MONA
Merging Optics & Nanotechnologies

MONA Roadmap on Lighting

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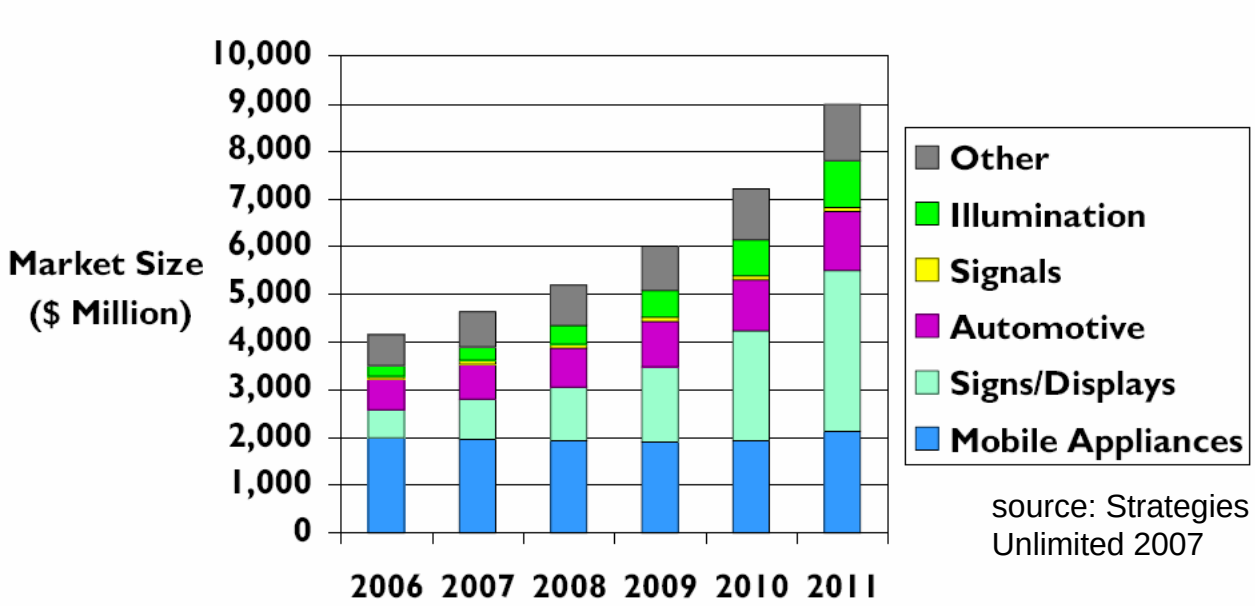
Solid State Lighting (SSL)

- High brightness LED industry today: 5 bn $



source: Strategies Unlimited 2007

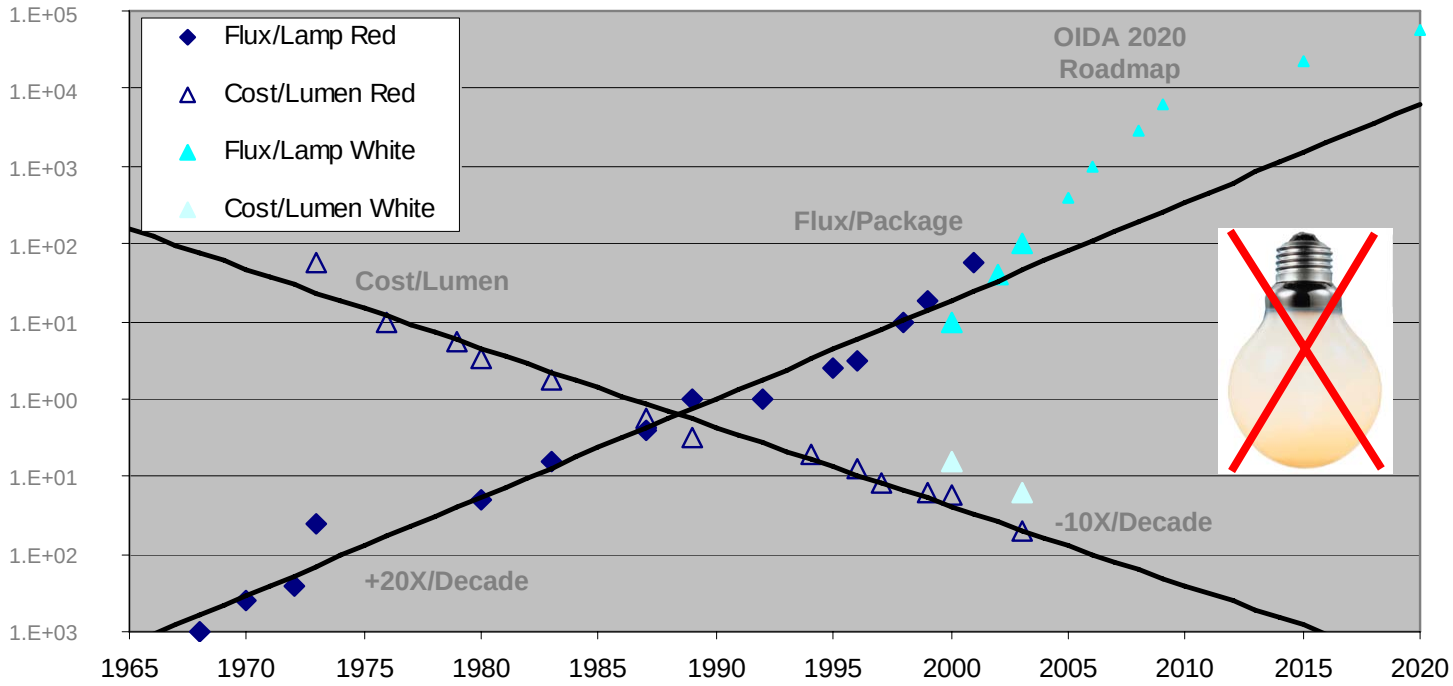
- Two major players in Europe: Philips and Osram
- Recent discussion on global warming pushes SSL

Solid State Lighting (SSL)

- Driving force: more lm/W, less $/lm
  - e. g. 2007: 75 lm/W announced for commercial LEDs

Flux/Lamp & Cost/Lumen (Red & White)

"Haitz" Law

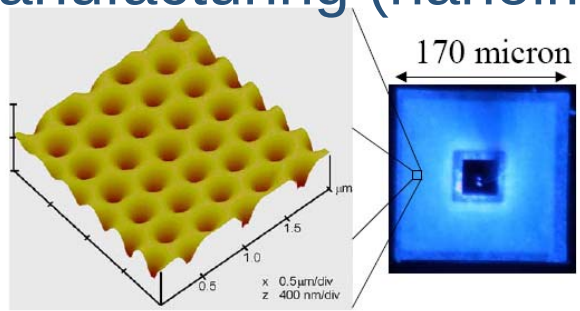


GaN LEDs with QD phosphors

- Conventional approach for white light:
  - blue GaN based LED + yellow phosphor
- nanophotonic approach: UV LED + QD phosphors
  - main benefits: high quantum efficiency, temperature stability
- Challenges: control of size, reproducible manufacturing

Photonic crystals

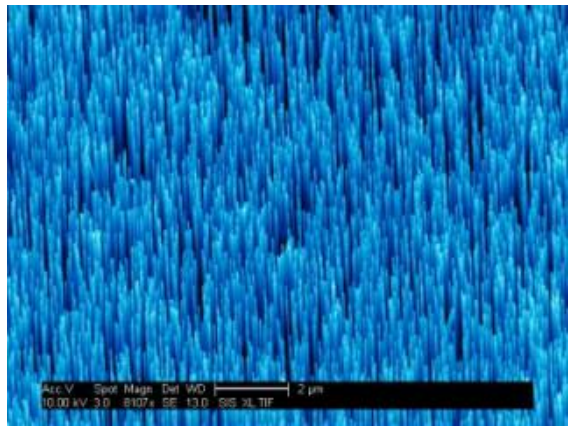
- Besides internal quantum efficiency, also light extraction out of the chip is critically limiting LED performance
- Conventional way of improving light extraction: surface roughening, thin film approach
- Nanophotonic approach: Photonic crystal structure (2D periodic pattern close to MQW)
- Target: Efficiency > 100 lm/W, long term 200 lm/W
- Challenge: low cost manufacturing (nanoimprint?)



source: Sandia National Laboratories

ZnO nanowires

- Alternative to GaN based LEDs
- Freedom to chose substrate
- Nanowires offer better structural properties than 2d films
- Challenges: p-type doping, control of growth



p-type ZnO nanowires

source: UCSD

Plasmonic structures

- Promise to improve light extraction
- Metal nanostructures (gratings)
- QW coupling with surface plasmons
- Challenges: very early stage, no proof yet that light extraction is enhanced
- Manufacturability?

III-V QDs and wires

- Target: improve efficiency (>100 lm/W short term, 200 lm/W long term); improve T and I stability
- Approaches: reduced dislocation density for UV emitters
- Low dimensional structures may improve stability of emission wavelength
- Challenges: size control

Organic nanostructures

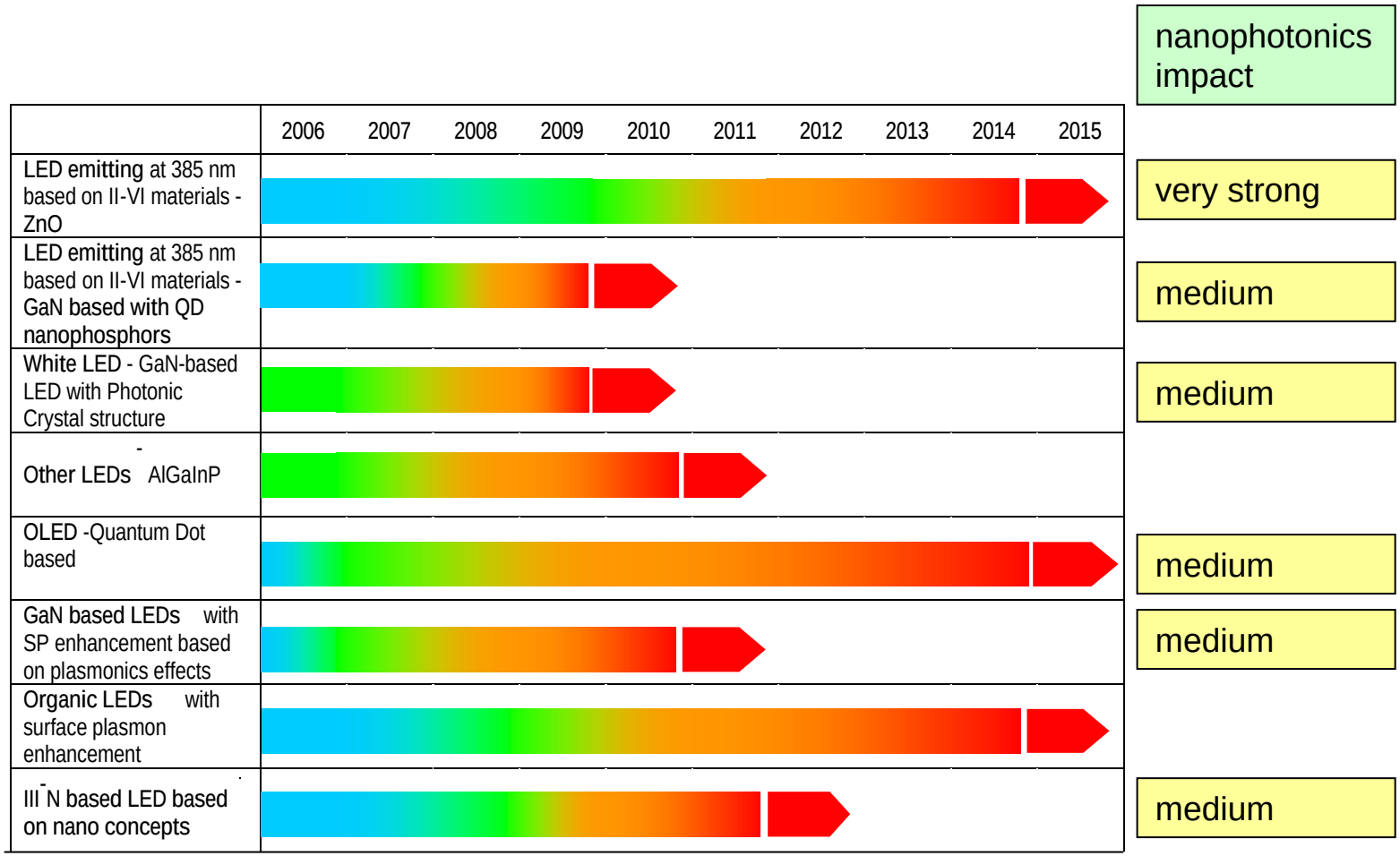
- OLED as an alternative to inorganic LEDs for lighting
- Main issues: lifetime, efficiency, cost
- QD approaches may improve light extraction, color temperature tuning
- Challenge: cost efficient manufacturing, reproducibility and control; manufacturing method may be critical

source: Philips

Key manufacturing technologies

Related Materials	Equipment
II-VI Quantum Dots	MOCVD Vapour Phase Deposition
Photonic Crystals high index nanostructures	Electron beam lithography, e-beam lithography Nano-imprint lithography
Plasmonics	Holographic Lithography Metal deposition Dry Etching
Organic nanostructures	Lithography Deposition technologies Encapsulation Roll-to-roll solutions

Lighting roadmap



Summary

- Nanophotonic approaches for lighting applications:
  - QD phosphors
  - photonic crystals
  - ZnO nanowires
  - plasmonic structures
  - III-V QDs and wires
  - Organic nanostructures
- Organics and ZnO may have high commercial impact
- GaN and AlGaInP are most developed