University of Padova
Department of Information Engineering

Current and temperature dependence of electroluminescence in InGaN-based LEDs with multi-wavelength emission

Summer School of Information Engineering
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Outline

- Introduction:
  - loss mechanisms occurring in InGaN-based LEDs;
  - problems related to MQW structures;
- Experimental details;
- Electroluminescence analysis:
  - current-dependent effects;
  - temperature-dependent effects.
- Conclusion.

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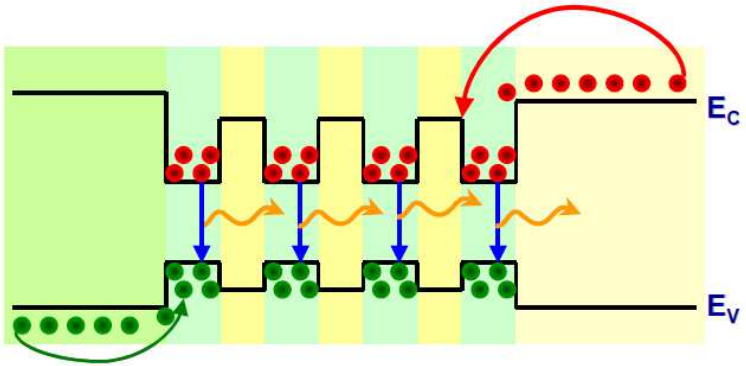
Introduction

InGaN-based Light-Emitting Diodes are required in most applications:

- street and indoor lighting;
- traffic lights;
- automotive.

Loss mechanisms occurring at high current densities:

- <u>solution</u> → distribution of carriers on a large number of wells



<u>Multiquantum well (MQW) structures</u>

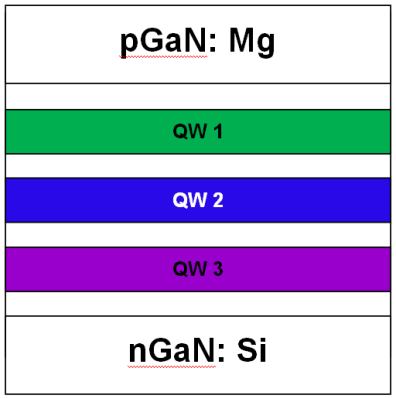
Introduction

- **Problem**: in InGaN MQW LEDs few wells contribute to the emission

usually due to the low mobility and density of holes

- Information about carrier distribution can be obtained from multicolor LEDs → each well emits its own characteristic color

- **Aim of this work:** to analyze the carrier distribution in InGaN-based LEDs at different temperature and current levels



analysis carried out on triple-quantum well InGaN-based LEDs

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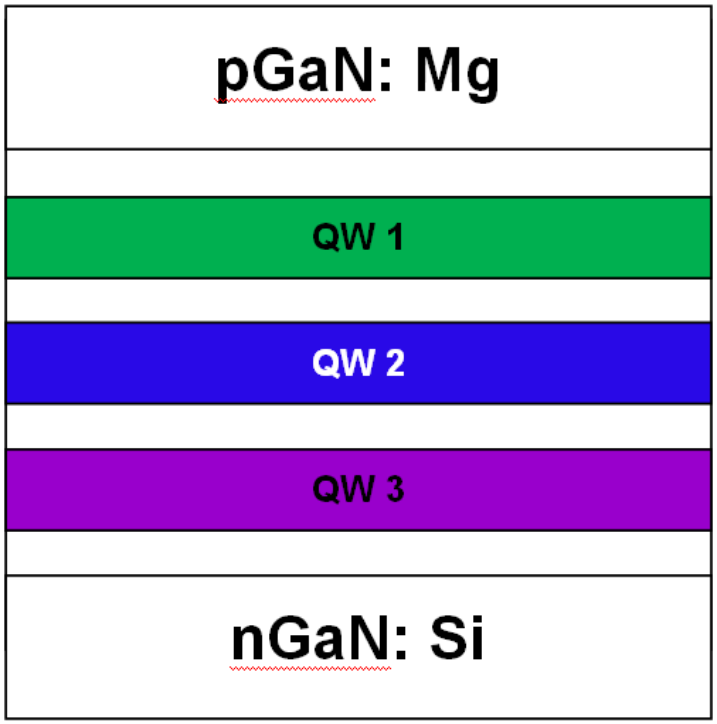
Experimental details



	Indium content (%)	wavelength emission (nm)
QW1	25	560
QW2	15	460
QW3	5	400

- Sapphire substrate (density dislocations ~5×10^{9} cm^{-2})
- n-GaN layer Si-doped
- p-GaN layer Mg-doped grown at 925 °C
- Active region: three quantum wells (2-3 nm) with different indium content in each well

Characterization: EL measurements at different temperature and current levels.

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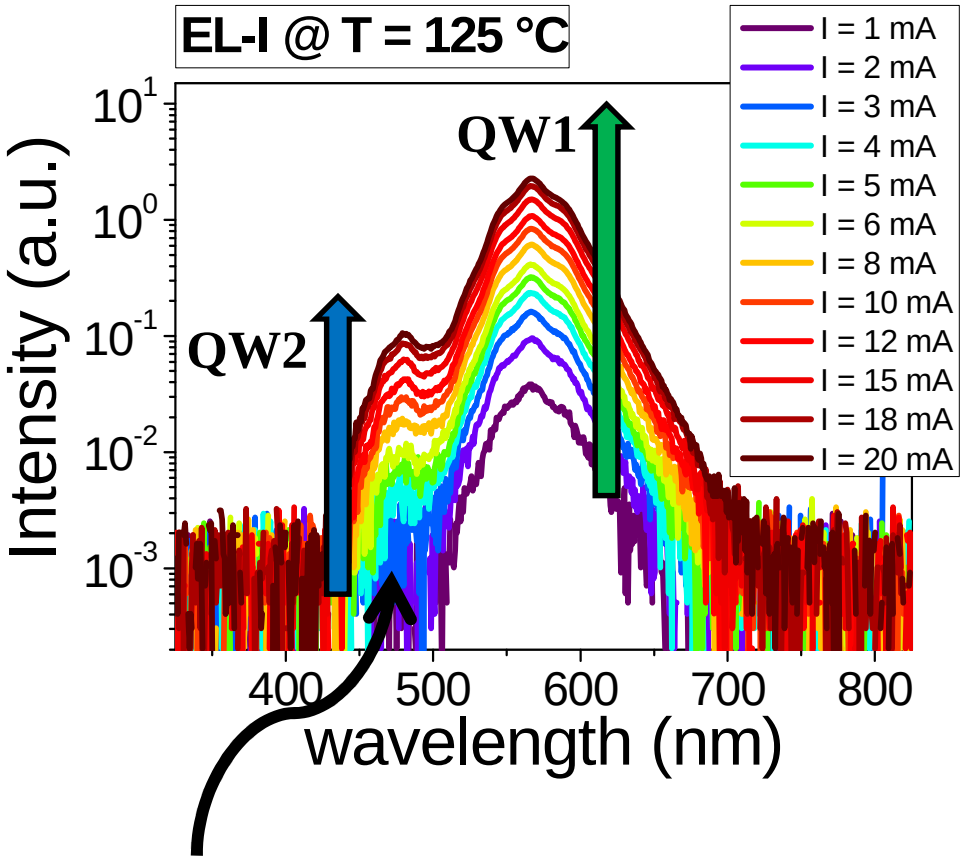
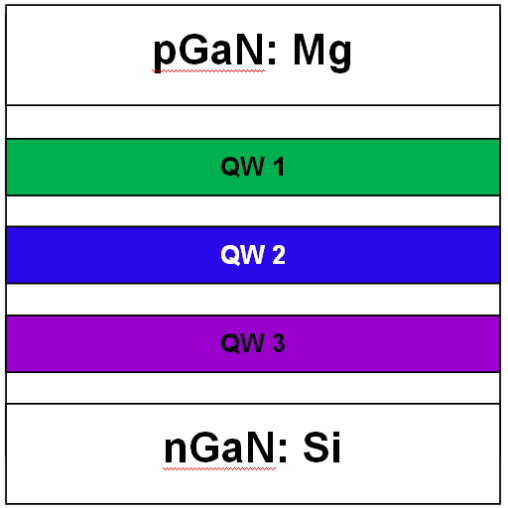
EL analysis: current-dependent effects



Two current dependent-effects:

1. increase in the EL intensity from both QW1 (560 nm) and QW2 (460nm) with increasing current;
2. no emission from QW3 (400 nm).



At low current levels no emission from QW2

→ efficiency limited by poor hole injection

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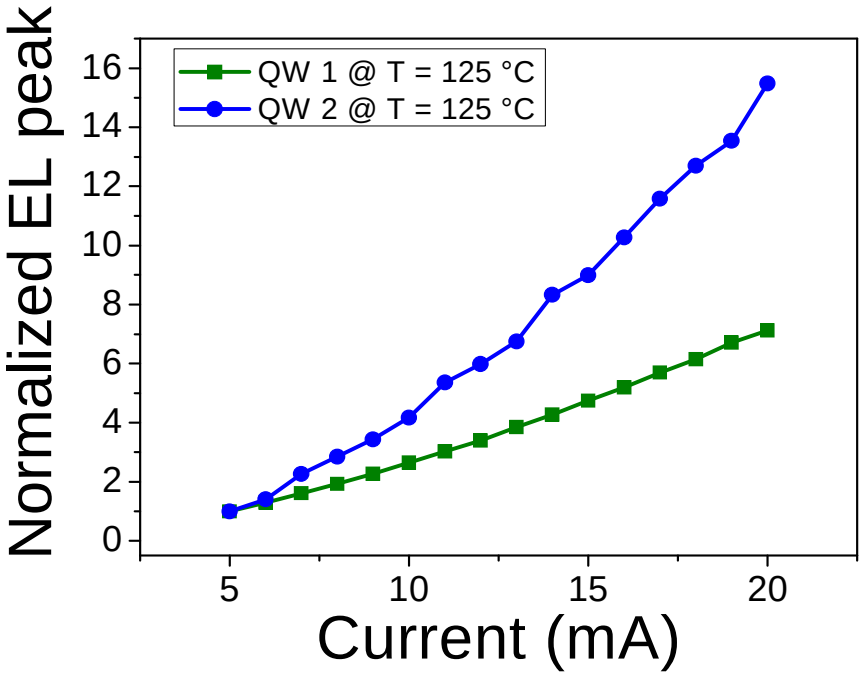
EL analysis: current-dependent effects



Increase of emission from QW2 particularly prominent at high current levels

At high current levels more carriers injected in the active region:

increase in the radiative recombination rate

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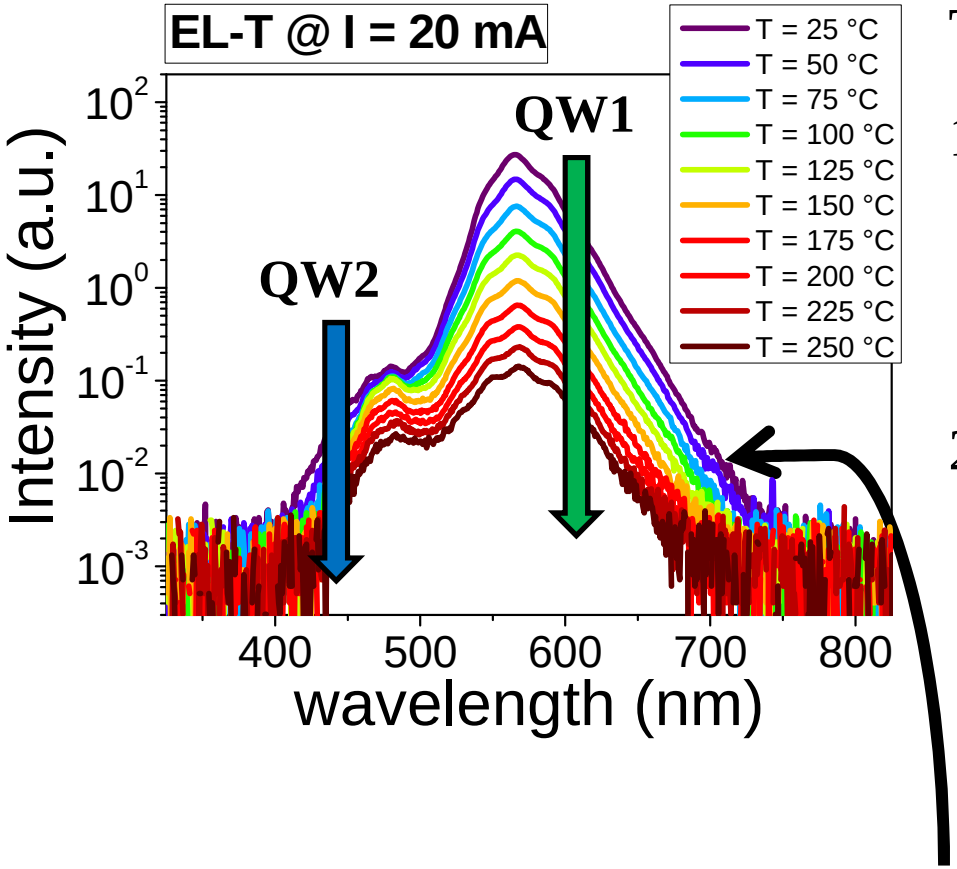
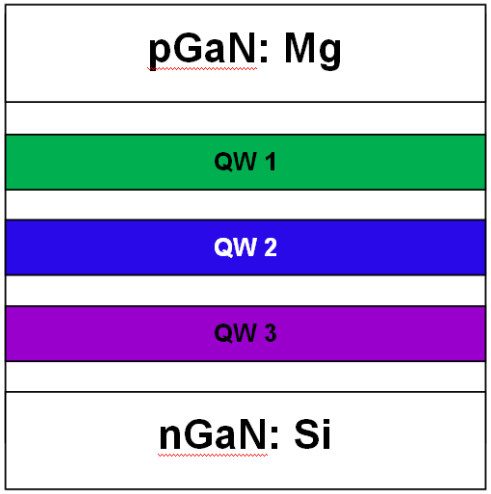
EL analysis: temperature-dependent effects



Two temperature dependent-effects:

1. decrease in the EL intensity from both QW1 (560 nm) and QW2 (460nm) with the increasing of temperature;
2. no emission from QW3 (400 nm).



Decrease in the emission with increasing temperature

→ increase in nonradiative recombination.

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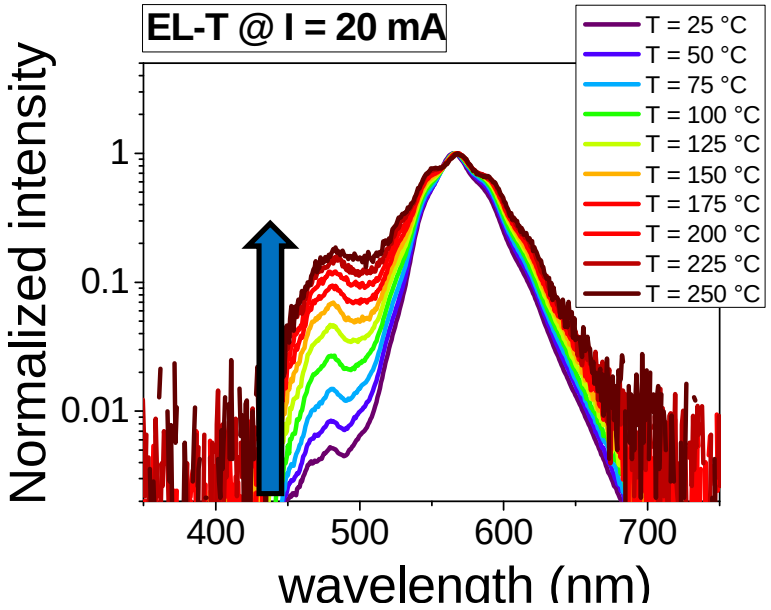
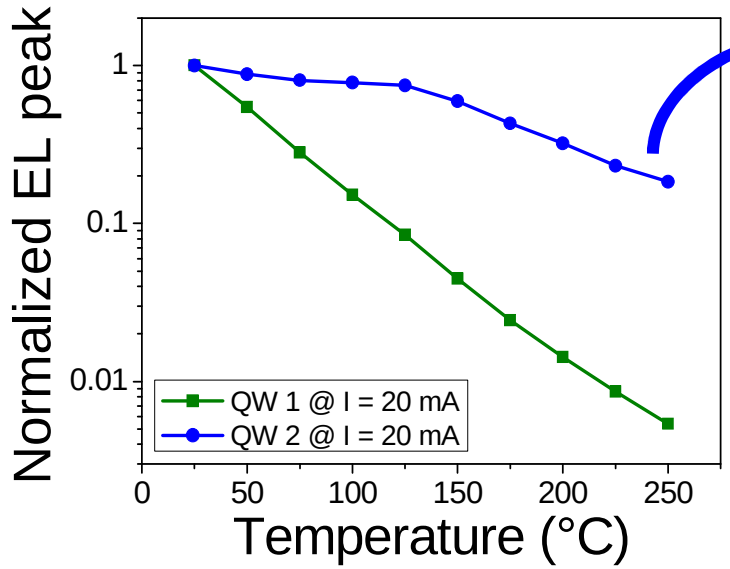
EL analysis: temperature-dependent effects





Decrease of emission from QW2 (460 nm) less prominent with respect to QW1 (560 nm)

At high temperature operation increased hole injection

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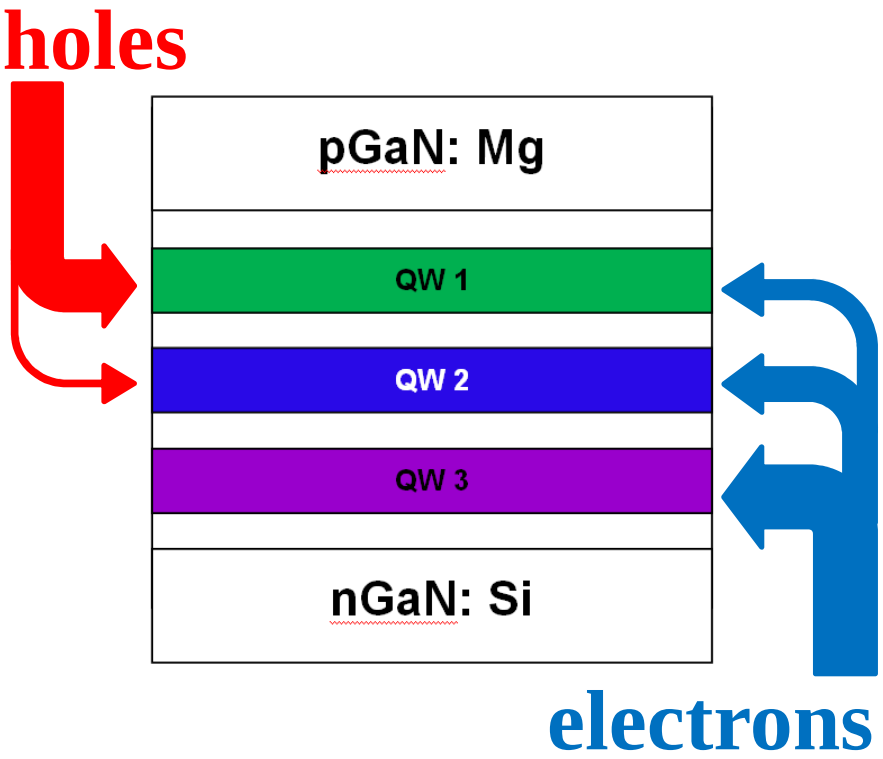
EL analysis: temperature and current-dependent effects

- **The previous results suggest a poor hole injection**

- **At high temperature levels:**
  1. holes with more thermal energy ⇒ increased probability of escaping QW1 and reaching QW2;
  2. stronger activation of the acceptor dopant (Mg).



- **At high current levels:** more holes can reach the second quantum well

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Conclusions

- Analysis of carrier distribution in triple-quantum well InGaN-based LEDs has shown that:

  1. MQW InGaN-LEDs efficiency is limited by poor hole injection;
  2. more holes can reach the second quantum well away from the *p*-type layer at high temperature and current levels.

- Future works:

  1. photoluminescence and cathodoluminescence measurements;
  2. analysis on similar structures (different position and thickness of wells).

Thanks for your attention

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