Parallel integration of high power laser arrays – technology and applications

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Abstract—**Massively parallel individually addressable laser arrays are reported, delivering 500 mW per element at 800-980 nm with 100 monolithic elements. By placing arrays side by side powers can be scaled further, with uncooled modules delivering 150 W cw.**

Keywords- Optoelectronics; photonic integrated circuits; semiconductor lasers; laser arrays; monolithic integration

I. INTRODUCTION (HEADING 1)

It has long been recognized that integration of photonic components into photonic integrated circuits (PICs) is necessary for complex optoelectronic systems to penetrate into mass markets. Monolithic PICs have evolved rapidly since the year 2000, with the two monolithic integration technologies of greatest importance being selective area epitaxy and quantum well intermixing (QWI) [1]. Either of these techniques may be combined with regrowth. For telecom applications, integrated transmitter and integrated receiver chips have been combined with silicon electronics in optical-electronic-optical (OEO) transceivers and these modules are now widely deployed in the telecom backbone. For non-telecom applications there has been considerable interest in monolithic, individually addressable arrays of semiconductor lasers. Highly parallel arrays of semiconductor lasers each delivering 100s of mW are already used in high-end printing [2] and materials processing. As the technical and cost challenges associated with PICs are overcome, new applications and commercial opportunities are opening.

This paper focuses on non-telecom applications, showing how integration using QWI can be used to manufacture wide parallel arrays of semiconductor lasers.

II. INDIVIDUALLY ADDRESSABLE LASER ARRAYS

The integration of parallel arrays of semiconductor lasers in a single chip appears at first to be a trivial problem, simply involving leaving the lasers cleaved from the wafer in the form of bars. However, many applications allow for zero redundancy and so significant technology development has been required to achieve an acceptable yield at array level. Exceptional reliability is needed because the entire module fails as soon as a single emitter in the array fails. Achieving high reliability at powers of several 100 mW requires careful design of the laser and a robust technique for passivating the facet. Moreover, many applications require a high uniformity of laser parameters, such as kink power and optical beam profile. Some applications require uncooled operation with the junction temperature approaching 100 °C.

The primary challenges in manufacturing semiconductor laser arrays are, therefore, to design a reliable laser that delivers a power of several 100 mW in a single transverse mode and that is robust against manufacturing tolerances. Here we use QWI to create relatively long (>100 µm) passive waveguides immediately adjacent to each facet of a ridge waveguide laser. As a result of the QWI processing, the passive waveguides have a larger bandgap than the gain section so raising the threshold power at which catastrophic optical mirror damage (COMD) of the facet mirror occurs [3]. The length of the passive waveguides enables large monolithic arrays to be cleaved from a wafer with high yield and also relaxes packaging tolerances as the passive waveguide sections can overhang the laser carrier. A novel ‘V-profile’ layer [4] has also been included in the structure to reduce the fast axis far-field divergence and to make the laser performance less vulnerable to processing variations across the wafer and from wafer to wafer.

III. ARRAY PERFORMANCE

Full 3 inch wafer processing using state-of-the-art photolithography and dry-etching techniques, in combination with passive waveguides and the V-profile laser design, allows very large element arrays of high-performance single-mode lasers to be fabricated with high yield. The design has been optimized to give extremely good uniformity across arrays containing up to 100 individually addressable lasers. An 86

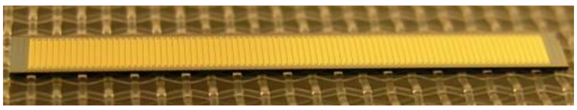

Figure 1. Processed array containing 86 lasers.

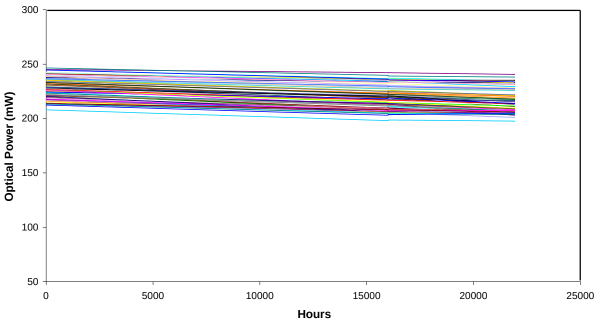

Figure 2. 22,000 hour lifetest of 64 element 200 mW, 8xx nm single mode laser module.

element array is shown in Fig. 1. The laser arrays are then die-bonded to a Cu:W composite metal carrier, using a hard solder.

IV. Reliability

Extensive reliability data have been collected for 2 µm wide ridge lasers operating at 808 and 830 nm in a single transverse mode at 200 mW per channel. Fig. 2 shows typical lifetest curves for a 64 element array operating at 200 mW per channel up to 22,000 h with a junction temperature >65 °C. More than 30,000,000 device hours of data have been collected with the lasers running continuously at 200 mW. The FIT rate (10^9 h) for individual elements is 118 and the resulting module MTTF is >17,000 h. The key to achieving this level of reliability is the use of quantum well intermixing (QWI).

V. Super arrays

Monolithic laser arrays are limited in size, partly by processing and handling considerations and partly by the by the need to have a reasonable yield from the size of wafer used in production (currently 3 inch). In applications such as coding and marking more elements may be required, e.g. for printing bar codes in a single pass of a label. In order to build larger arrays, monolithic arrays are placed side by side using precision die bonding to maintain a constant laser pitch across the super array.

Fig 3 shows a super array built using arrays of 16 elements. Current designs use individual bars with typically 100 lasers on a pitch of 125 µm at wavelengths of 808, 830 and 980 nm. Moreover, individual lasers can deliver up to 500 mW with good uniformity in continuous wave operation with all elements 'on' (Fig. 4). Uncooled modules with 300 elements are now capable of delivering 150 W of power under precision

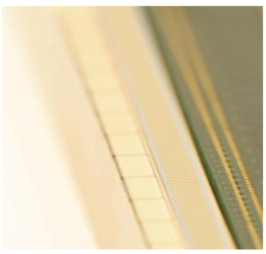

Figure 3. Part of a super array assembled using monolithic lasers containing 16 elements.

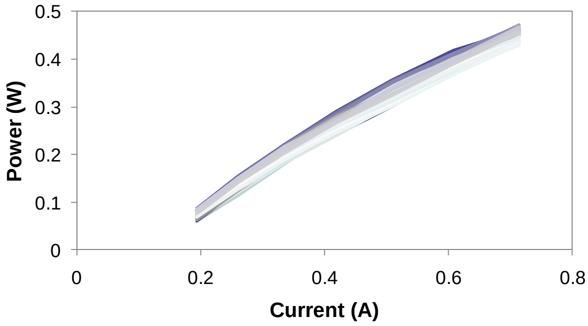

Figure 4. Light-current characteristics of 250 elements of a 980 nm super array.

control to precision locations.

Higher powers are possible in pulsed operation. 2 µm wide ridge lasers deliver >7 W for 50 ns pulses without exhibiting facet failure, the power being limited by the maximum drive current. For longer pulses (200 ns) 10 µm wide ridge lasers deliver >8 W, although roll-over is observed for the longer pulses.

VI. Conclusions

This paper has focused on technology for non-telecom applications, in particular technology for manufacturing wide arrays of semiconductor lasers. It is clear that integration of passive waveguides within laser cavities has led to significant improvements in yield and in device performance, particularly reliability. Such arrays have many applications in printing [2], where they are already deployed in computer to plate systems and digital presses. They are also being used in coding and marking applications, and have potential applications in LADAR, bio-sensing, processing of plastics and laser displays. It is now possible to deliver more that 150 W of optical power from a single compact semiconductor laser module under precision control to precise locations.

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