References

1. X.F. Li *et al*, "Multiple-harmonic generation in rare gases at high laser intensity," Phys. Rev. A **39**, 1989, 5751-5761.
2. J.J. Macklin *et al.*, "High-order harmonic generation in neon," Phys. Rev. Lett. **70**, 1993, 766-769; A. L'Huillier and Ph. Balcou, "High-order harmonic generation in the rare gases with a 1 psec 1053 nm laser," Phys. Rev. Lett. **70**, 1993, 774-777.
3. J. Krause *et al.*, "High-order harmonic generation from atoms and ions in the high intensity regime," Phys. Rev. Lett. **68**, 1992, 3535-3538; P.B. Corkum *et al.*, *Proceedings of Physics with Intense Laser Pulses*, M.D. Perry and P.B. Corkum, Eds., San Diego Calif. 1993.
4. Ph. Balcou and A. L'Hullier, "Phase-matching effects in high-order harmonic generation in Xe," Phys. Rev. A **67**, 1993, 1667-1671.
5. J.K. Crane and M.D. Perry, "High-order harmonic emission from mixed fields," to appear in Phys. Rev. A, Dec. 1993.
6. P. Saliere *et al.*, "The spatial coherence of the high harmonics," submitted to J. Phys. B, 1993.

Uncooled Lasers for Deployment of Fiber in the Loop

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Among other factors, the wide-spread deployment of fiber in the loop (FITL) is hindered by the lack of availability of low-cost laser transmitters that emit at 1.3 μm and operate reliably over a temperature range of −40° to 85°C. To date, commercial laser transmitters have relied on thermoelectric (TE) coolers to maintain the laser temperature constant against the variations in the ambient temperature. However, the TE cooler and associated controller add substantial costs to the laser transmitter. A significant new advancement[1] over existing approaches[2-4] has been made by prototyping a laser that incorporates a strained quantum well structure based on the AlGaInAs/InP material system.

The commercial $Ga_xIn_{1-x}As_yP_{1-y}$/InP lasers emitting at wavelengths in the optical fiber window (1.3-1.5 μm) have shown a strong temperature dependence on threshold current and external quantum efficiency. We believe that it is partly due to Auger recombination in the low bandgap material and partly due to poor electron confinement resulting from the small conduction band offset of the conventional $Ga_xIn_{1-x}As_yP_{1-y}$/InP material system.

In this work, we examined design considerations for making highly efficient, uncooled semiconductor lasers and fabricated 1.3-μm ridge waveguide strained quantum well lasers for high temperature operation. To prevent carrier overflow across the quantum well barriers under high temperature operation, we used the $Al_xGa_yIn_{1-x-y}As$/InP material system which increased electron confinement energy. The carrier induced loss such as intervalence band absorption loss is reduced by using strained quantum wells as the active layer.[5]

These lasers exhibit excellent extrinsic temperature characteristics. When the heat sink temperature changes from 25°-100° C, the differential quantum efficiency decreases by a small amount 0.3 dB (see Fig. l(a)). Also, a maximum operating temperature of 140° C and a large modulation bandwidth of 14 GHz at 85° C have been obtained. For these lasers operating at 85 °C with more than 5 mW output power, a mean-time-to-failure (MTTF) of 110 years is projected from a preliminary life test. With these newly-designed uncooled lasers, low cost and reliable transmitters are being built for FITL applications (see Fig. 1(b)).

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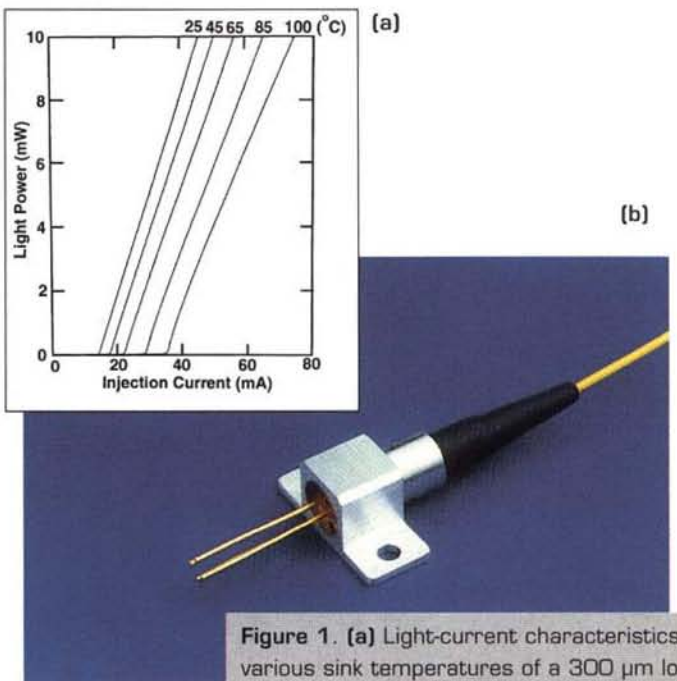

Figure 1. (a) Light-current characteristics at various sink temperatures of a 300 μm long AlInGaAs compressive-strained five-quantum-well laser with a 70% high reflection coating on the rear facet. **(b)** The uncooled laser in a cylindrical package for FITL applications.

References

1. C. E. Zah *et al.*, "High performance uncooled 1.3 μm $Al_xGa_yIn_{1-x-y}As$/InP strained-layer quantum well lasers for subscriber loop applications," to be published in IEEE, J. Quant. Elect., January 1994.
2. P. J. A. Thijs *et al.*, "High output power (380 mW) low threshold current (1.3 mA), low linewidth enhancement factor (≤2) λ=1.3 μm strained quantum well lasers," Proc. of 17th Eur. Conf. on Opt. Comm. **2**, Paris, France,1991, 48-51.
3. T. Namegay *et al.*, "High temperature operation of 1.3 μm GaInAsP/InP GRINSCH strained-layer quantum well lasers," Electr. Lett. **29**, 1993, 392-393.
4. H. Temkin *et al.*, "High temperature characteristics of InGaAsP/InP laser structures," Appl. Phys. Lett. **62**, 1993, 2402-2404.
5. I. Joindot and J. L. Beylat, "Intervalence band absorption coefficient measurements in bulk layer, strained and unstrained multiquantum well 1.55 μm semiconductor lasers," Electr. Lett. **29**, 1993, 604-606.