIU board and is delivered to the high-speed board containing the 1.11 and LD drivers via a 50 Ω coaxial cable. Each one of the four LD drivers consists of a surface mount IC chip, modified with an external transistor, to

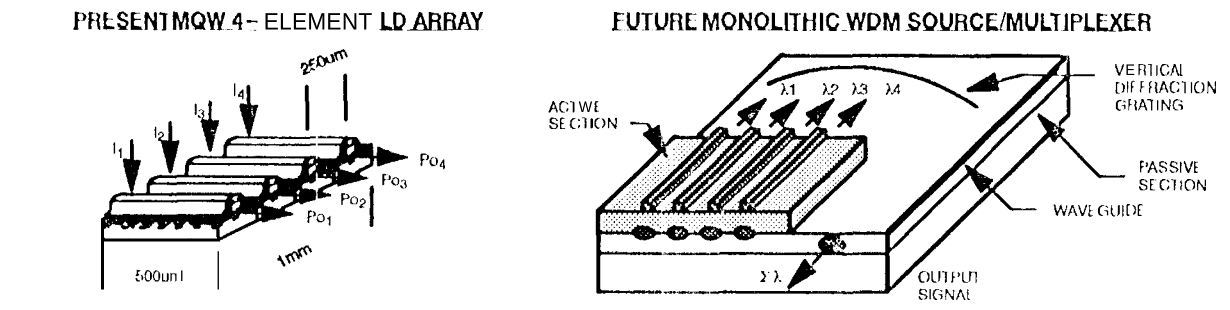

Figure 2: LD array - present and future designs

handle bias currents of up to 100 mA. The driver chip is directly connected to the LD, which has an impedance of around 3 Ω in addition, the board also contains the DC biasing circuitry, allowing the setting of LD threshold and modulation depth.

Fiber Optic Media

Optical Fibers and Couplers: The four individual fibers, aligned with the four LD array elements, are fusion spliced to a 4:1 fused fiber coupler, and a single SM fiber is now carrying all four channels sent by the WDM transmitter, in this arrangement, a 6 dB loss is incurred in combining the signals and another 6 dB are lost at the other end, where a 1:4 splitter is used to route the incomming data the individual FOTLAN NIU receivers. A 10 km, dispersion shifted, single mode fiber is utilized in the testbed. The components of one branch of the WDM link and their associated optical loss are depicted in Figure 3, below.

WDM Receiver

Receivers and Wavelength Tuning: The fiber optic receivers currently used on the FOTLAN NIU board have a sensitivity of -34 dBm at 125 Mbit/s, Each optical fiber, containing all data channels at different wavelengths, is first connected to an optical filter, in order to select a particular data channel. The ANCT configuration uses tunable fiber optic filters, each having a 3.5 dB insertion loss and crosstalk levels of less than --20 dB between adjacent channels which are 5 nm apart, For a LD optical power output of 10 mW and a link loss totalling 29 dB, the receiver input power is expected to reach -19 dBm, leaving a 15 dB margin in the optical power budget .

System Software

The FDDI Station Management software will be augmented to route the data onto an available fiber optic channel. in the event that higher bandwidth data transmission is required, two or more channels could be allocated for parallel transmission to the. same destination. in scalab]c-rate, multi - tier backbone networks a particular wavelength will be reserved for a particular transmission protocol, i.e. channel 1: FDDI, channel 2: SONET OC--3, channel 3: 1111'1'1, etc'. In this scenario the software will det ermine the transmission channel based on data packet size.

4. ANCT SYSTEM ISSUES

In order to realize a field deployable system, which has a multitude of channels (i.e. wavelengths), the following issues will need to be addressed:

LD Wavelengths Stabilization: The global temperature stabilization scheme, used in the current four-element LD array, will need to be augmented with injection current tuning of individual LD elements. As more channels are added, reducing the wavelength spacing between adjacent channels even further, this will provide a fine tuning mechanism for each LD element, providing a more accurate means of maintaining the channels' wavelengths. A recently proposed current tuning scheme involving a single Fabry-Perot etalon, used as a

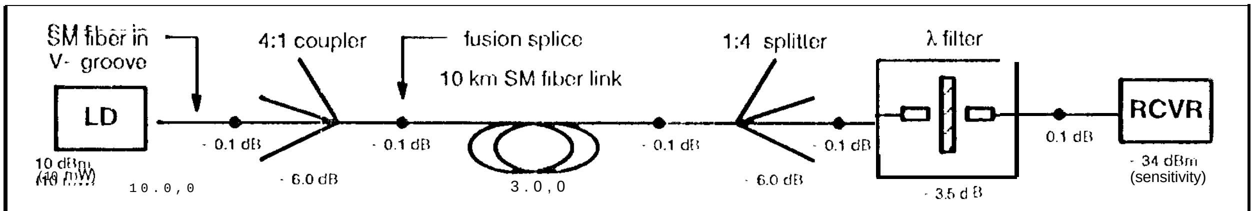

Figure 3: WDM link components and loss budget

master frequency reference, produced laser line widths of less than 10 MHz with 0,1 nm channel spacings[2].

LD Mode Reduction: The TE and TM modes, making up the main lasing mode of the DFB LD source, arrive at the receiver shifted in time due to fiber dispersion, If both modes have enough optical power to exceed the decision threshold of the receiver logic, the BER will inc~'case. One solution, the reduction of the TM mode power 40 dB below the TE mode power for BER <10-13, has already been implemented in some discrete DFB devices[2], but will need to be addressed in the LD array scheme.

Optical Mux/Dmux: The current design uses two 4:1 star couplers to couple and split the data channels entering, and emerging from, the fiber resulting in a 12 dB link loss. This scheme becomes increasingly more inefficient as the number of channels increases. In addition, the passband of the tunable filter further limits the number of channels that can be implemented, due to increased crosstalk. More effective methods, such as using diffraction gratings to multiplex/demultiplex the optical data channels or using cascaded Fabry-Perot filters, which can achieve <20 dB crosstalk for channels separated by 2 nm, are available[3].

5. CONCLUSIONS

As multimedia workstations are starting to integrate data, voice, and video into a variety of new applications, their interconnecting networks will have to keep up with higher bandwidth requirements. The AN(X program is taking the first step in bandwidth enhancement by demonstrating the feasibility of multiple FDDI channels on a single optical fiber using dense WDM techniques. As higher resolution and more stable tunable LD sources and filters will emerge from the lab environment, more robust, field deployable systems can be integrated into the Army communication grid. Due to the bandwidth capacity offered by single mode fibers, specific wavelength channels can be dedicated to different transmission protocols and speeds, allowing the implementation of scalab]c--rate network technology for supporting multi– tier tactical battlefield backbone networks.

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