InAs chirped quantum dot growth on Si for broadband spectral gain mode-locked laser

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Monolithic integration of an efficient and reliable III-V light source onto Si has been heavily studied for the past decades. Recently, quantum dot (QD) lasers directly grown on Si have shown tremendous improvements in performance and device reliability, primarily due to the effective carrier localization of QDs. [1] Furthermore, QD lasers are promising for generation of ultra-short pulses by operating them in the passively mode-locking regime. We have shown that QD lasers epitaxially grown on Si could be used as a source for a dense wavelength-division multiplexing (DWDM) system. [2] The monolithically integrated mode-locked QD laser consisted of five layers of InAs/$In_{0.15}Ga_{0.85}As$ dot-in-a-well (DWELL) structure and showed an optical gain spectrum full-width at half-maximum (FWHM) of 3.56 nm. The relatively small optical spectrum width can be further increased by considerately designing the QD active region on Si.

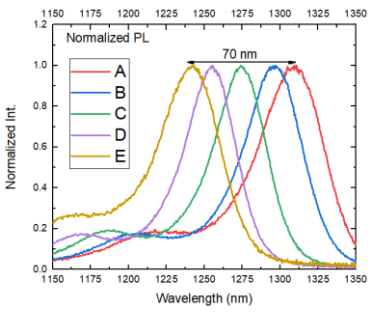
For conventional low threshold current QD lasers, growing the multiple QD layers in an identical growth condition (i.e. temperature) is crucial. Doing so, a full epitaxial laser structure will have narrow photoluminescence (PL) linewidth. However, for broadband gain mode-locked lasers, growing the QD layers at slightly different QD structures is important so that the ensemble of individual PL spectra possesses broad PL spectrum while maintaining a high intensity.

Here, we report growth of chirped InAs/GaAs QDs by solid state molecular beam epitaxy. The InAs/InGaAs DWELL structures vary as shown in the Table I. Five samples were grown on native GaAs substrates to investigate their PL properties. The DWELL active region was grown at 495 ℃ by an optical pyrometer. The InAs QD deposition rate was 0.1132 monolayer (ML) per second. Figure 1 shows PL spectra of the five different samples. The PL peaks are well spaced to have a broadened optical gain. Full laser structures were grown on Si to compare the FWHMs of a broadband gain laser with chirped QD growth and a conventional laser. Figure 2 shows the two different lasers grown on Si have similar PL intensities. However, the broadband gain laser possesses a much wider PL linewidth (FWHM= 43 meV) than the reference laser in which the linewidth is 28.6 meV). More optimizations on the chirped QD growth could lead to further broadened PL widths. We believe that the chirped InAs DWELL structure is a promising method to realize passively mode-locked QD lasers with broadband optical gain spectrum.

[1] Daehwan Jung *et al.* Appl. Phys. Lett. 111 (12), 122107
[2] Song Tao *et al.* Appl. Phys. Lett. 113 (4), 041108

Sample	Pre-InGaAs QW ML	Post-InGaAs QW ML
A	2	6
B	2	4.5
C	2	3
D	1	3
E	0	3

Table I. Summary of chirped InAs QD samples. $In_{0.15}Ga_{0.85}As$ QW ML thickness before and after QD deposition are listed.



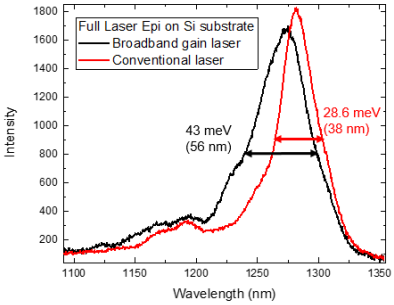


Figure 1 (left). Normalized PL of chirped QD samples. Figure 2 (right). PL comparision of full laser epitaxial structures.