50 years of the Institute of High Pressure Physics Polish Academy of Sciences
Highlights in III-V semiconductors, THz physics and nanomaterials
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Efficient radiative transitions in wide InGaN QWs

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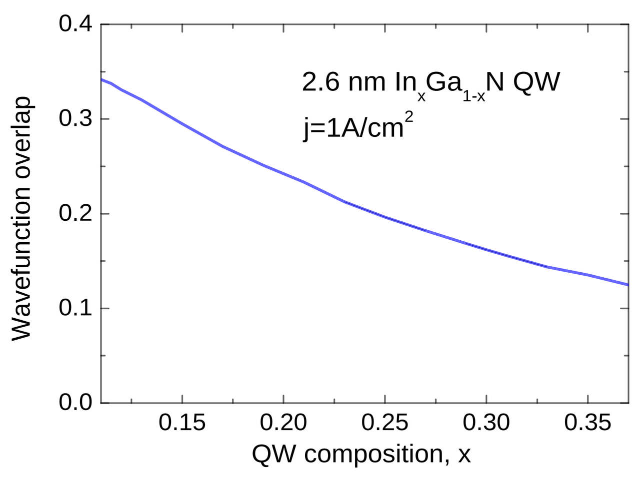
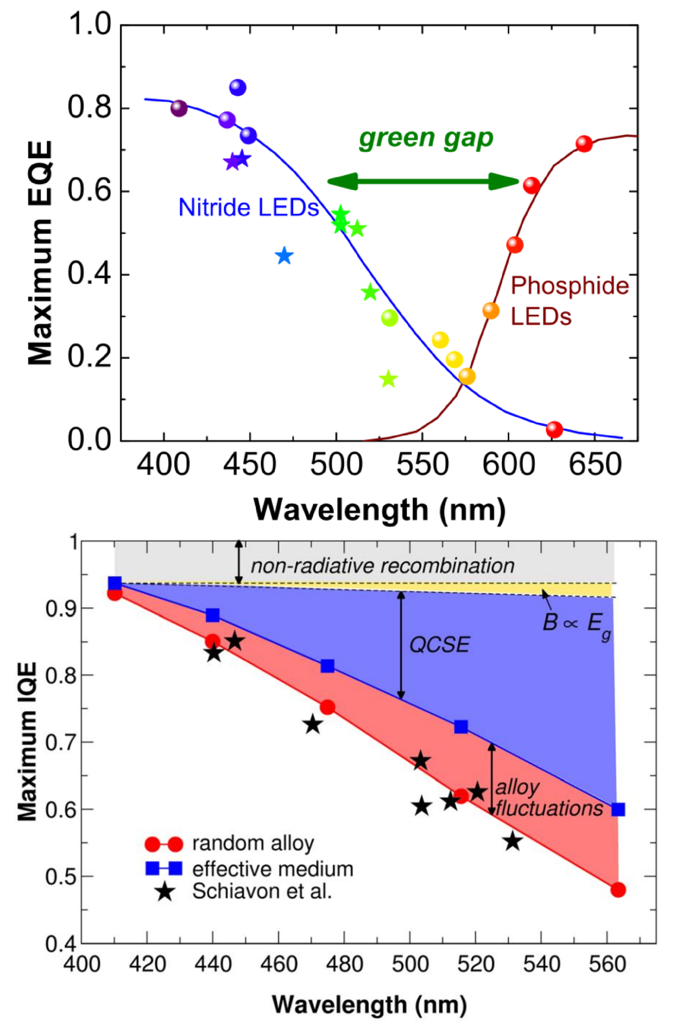
1. Motivation

Blue LEDs based on InGaN have a strikingly high quantum efficiency. However, the efficiency significantly drops for long-wavelength devices.

It was proposed that the separation of electron and hole wavefunctions cause decrease of the oscillator strength and lower efficiency.

Remarkably, wide InGaN QWs can solve this problem.





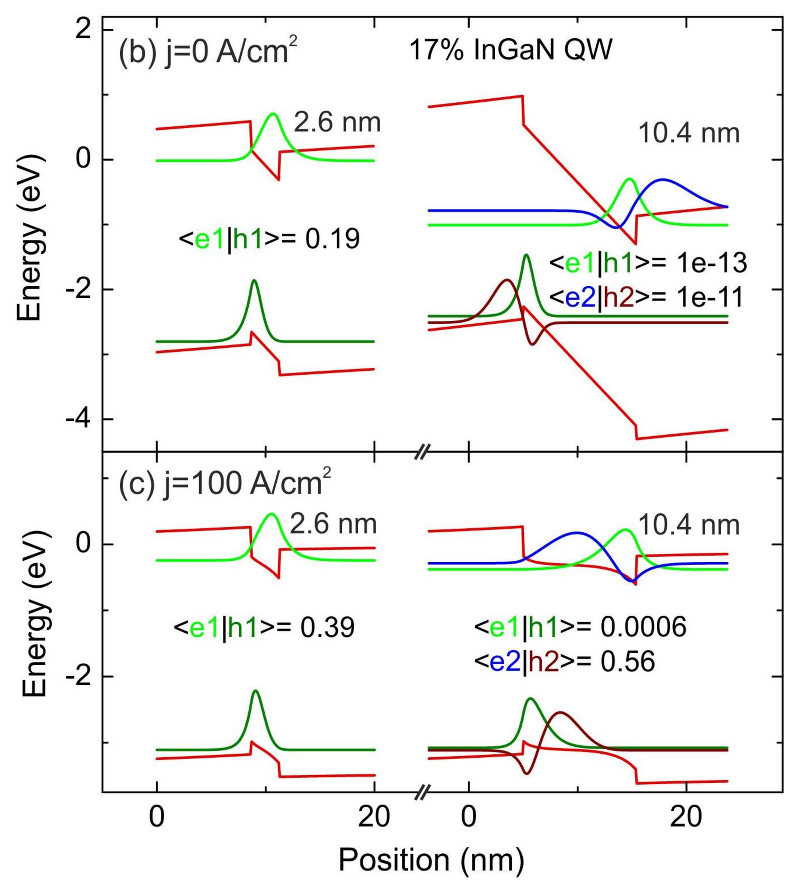
M. Auf der Maur et al., PRL 116, 027401 (2016)

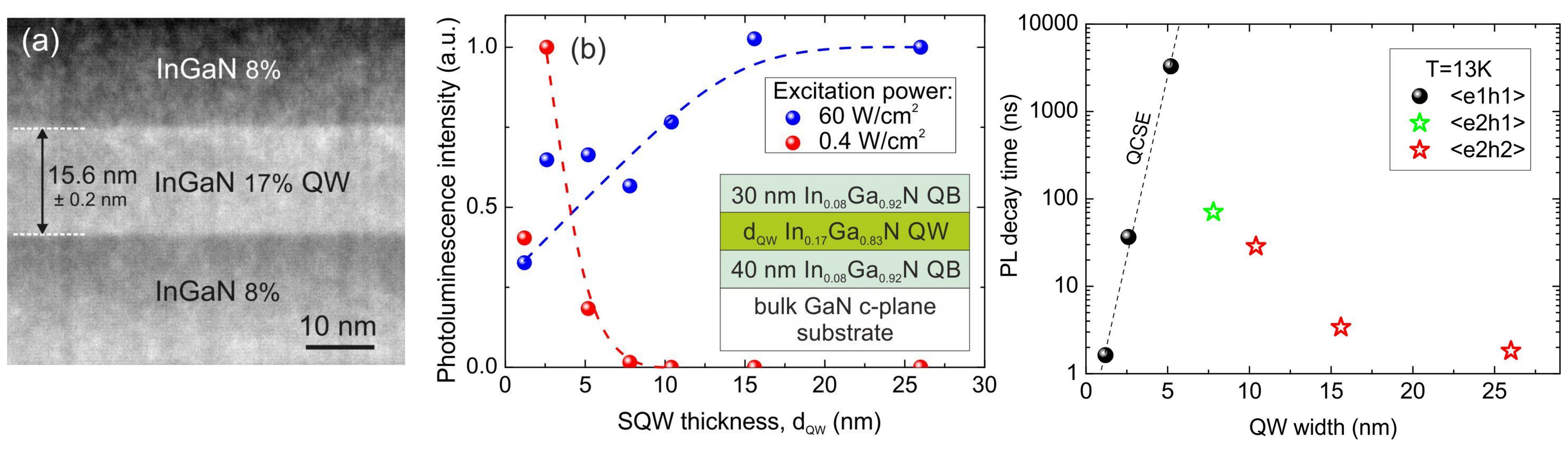
2. Role of excited states in wide InGaN QWs

Without excitation the wavefunction overlap in the wide QW is extremely low. This prevents carrier recombination.

Under excitation the carriers cannot initially recombine which leads to screening of the built-in electric field.

Efficient transitions through excited states emerge after screening of the built-in field.

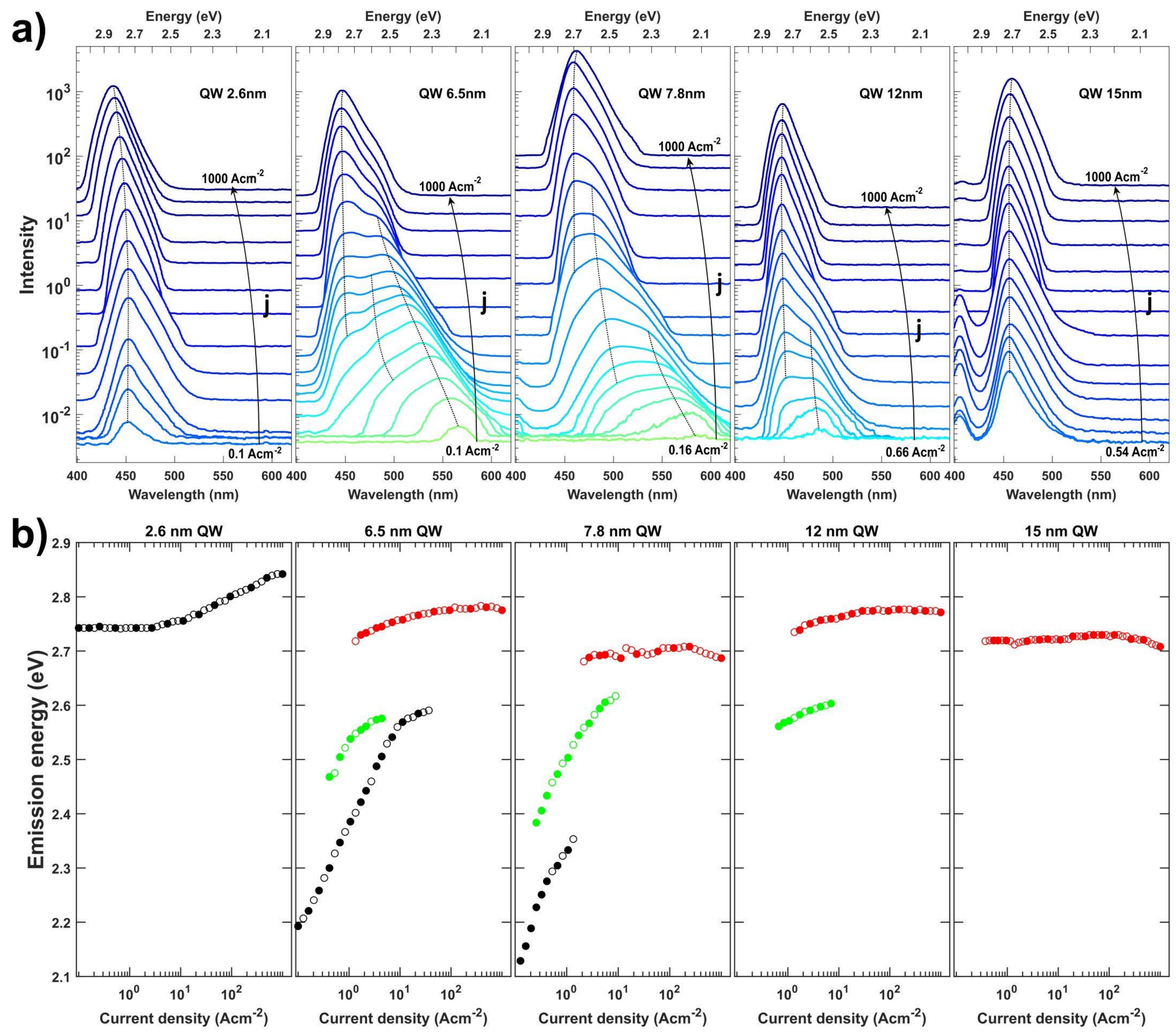




QW structures were grown by plasma-assisted molecular beam epitaxy.
At low excitation power we observe a drop of PL intensity, however, as the excitation power increases, the efficient transitions through excited states start to appear.

3. LEDs with wide InGaN QWs

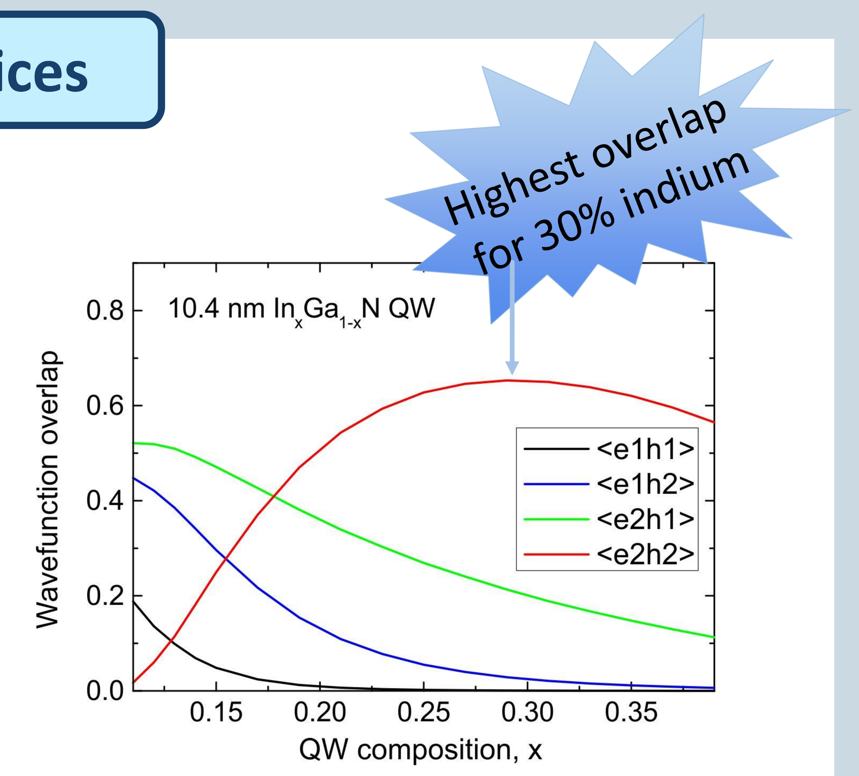
Thin QW:	Intermediate QW:	Wide QW:
single peak emission with blue-shift due to screening of QCSE	multiple peaks indicating excited states, large blue-shift at low currents	stable transitions through excited states, built-in field entirely screened



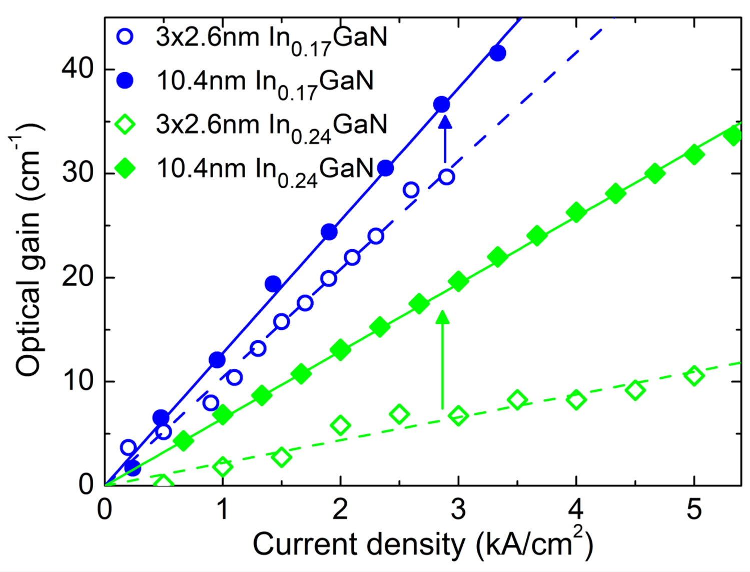
4. Towards long wavelength devices

For-long wavelength emitters indium content in the QWs needs to be increased, leading to higher piezoelectric field.

Surprisingly, wide QWs can be used with an extremely high wavefunction overlap between excited states.



Optical gain measurements performed on laser diodes reveal an increase of differential gain for LDs with wide QWs. Indeed, a greater improvement of differential gain is observed for the long-wavelength device.



Further reading

1. G. Muziol et al., "Beyond Quantum Efficiency Limitations Originating from the Piezoelectric Polarization in Light-Emitting Devices," ACS Photonics 6, 1963 (2019).
2. G. Muziol et al., "Optical properties of III-nitride laser diodes with wide InGaN quantum wells," Appl. Phys. Express 12, 072003 (2019).
3. G. Muziol et al., "III-nitride optoelectronic devices containing wide quantum wells—unexpectedly efficient light sources," Jpn. J. Appl. Phys. 61, SA0801 (2022).
4. M. Hajdel et al., "Dependence of InGaN Quantum Well Thickness on the Nature of Optical Transitions in LEDs," Materials 15, 237 (2022).

Summary

- Wide InGaN quantum wells can efficiently emit light despite the large piezoelectric field.
- The built-in field gets screened fast due to low overlap between carriers on ground states.
- Optical transitions through excited states with high wavefunction overlap emerge after screening of the built-in field.
- Wide InGaN quantum wells might become the solution to the „green gap" problem.

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