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Sejka, Milan; Hübner, Jörg; Varming, Poul; Nissov, Morten; Kristensen, Martin

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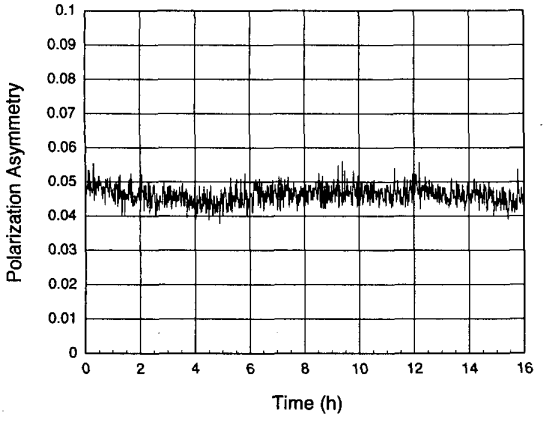

TuJ1 Fig. 2. Stability of the polarization asymmetry of a fiber-coupled microchip laser. The polarization asymmetry was measured over a 16 h period and demonstrates excellent stability.

mW), low noise (≤−165 dB/Hz at frequencies >10 MHz) sources.

Operation of a miniature, monolithic Nd:YAG laser in two orthogonal polarization states has been previously observed and the frequency splitting between the two states was adjusted from ~300 MHz to 3 GHz by the application of stress.[5] We use a similar technique in this work to adjust the frequency difference between the two polarization states of a microchip laser from 100 to 500 MHz. The microchip laser was isolated with a 60-dB polarization-independent isolator and coupled to a SMF. The power in each polarization state was >60 mW. Each polarization state lased in ~3 longitudinal modes, which minimizes the effects of SBS by dividing the launched power into several frequencies.

We have found that the polarization asymmetry could be optimized by adjusting the temperature of the microchip with a thermoelectric cooler. The polarization asymmetry is defined as $(I_{max} - I_{min})/(I_{max} + I_{min})$ where I_{max} is the maximum and I_{min} is the minimum transmission of the output of the SMF through a polarizer while the SMF was subjected to a range of mechanical stresses. The mechanical stresses emulated the random phase variations that would occur over several kilometers of fiber (which we did not have available to us). The polarization asymmetry is shown in Fig. 1 as a function of the thermoelectric cooler temperature and can be seen to have a minimum value of very nearly zero. Figure 2 shows the polarization asymmetry measured over a 16 h period and demonstrates the excellent stability of the polarization ratio.

In conclusion, we have constructed a dual-polarization microchip laser, which provides greater than 60 mW in two orthogonal polarizations. The microchip laser was coupled to a SMF through a 60-dB polarization-independent isolator and a stable polarization asymmetry of ~0 was obtained using temperature tuning. Results of experiments using this laser to drive a remote $Li:NbO_3$ modulator will be presented.

1. W. K. Burns, R. P. Moeller, C. H. Bulmer, and A. S. Greenblatt, "Depolarized source for fiber-optic applications," Opt. Lett. **16,** 381 (1991).
2. A. D. Kersey and A. Dandridge, "Monomode Fibre Polarisation Scrambler," Electron. Lett. **23,** 634 (1987).
3. M. M. Howerton, R. P. Moeller, C. H. Bulmer, and W. K. Burns, "Use of a Doubly Polarized Laser for Remote Powering of an Integrated Optical Modulator," IEEE Photon. Tech. Lett. **4,** 1127 (1992).
4. J. J. Zayhowski and A. Mooradian,"Single-frequency microchip Nd lasers," Opt. Lett. **14,** 24 (1989).
5. P. Esherick and A. Owyoung, "Polarization feedback stabilization of an injection-seeded Nd:YAG laser for spectroscopic applications," J. Opt. Soc. Am. B **4,** 41 (1987).

TuJ2 2:15 pm

Fiber-distributed feedback lasers for high-speed wavelength-division multiplexed networks

Milan Sejka, Jörg Hübner, Poul Varming,* Morten Nissov,* Martin Kristensen, *Mikroelektronik Centret, Technical University of Denmark, Bldg. 345e, DK-2800 Lyngby, Denmark*

Single-mode distributed feedback (DFM) erbium-doped fiber lasers, based on directly UV-written Bragg gratings in fibers were demonstrated recently.[1-3] A $\pi/2$ phase-shift, introduced in the central part of the structure, results in robust single-longitudinal-mode operation with high stability and low lasing threshold. These characteristics combined with optical fiber compatibility, compact size, and wavelength setability make fiber DFB lasers highly attractive sources for externally modulated high bit-rate[4,5] and wavelength-division multiplexed (WDM) systems.

The fiber DFB lasers, used in this experiment, were fabricated by UV exposure of a highly photosensitive erbium-doped fiber through a phasemask. The central part of the grating was illuminated by additional UV radiation, resulting in the permanent $\pi/2$ phase shift required to achieve the single-frequency operation.[2] The grating length was typically ~3.5 cm with a reflectivity of ~20 dB. The erbium-doped fiber, produced by Lycom A/S, has a dopant concentration of 1.5×10^{25} m^{-3}, a core diameter of 4 μm, and a numerical aperture of 0.27. We fabricated two lasers with operating wavelengths of 1533 nm and 1547 nm. They yield a stable single-mode output with linewidth of 15 kHz and signal power of ~20 μW at 50 mW of launched pump power at 1480 nm. A signal power of 5.4 mW can be achieved by absorbing the residual pump power in a subsequent length of erbium-doped fiber.[2] Furthermore, for WDM systems and sensor applications, two or more lasers with different signal wavelengths can be connected in series.

We used bit-error-rate (BER) measurements to evaluate the performance of our fiber DFB lasers (Fig. 1). The measurements were performed at 2.488 Gbit/s using a NRZ $2^{31} - 1$ pseudo-random bit sequence. First we measured BER curves for a single-fiber DFB laser (DFB 1) both back-to-back and through 30 km of standard fiber. After that, we spliced two fiber DFB lasers together (Fig. 1, with DFB 2 included) and measured a back-to-back BER curve. These measurements are shown in Fig. 2 and indicate no power penalty.

We improved the setup by inserting a polarization controller in front of the optical bandpass filter. This setup was used to compare our fiber laser with a commercial semiconductor DFB laser by measuring back-to-back BER curves (Fig. 3). Both lasers behaved similarly, demonstrating the fiber DFB

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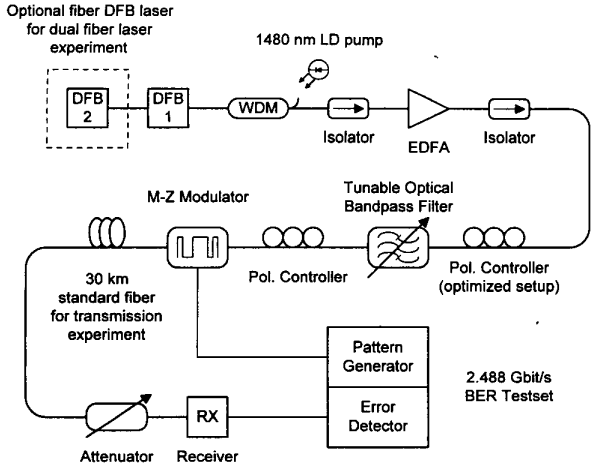
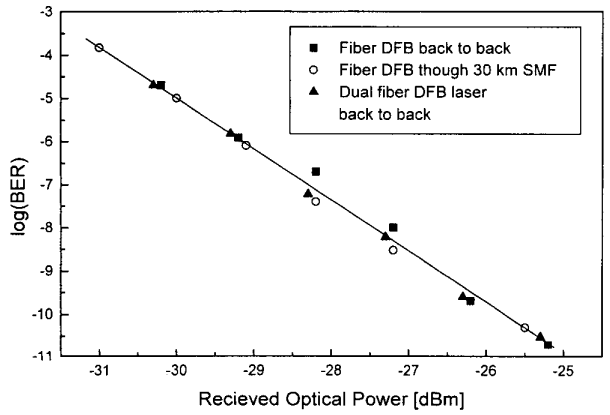
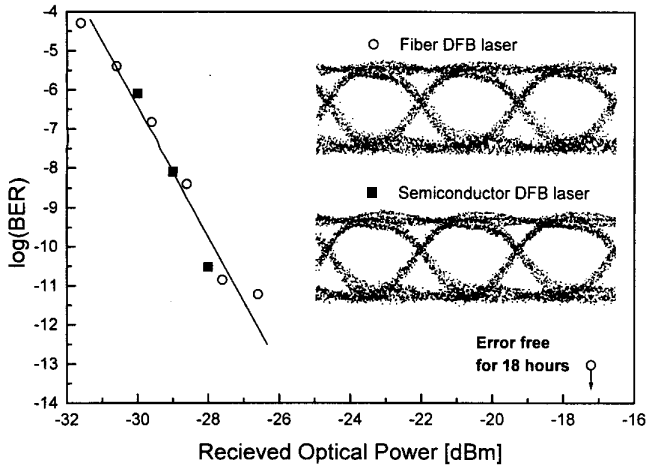


TuJ2 Fig. 1. Experimental setup for 2.488 Gbit/s BER measurements of DFB lasers.



TuJ2 Fig. 2. BER curve for single- and dual-fiber DFB lasers, including 30-km standard single-mode fiber experiment.



TuJ2 Fig. 3. BER curve and eye diagrams comparing the fiber DFB laser to conventional semiconductor DFB laser. Eye diagrams were obtained at −17 dBm of received signal power.

laser as an attractive new alternative. Finally, we performed a long-term stability test by measuring BER back-to-back for a single-fiber DFB laser. No error floor was detected after 18 hours of error-free operation (Fig. 3).

In conclusion, we have demonstrated that fiber DFB lasers constitute an excellent alternative to commercially available semiconductor DFB lasers. We have also shown that two fiber DFB lasers can be spliced together without any BER power penalty. Therefore, we suggest the possibility of using a single pump source for pumping a WDM laser array consisting of a number of fiber lasers spliced in series.

1. J. T. Kringlebotn, J.-L. Archambault, L. Reekie, and D. N. Payne, Opt. Lett. **19,** 2101 (1994).
2. M. Sejka, P. Varming, J. Hübner, and M. Kristensen, Electron. Lett. **31,** 1445 (1995).
3. W. H. Loh and R. I. Laming, Electron. Lett. **31,** 1440 (1995).
4. V. Mizrahi, D. J. DiGiovanni, R. M. Atkins, S. G. Grubb, Y.-K. Park, and J.-M. P. Delavaux, J. Lightwave Technol. **LT-11** (1993).
5. J. L. Zyskind, J. W. Sulhoff, P. D. Magill, K. C. Reichmann, V. Mizrahi, and D. J. DiGiovanni, Electron. Lett. **29,** 1105 (1993).

Center for Broadband Telecommunications, Electromagnetics Institute, Technical University of Denmark, DK-2800 Lyngby, Denmark

TuJ3 (Invited) 2:30 pm

Manufacturing and packaging of optoelectronic components

Robert H. Weissman, *Hewlett-Packard Co., Optical Communications Division, 370 W. Trimble Road, San Jose, California 95131*

Wide-scale system deployment of optoelectronic components requires continuing reductions in product selling price. Particularly price-sensitive applications include computer local area networks and fiber-to-the-curb interconnects. To satisfy market needs a successful manufacturer must have a highly flexible, efficient, and robust production capability. This paper reviews how device technologies, assembly techniques, packaging materials, and designs are evolving to meet this challenge without sacrificing component quality and reliability.

Packaging and testing can account for 40–75% of product cost. Historically, high costs have been associated with expensive optical lenses, custom-tooled metal packages, costly ceramic substrates, active alignment of optical sources to fibers, electrical trimming of every assembly, lengthy testing procedures, and costly burn-in techniques. Another common problem has been independent design of optical sources and their associated packages. Overly complex, poorly controlled assembly processes cause low assembly yields and contribute to high product cost.

Cost effective products optimize the following critical factors: (1) design simplicity, (2) process robustness and complexity, and (3) volume scalability. Specific examples are presented showing current trends towards high-volume, standardized optoelectronic components that are very cost effective. Discussed are use of low-cost ball lenses in place of custom-made fiber lenses. Metal and ceramic packages are being replaced with very low-cost CD-type headers, inexpensive printed circuit boards, and plastic-molded piece parts. We have achieved

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