Wide emission spectrum from superluminescent diodes with chirped quantum dot multilayers
Li, L.; Rossetti, M.; Fiore, A.; Occhi, L.; Velez, C.

Published in:
Electronics Letters

DOI:
10.1049/el:20056995

Published: 01/01/2005

Document Version
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author’s version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain.
• You may freely distribute the URL identifying the publication in the public portal?

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Wide emission spectrum from superluminescent diodes with chirped quantum dot multilayers

L.H. Li, M. Rossetti, A. Fiore, L. Occhi and C. Velez

A superluminescent diode (SLED) using chirped multiple InAs quantum dot (QD) layers as the active region is demonstrated. The fabricated QD SLEDs exhibit a large spectral width up to 121 nm, covering the range 1165–1286 nm.

Introduction: Superluminescent diodes (SLEDs) are the light sources of choice in optical measurement systems needing a broad emission spectrum, such as gyroscopes, fibre-optics sensors and optical coherence tomography. Large spectral width is one of the most important features of SLEDs [1, 2], as the correspondingly short coherence length can significantly improve the spatial resolution in coherence-based systems. Multiple quantum wells engineering is a flexible approach that has been extensively used to broaden the spectral width of SLEDs [3]. Recently, it was proposed that the naturally-occurring size dispersion in self-assembled growth of quantum dots (QDs) can be beneficial to SLEDs requiring larger spectral width [4]. SLEDs using stacked In(Ga)As/GaAs QD layers emitting around 1000 nm have been demonstrated [5, 6] with a spectral width of 80 nm. To further increase the spectral width of QD SLEDs, a deliberate increase of the dot size distribution has been suggested [4]. However, the exact control of the QD size dispersion is not easily reproducible. Another possible approach would be to use chirped multiple QD layers with different amounts of InAs deposition in the QDs, as proposed in [5, 6]. Since the amount of InAs also affects the density and radiative efficiency of the QDs, this last approach is difficult to implement, too.

In contrast, in this Letter we propose the control of the emission wavelength in the chirped structure by a change in the matrix surrounding the QDs. Specifically, when the QDs are covered by an InGaAs strain-reducing layer (SRL), a red-shift of the emission wavelength is observed, owing to the relatively slow carrier relaxation rate and population saturation in the GS, as previously reported [10]. In contrast to other approaches, this technique is reproducible and easy to implement, since it relies on well-controlled growth parameters.

Experimental setup: The device growth was performed using solid-source molecular beam epitaxy on n⁺-GaAs substrate. QDs were formed by continuous deposition of InAs material at the growth temperature of 530°C and growth rate of 0.163 µm/h. The active region consists of five stacks of InAs QDs separated by a 40 nm GaAs barrier. Each layer of InAs QDs is capped by a 5 nm InGaAsAs matrix SRL. The In composition in the different layers is varied from 0.09 to 0.15 by an interval of 0.015. The active layers were grown at the centre of a 310 nm-thick GaAs undoped waveguide. Next to the GaAs waveguide, graded index-separating confinement heterostructures (GRIN SCH) were grown. The n- and p-type cladding layers consist of 1.5 µm-thick AlₓGa₁₋ₓAs material. 1 µm-thick cladding layers far from the active region were doped with Si and Be to 10¹⁷ cm⁻³, respectively. The doping level in approximately 0.5 µm-thick cladding layers close to the active region was intentionally reduced to 2 × 10¹⁵ cm⁻³ in order to reduce the optical loss induced by free-carrier absorption. The structure was capped with a 40 nm p⁺-GaAs contact layer (p = 2 × 10¹⁸ cm⁻³).

Fabrication starts with the reactive-ion etching of 8 µm-wide ridges, stopping at ~300 nm above the GRIN SCH layer. The ridge was orthogonal to the cleaved facets for test laser structures and tilted by 7° in SLEDs to suppress lasing. After etching, the unetched areas were passivated by wet oxidation of the AlGaAs cladding layer, thus forming a self-aligned current aperture [9]. The fabrication was completed by substrate thinning and p- and n-contact metallisation.

Measurements: Room temperature (RT) PL measurement was performed on a reference chirped multiple InAs QDs structure grown in the same conditions as the device. A spectral width of 78 nm (full-width at half-maximum) was observed from the GS emission centred on 1270 nm, as shown in Fig. 1 (continuous line). A schematic drawing of the band diagram in chirped InAs QDs is shown in the inset. The achieved spectral width is much larger than the typical spectral width of 44 nm from the single-layer QD sample (Fig. 1, broken line). The high energy tail merging with the main peak comes from the first ES transition. To validate the device structure, we first processed a part of the as-grown wafer into 5 µm-wide ridge-waveguide edge-emitting lasers. Fig. 2 shows the measured emission spectra in pulsed operation from a 2 mm-long device at different injection currents. Well above GS lasing threshold of 180 A/cm², an extremely broad lasing spectrum of >30 nm is observed, which stems from the combined effect of the broad gain spectrum of the chirped QD active region and of the decoupling of the spatially-separated QDs. At a current density of 6000 A/cm², simultaneous lasing from both GS and ES is observed, owing to the relatively slow carrier relaxation rate and population saturation in the GS, as previously reported [10].
density, the number of stacked layers or the device length, and by applying antireflective coatings.

Fig. 3 Emission spectra and typical light–current curve

\( a \) Emission spectra of 8 \( \mu \)m × 4 mm QD SLED at various injection currents

\( b \) Typical light–current curve under pulsed operation

Conclusions: The technique of chirped QD multilayers is introduced as a means of reproducibly broadening the gain spectrum of a QD active region. QD SLEDs with chirped multiple InAs QD layers have been fabricated, showing a large spectral width of 121 nm. The same concept can be applied to other broad-gain devices such as semiconductor optical amplifiers and tunable lasers.

Acknowledgments: We acknowledge financial support from the Swiss Commission for Technology and Innovation (CTI-TOPNANO21 program), the OFES (COST program) and the Swiss National Science Foundation.


L.H. Li, M. Rossetti and A. Fiore (Institute of Photonics and Quantum Electronics, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland)

E-mail: Lianhe.Li@epfl.ch

L. Occhi and C. Velez (EXALOS AG, Technoparkstrasse 1, CH-8005 Zürich, Switzerland)

A. Fiore: Also with Institute of Photonics and Nanotechnology, CNR-IFN, via del Cineto Romano 42, 00156 Roma, Italy

References

8. Nishi, K., et al.: ‘A narrow photoluminescence linewidth of 21 meV from 1.35 \( \mu \)m from strain-reduced InAs quantum dots covered by In\(_{0.2}\)Ga\(_{0.8}\)As grown on GaAs substrates’, Appl. Phys. Lett., 1999, 74, pp. 1111–1113