New Perspectives on High Power Single-Mode GaAs-based Pump Lasers

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Abstract: Recent results obtained at 3S PHOTONICS on 980 nm high power single-mode pump lasers are reviewed, with emphasis on the challenges that still exist in this mature technology and on new development trends.

High power single-mode GaAs-based pump lasers have been developed for more than 20 years now, but the momentum for increasing their performances is still present. In the first phase of their development the telecom applications have played the most substantial role with strong request for 980 nm pumps for EDFAs, but recently other non-telecom applications such as frequency doubling or fiber lasers seeding induced suppliers to extend the range of fiber output powers up to 750 mW and the spectral band to the whole 920-1060 nm span. Most of these applications also need the chip wavelength to be stabilized by means of a Fiber Bragg Grating (FBG), and this specific feature adds extra-requirements on the chip properties needed to reach the overall desired performance.

The development of 980 nm pump lasers at 3S PHOTONICS has gone through several generations of devices to reach full maturity, high reliability and unprecedented output power levels in this decade. In 2005 we developed a record saturation-power (> 2.5W @ 25°C) 980 nm single-mode chip that is now used in uncooled submarine applications with up to 400 mW reliable power and in terrestrial and non-telecom applications with up to 750 mW reliable power [1]. More recently a 1060 nm record kink-free and saturation powers was also optimized derived from the low loss (0.85 ± 0.10 cm-1) vertical structure used for the 980 nm chip [2]. While chip length scaling was first successfully introduced to improve the kink-level of chips [3] with an identical vertical structure, it was immediately clear that longer chips would need reduced internal losses to keep the slope efficiency at a high value, and, consequently, optimized vertical structures. One interesting question about future trends on 9xx nm devices is what the lowest attainable internal loss figure is. Most suppliers currently claim internal loss levels lower than 1 cm^{-1}, sometimes without stating a precise value for this important parameter. The subsidiary question is: can an internal loss level be made so low that we can consider having a « lossless » structure for every practical chip length we may want to use? This ideal vertical laser structure should have internal losses measured in dm^{-1} or m^{-1}, as it would probably need a figure below 0.2 - 0.1 cm^{-1}. The quest for this “lossless structure” calls for a systematic fundamental study of the remaining contributions to the total internal losses, as they still are controversial. Contributions from free-carrier absorption, different scattering mechanisms, quantum-well losses would need to be identified and separated to find appropriate means to reduce the global figure to extremely low values.

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Apart from the important issue on internal losses, it must be made clear that several other constraints strongly limit any simple chip length scaling approach. The most severe constraints are related to the specific needs of wavelength stabilization using FBGs. As a simple example, longer chips generally need larger gain bandwidths to keep unchanged the device locking range [4], and this is only one of several design constraints related to wavelength stabilization. The additional constraint that should be kept in mind, apart from those that are performance and wavelength stabilization related, is reliability. Based on standard reliability models, one of the requirements to keep the lifetime unchanged is to keep the junction temperature and the injection current density at a level similar to previous generations of devices [5].

Currently, at 3S PHOTONICS, we are developing a new generation of 980 nm ultra-high power chips that will bring the ultimate performance for non-telecom applications close or equal to 1 Watt and we have addressed all the vertical structure issues needed to keep the global chip performance at the desired level. Our first results show that we were able to reduce the internal losses figure down to reproducible values around 0.5-0.6 cm^{-1}, while coping with all other constraints, those related to wavelength stabilization as well as those related to reliability. The internal quantum efficiency was kept at high values around 0.95 ± 0.02 and the external efficiency higher than 70% even for very long devices of 5 mm or more. Record kink-free powers quite close to 2 W have been recorded on the longest devices (7.5 mm cavity length) with very stable beam quality and properties. To reach such high kink-free powers both the flared ridge geometry [1] and the ridge etching depth [6] must be optimized. Wavelength stabilization experiments showed that it is still possible to lock long chips if the gain spectrum is correctly engineered and the overall external feed-back system is properly designed.

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