3-Dimensional Simulation of InGaN/GaN Micro-Ring Light-Emitting Diodes

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Background: research on extraction efficiency of LEDs

- Optimizing of epitaxy and processing
- Improving current spreading
- Designing of resonant cavity structures
- ……

Here: geometrical design

H. W. Choi and M. D. Dawso, "High extraction efficiency InGaN micro-ring light-emitting diodes", Appl. Phys. Lett., vol. 83, pp. 4483–4485, 2003

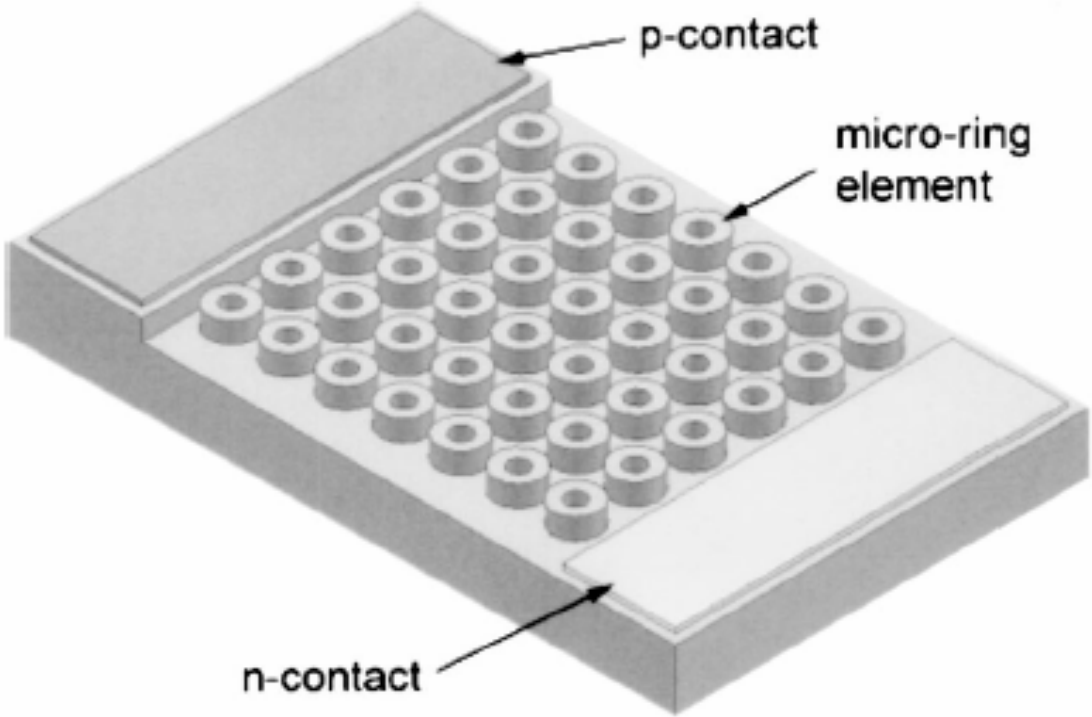


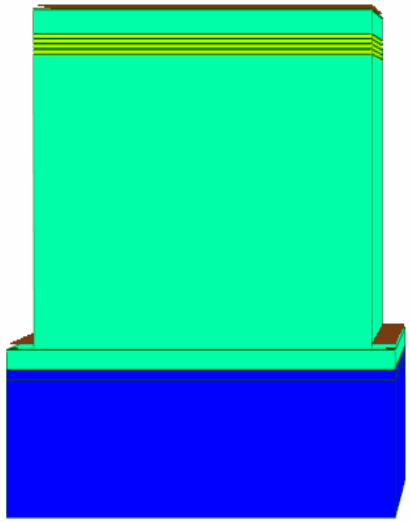
FIG. 1. Schematic diagram of a micro-ring LED (not to scale).

They have higher extraction efficiency than micro-disk and broad-area (BA) LEDs

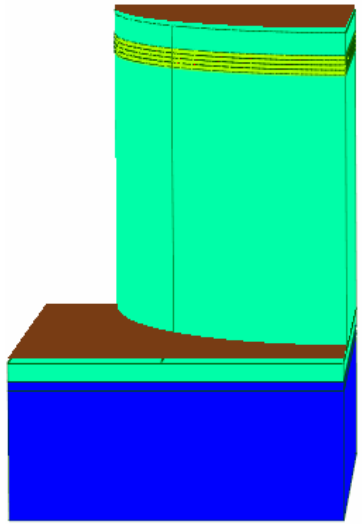
Simulator: APSYS by crosslight

About APSYS

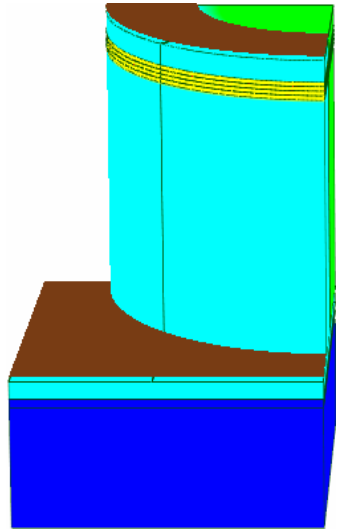
- Quantum drift-diffusion model for current flow/spreading (included).
- MQW quantum well gain/spontaneous emission model with effective mass approximation (included).
- 3D ray-tracing model (included).
- K.p model for MQW (optional).
- Self-heating model (optional).
- Polarization surface charge/self-consistent model (optional).



BA LED

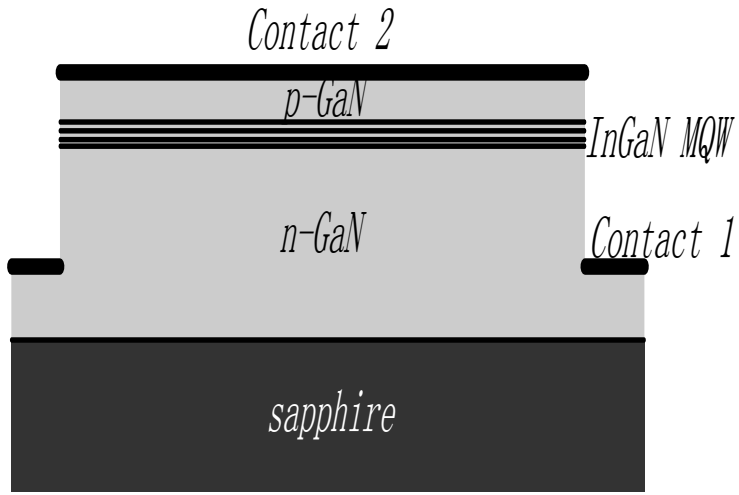


micro-disk LED(¼)



micro-ring LED (¼)

Simulator: APSYS



Schematic structure

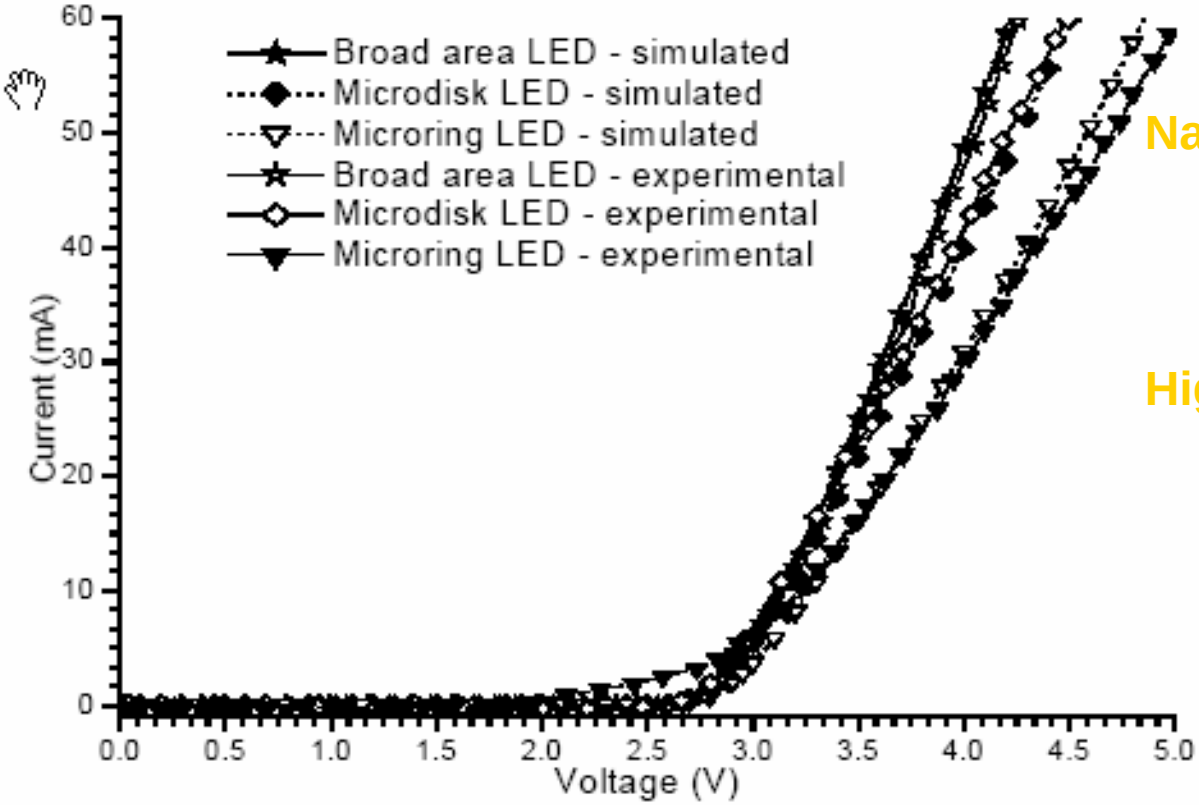


Fig. 2. I-V curves of different structures.

Narrower conduction path

↓

Higher ohmic resistance

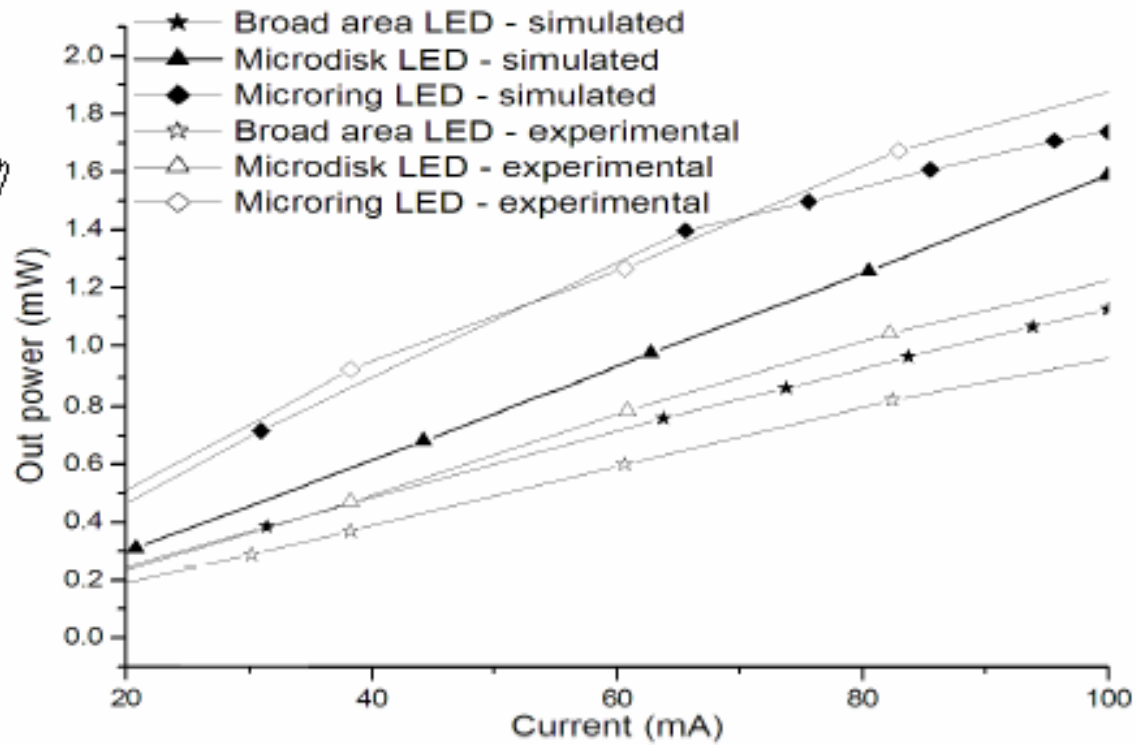


Fig. 3. Emission power from different devices

Out power: simulation > experiment

Reasons: 1, substrate absorption
2, package absence
3, reabsorbed by neighbors

3D ray-tracing technique in APSYS applied to detect angular dependence of emitted power

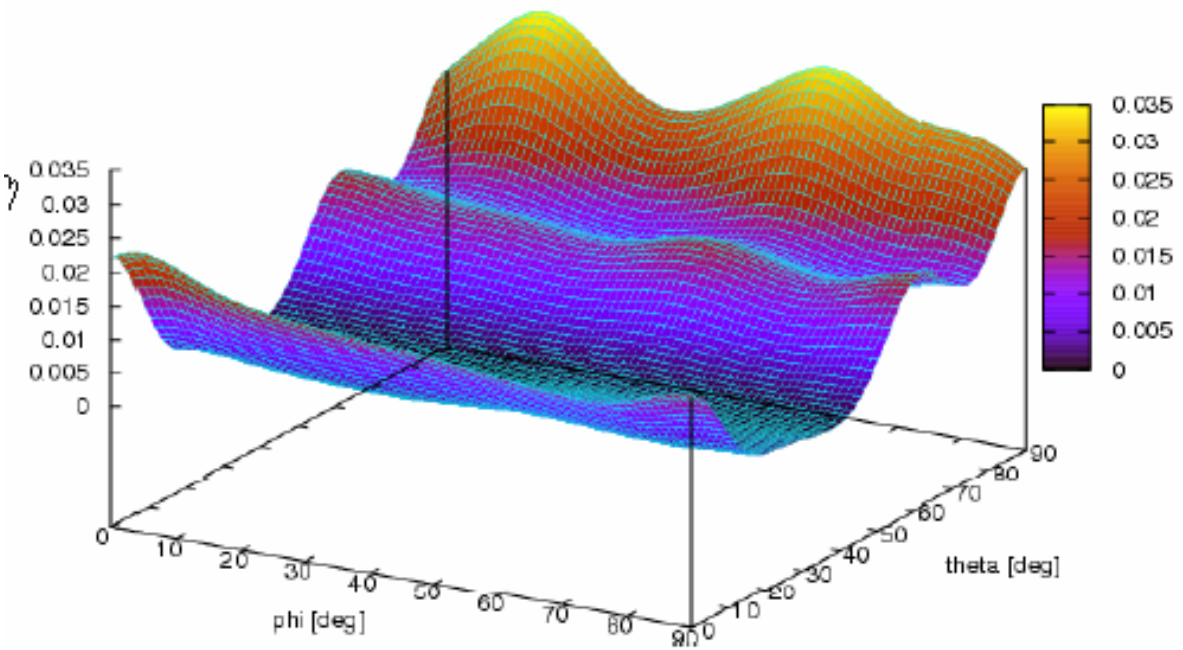
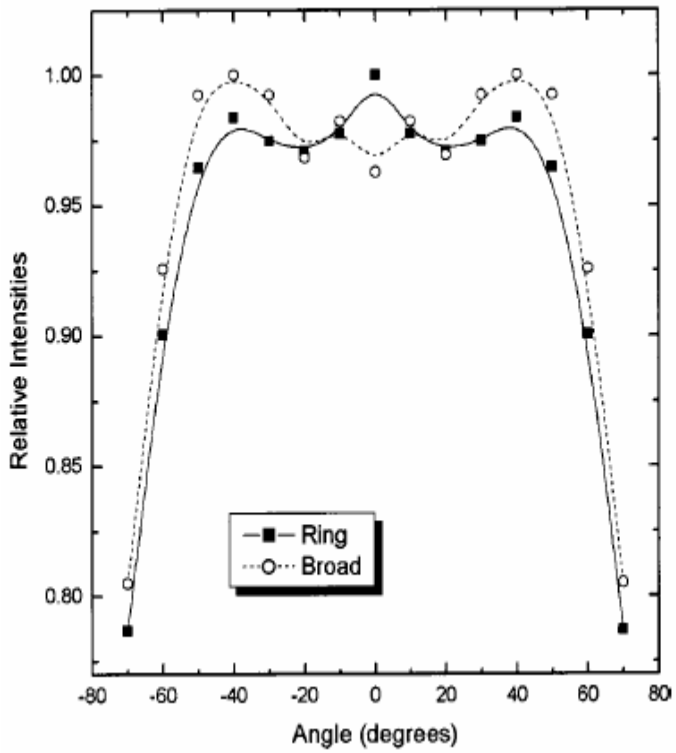


Fig. 5. Simulated 3D angular distribution of power



<50degree agree with experiment
>50degree disagree
Reason: 1, reabsorbed before detected
2, sidewall of micro-ring is not vertical to substrate in experiment

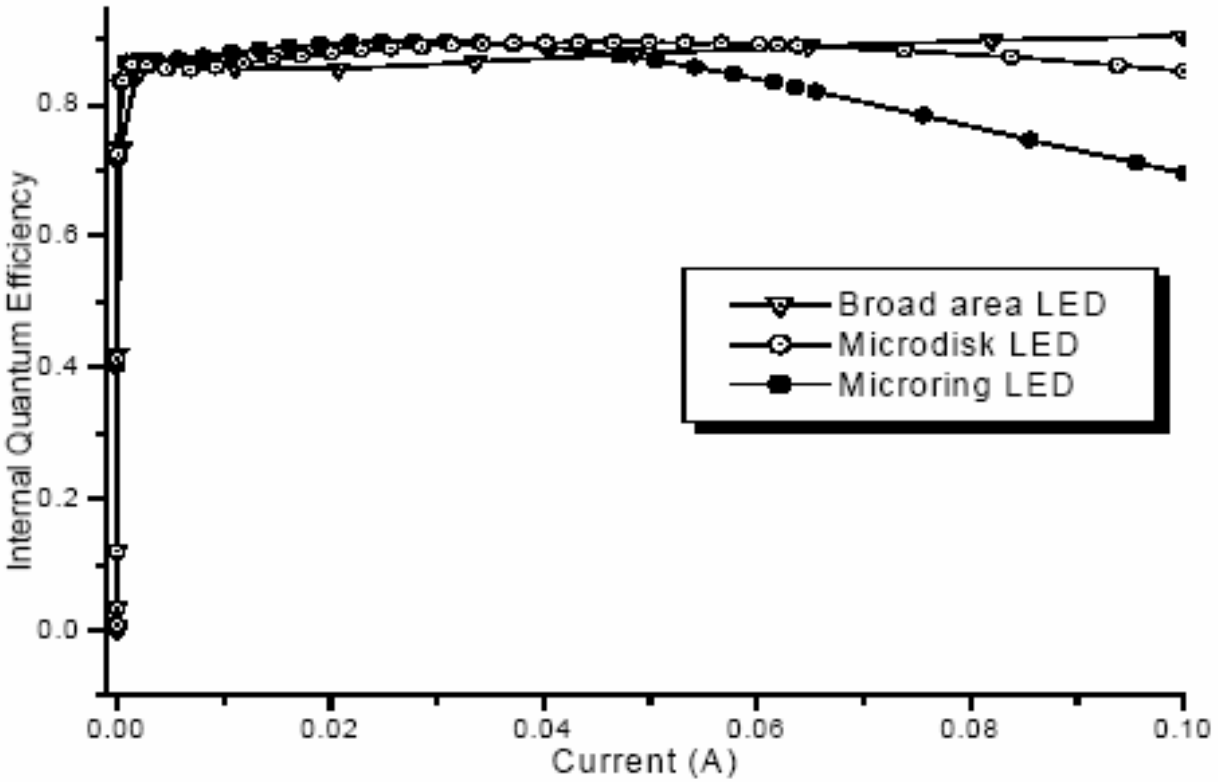
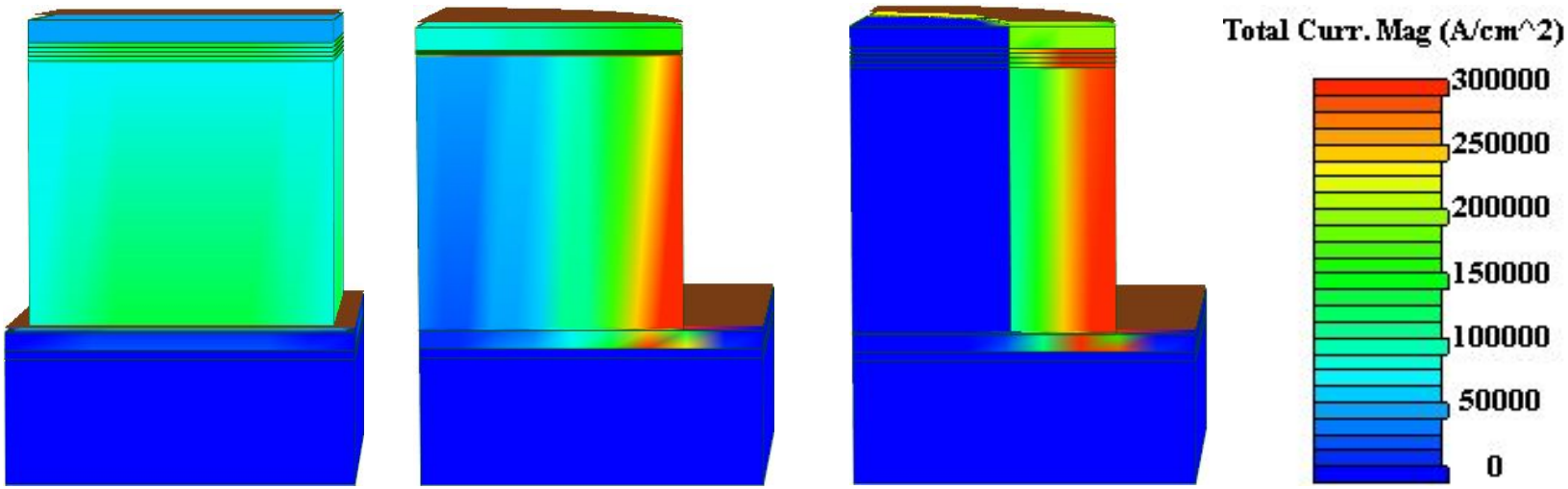


Fig. 4. Simulated internal quantum efficiency.

Smaller active region ➔ more current crowding ➔ more overflow loss ➔ IQE decreased



a) BA LED b) micro-disk LED c) micro-ring LED

Current in micro-ring device is more crowded than those in micro-disk/BA devices

Next:

1: multi-ring simulation to research inter-device reaction

2: relationship between IQE and diameter of micro-ring LED

3: relationship between extraction efficiency and diameter of micro-ring LED

That's all, thank you very much!