PhlatLight: The most powerful LED in the world

Alexei Erchak, CTO and Founder, Luminus Devices, Inc.

September 2006

Luminus Devices Corporate Information

- Using the concept of Photonic Lattices, Luminus has developed products and manufacturing processes that substantially enhance the brightness of Light Emitting Diodes (LEDs)
- Focus has been on MD-TV (e.g. DLP) applications
  - Although we are expanding to LCD backlighting
- Founded in 2002 with technology that emerged from MIT
- Headquarters in Woburn, Massachusetts
- Over 100 employees
- $70 million of equity capital raised (through Series D)
- Intellectual Property portfolio includes ~100 patents filed worldwide

PhlatLight™ product name is derived from Photonic Lattice technology

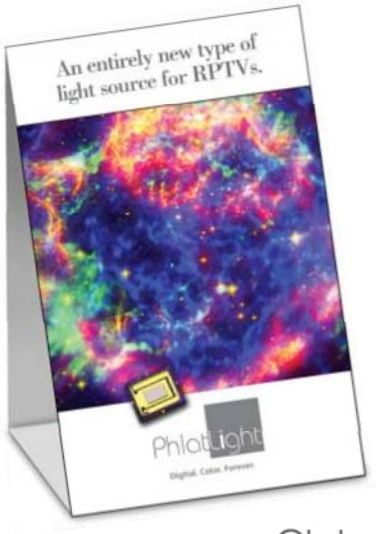
Because of PhlatLight LEDs microdisplay (MD) TVs have become a reality in 2006

- 3-5 years ahead of schedule
- Samsung 56” HL-S5679W is available in retail stores today
  - Magnolia Home Theatre (Best Buy), Tweeter, others
  - Based on TI MD chip (DLP)
- Others are launching PhlatLight based RPTVs in 2006 and 2007
  - With screen sizes from 50” to 62
  - All MD-TVs out there are powered by PhlatLight™ LEDs

Check out Burlington Tweeter

PhlatLight™ Award Winning RPTV Products

- 11 TV manufacturers present 6 different PhlatLight™ based designs with DLP™, HTPS and LCoS light engines at CES 2006
- Samsung's 56" HL-S5679W wins "CNET Best of CES 2006" Award for televisions
- Luminus' PhlatLight Technology wins Insight Media's Best Buzz Award for "Best New Enabling Technology"
- PhlatLight based microdisplay televisions win Insight Media's Best Buzz Award for "Best New Display" Category

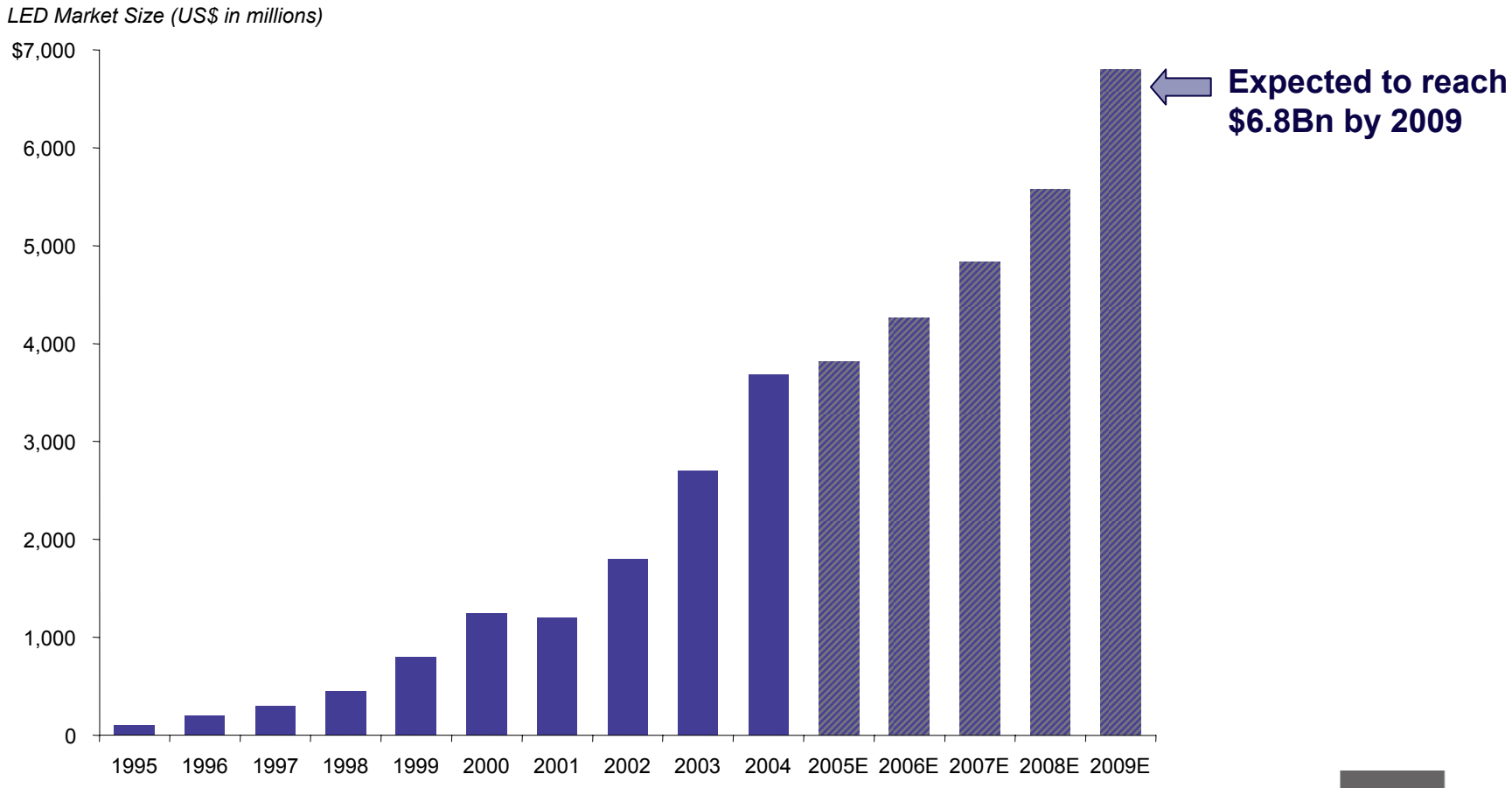


PhlatLight

Light emitting diodes, or LEDs, are re-emerging as a new industry called Solid State Lighting (SSL)

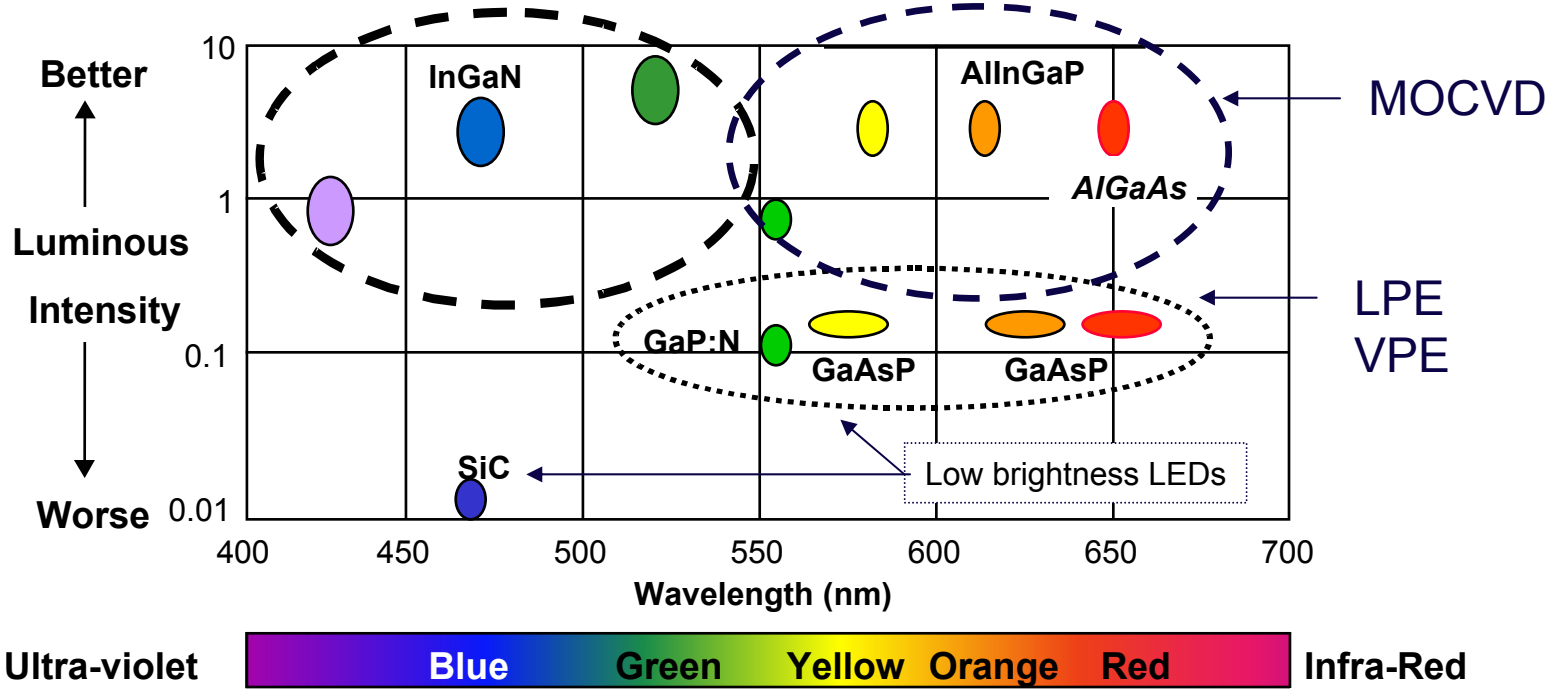
- LEDs have been around since the 1960s
  - But only recently achieving required brightness, efficiency and coverage of the entire white spectrum
- The vision of SSL: light bulbs will gradually be replaced by LEDs
  - Robust, brighter, long-lived and compact
  - Energy efficient
- Potential power savings provide massive benefits to the economy and environment
  - Billions in savings on fuel and infrastructure
  - Reduction in carbon emissions

High-Brightness LEDs have seen explosive growth in recent years.



Source: Strategies Unlimited, July 2005.

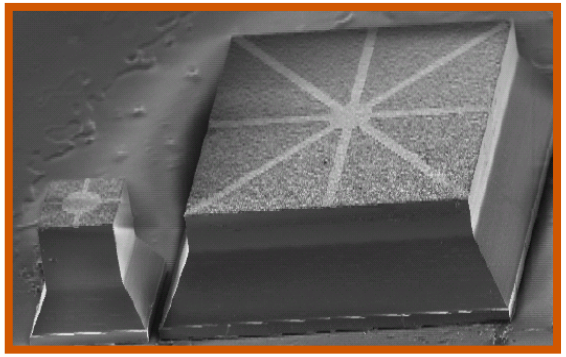
Semiconductor LEDs have benefited from impressive innovation in growth technology over several decades



PhlatLight

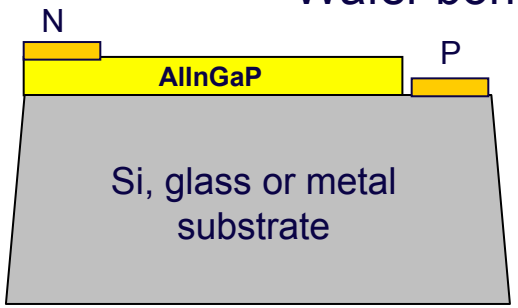
The 1990s experienced substantial innovation in chip design

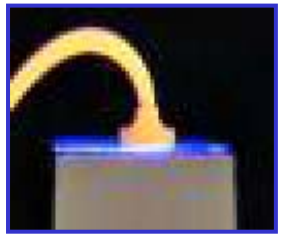
Chip shaping



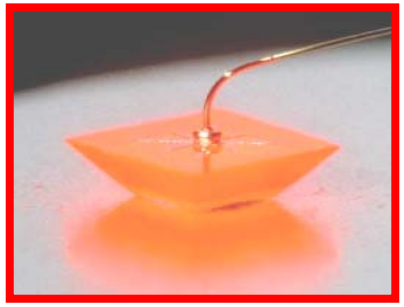
Cree

Wafer bonding



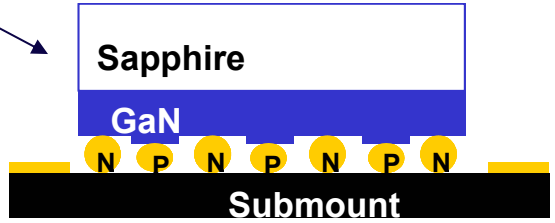


Osram



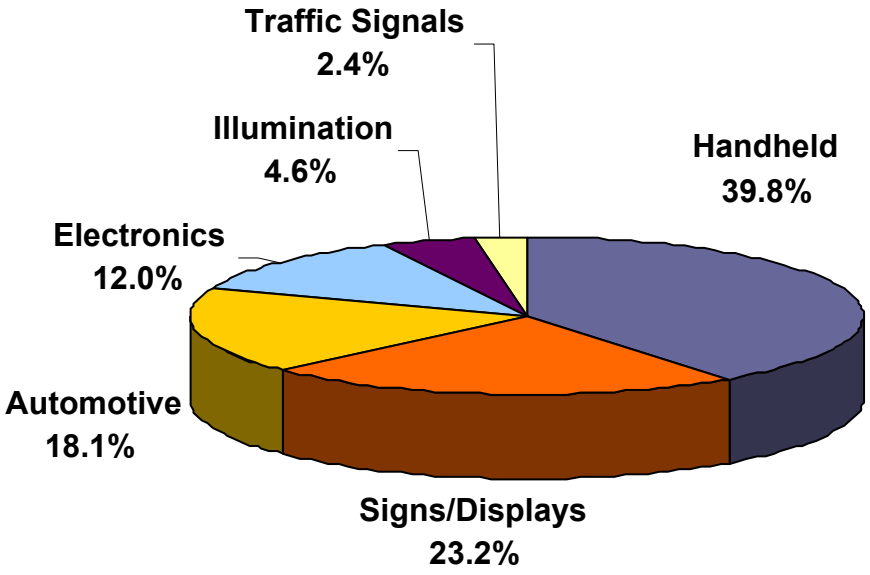
Lumileds

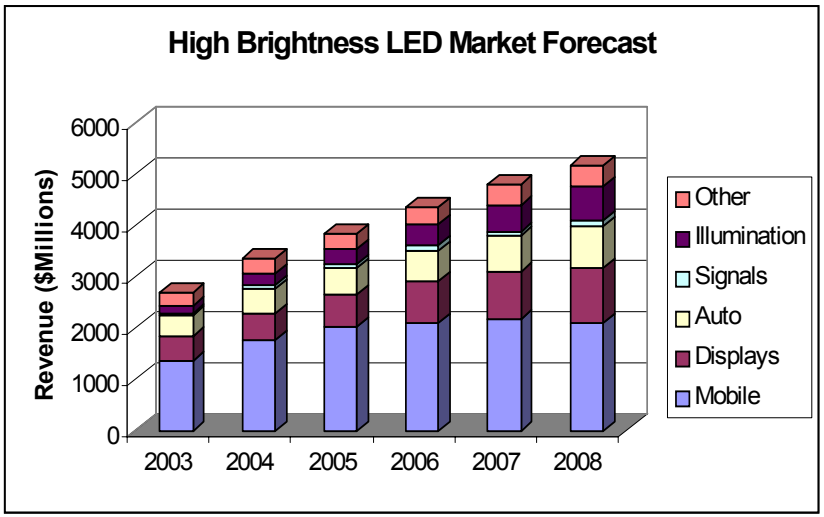
Luxeon (Flip-chip)



PhlatLight

Low brightness LEDs continue to drive today's LED market





The new generation of digital projectors are based on microdisplay panels and very bright light sources

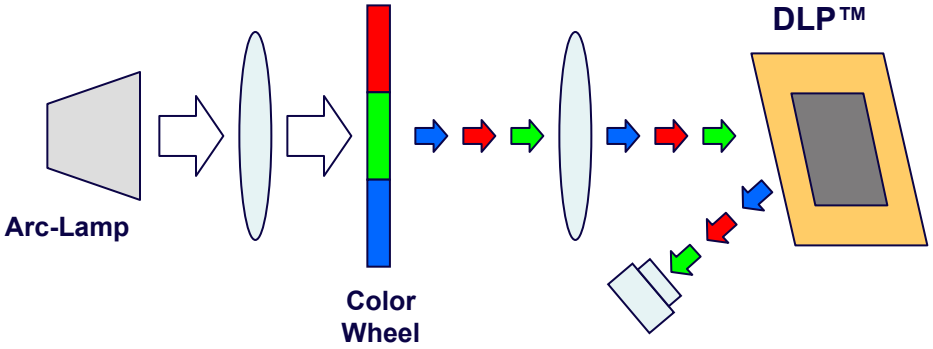
- Three competing **microdisplay technologies**
  - Transmissive liquid crystals (HTPS)
  - Micro-mirror arrays (DLP™ or DMD)
  - Reflective Liquid Crystal on Silicon (LCoS)

- The **light sources** are predominantly arc-lamps
  - Also known as UHP, HID, Mercury, Metal Halide
  - Short lived (a few 1000 hrs)
  - Expensive (~$100)
  - Need color separation and filtering
  - Fragile, finicky and hazardous

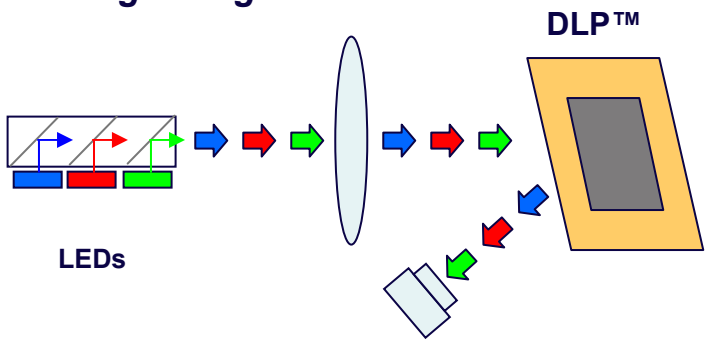
PhlatLight

The advantages of LED-lit MD-TVs are universally recognized, and apply to all microdisplay "flavors" and all manufacturers

Conventional Light Engine for DLP



LED Based Light Engine



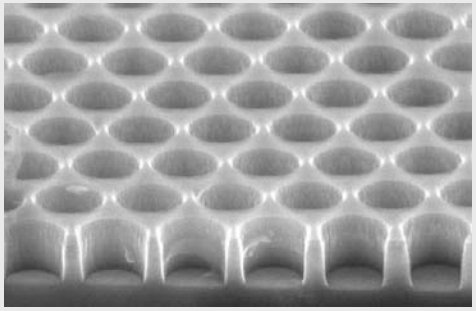
Benefits of LEDs over arc lamps

- Wider color gamut
- Instant-on
- Digital compensation for variations in color temperature, wavelength and brightness
- Fast switching results in faster refresh rates and elimination of rainbow effects
- Long lifetime: 60,000 hours
- No color wheel noise
- Environmentally safe

PhlatLight

PhlatLight technology from Luminus Devices: a breakthrough for LEDs

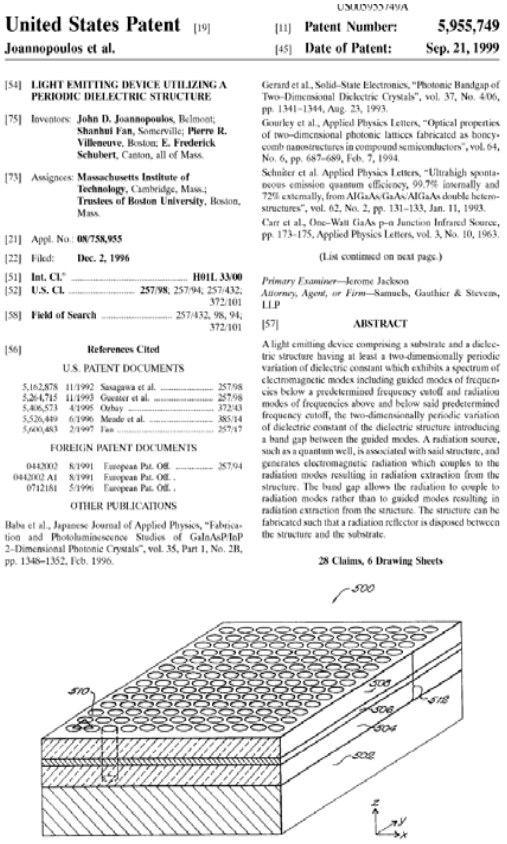
- **PhlatLight™ = Photonic Lattice** Light Emitting Diodes
- What is a "Photonic Lattice", why do we need it?
  - An intricate microstructure embedded in the LED
  - Efficient, uniform, collimated light extraction from the chip surface
  - Enables brighter, high power, large area devices



Photonic Lattice Example

The PhlatLight™ platform is a nanostructured approach, built around photonic lattice technology developed at MIT

- Idea originated & patented at MIT in 1996
- Research at MIT demonstrated that a photonic lattice can significantly increase LED extraction efficiency
- Results were dramatic enough to motivate founding of Luminus



United States Patent [19]
Joannopoulos et al.

[11] Patent Number: 5,955,749
[45] Date of Patent: Sep. 21, 1999

[54] LIGHT EMITTING DEVICE UTILIZING A PERIODIC DIELECTRIC STRUCTURE

[75] Inventors: John D. Joannopoulos, Belmont; Shanhui Fan, Somerville; Pierre R. Villeneuve, Boston; E. Frederick Schubert, Canton, all of Mass.

[73] Assignees: Massachusetts Institute of Technology, Cambridge, Mass.; Trustees of Boston University, Boston, Mass.

[21] Appl. No.: 08/758,955

[22] Filed: Dec. 2, 1996

[51] Int. Cl.° H01L 33/00

[52] U.S. Cl. 257/98; 257/94; 257/432; 372/101

[58] Field of Search 257/432, 98, 94; 372/101

[56] References Cited

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5,600,483	2/1997	Fan	257/17

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(List continued on next page.)

Primary Examiner—Jerome Jackson
Attorney, Agent, or Firm—Samuels, Gauthier & Stevens, LLP

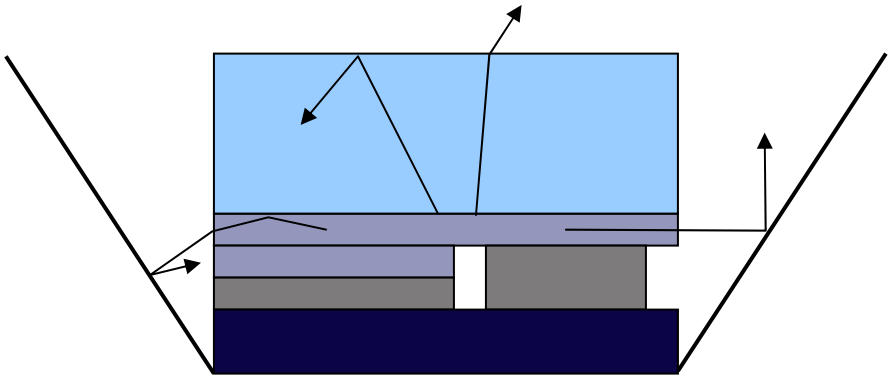
[57] ABSTRACT

A light emitting device comprising a substrate and a dielectric structure having at least a two-dimensionally periodic variation of dielectric constant which exhibits a spectrum of electromagnetic modes including guided modes of frequencies below a predetermined frequency cutoff and radiation modes of frequencies above and below said predetermined frequency cutoff, the two-dimensionally periodic variation of dielectric constant of the dielectric structure introducing a band gap between the guided modes. A radiation source, such as a quantum well, is associated with said structure, and generates electromagnetic radiation which couples to the radiation modes resulting in radiation extraction from the structure. The band gap allows the radiation to couple to radiation modes rather than to guided modes resulting in radiation extraction from the structure. The structure can be fabricated such that a radiation reflector is disposed between the structure and the substrate.

28 Claims, 6 Drawing Sheets

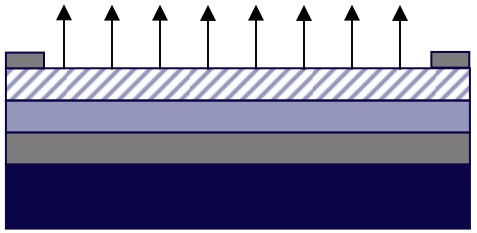
PhlatLight

PhlatLight™ technology is based on a fundamentally different approach to LED design



Luxeon

- The industry benchmark
- ~50% edge emission
- Efficiency drops for larger chips

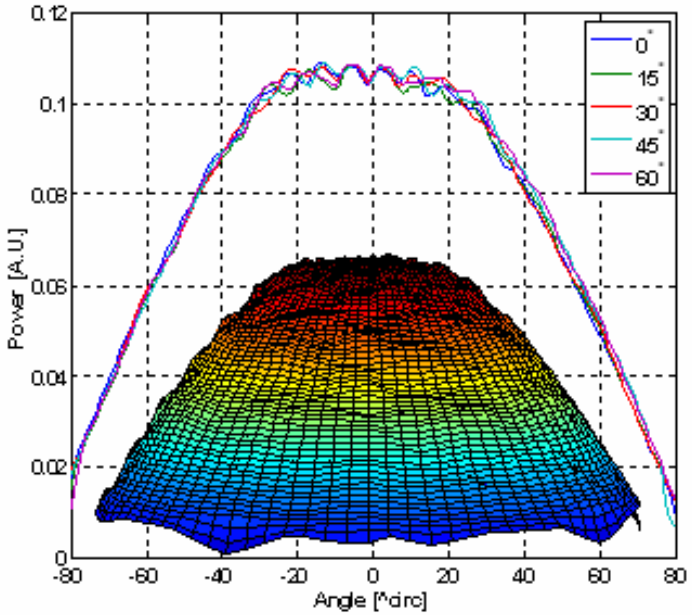


PhlatLight™

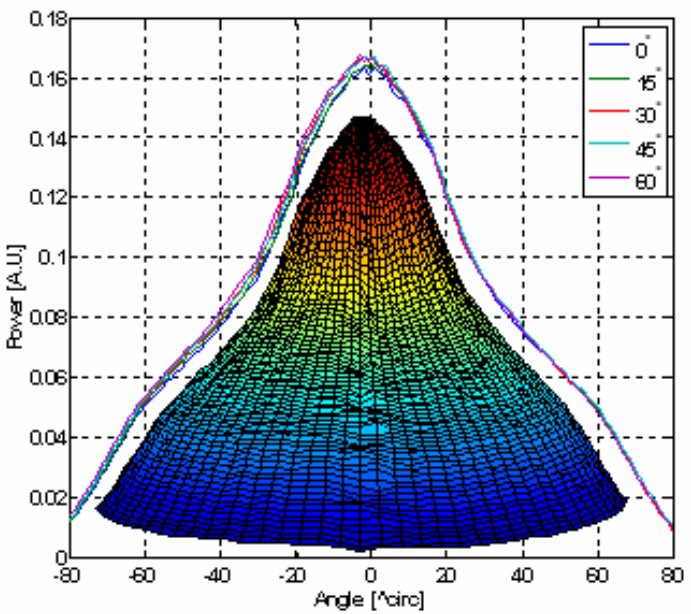
- Surface emission
- Scalable for high power operation
- High efficiency even for large chips

Collimation at the chip surface without a lens provides higher efficiency especially in etendue limited optical systems

Lambertian Output



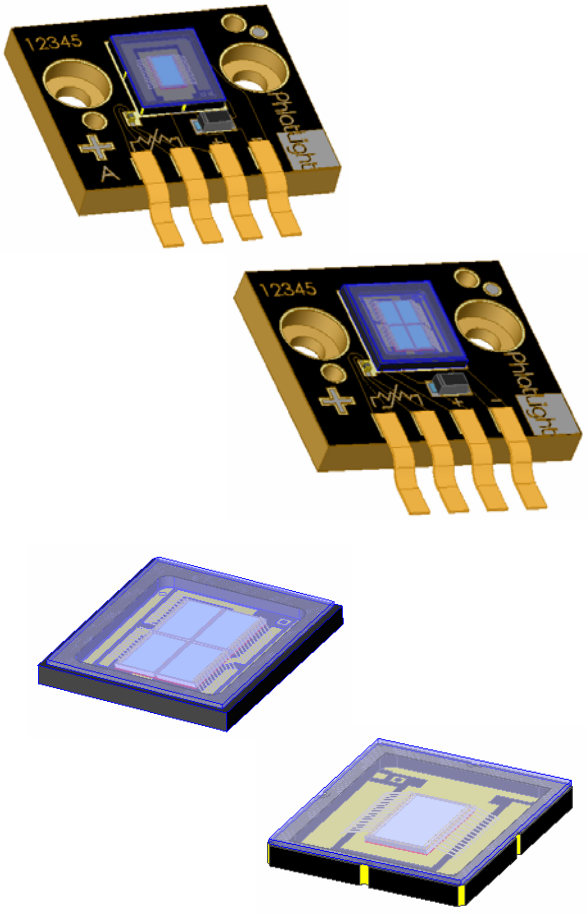
Collimated output for narrow viewing angle



PhlatLight

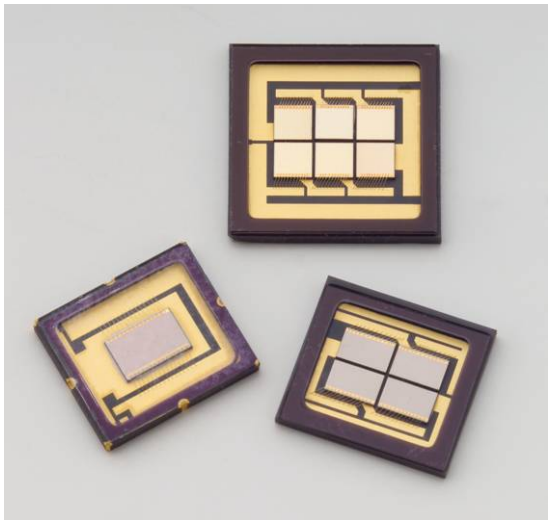
PhlatLight™ Package Advantage

- **Lowest thermal resistance** for high reliability
- High power operation
- **Low profile** to allow shortest distance between emitting area and collection optics
- Emission into air - **no encapsulant**
  - Simplified optical design for collection optics
  - High reliability
- Surface mount – for highest **design flexibility**
- Available as surface mount package, or mounted on high-performance core-board
  - Core-board includes thermistor for thermal management



Unique properties combine to make PhlatLight™ superior to conventional LEDs for MD-TV applications

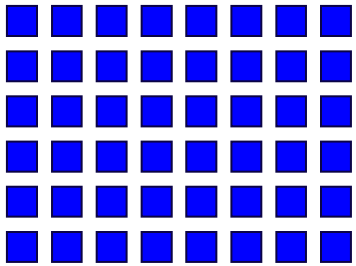
- High extraction efficiency: more light output for any given LED size and input power
- Scalability: Enables high-efficiency, uniform brightness, large area single LEDs
- Surface emission: simplifies and maximizes light collection
- Reliable: no encapsulant – the single greatest failure mode for LEDs
- Customizable: 16:9 chip design

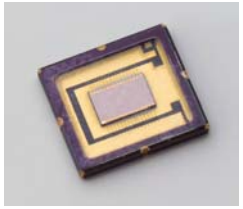


PhlatLight

PhlatLight™ was developed for projection applications from the ground up

LED Arrays	PhlatLight™
▪ Not enough brightness – limited by etendue of optical system ▪ Requires hundreds of LEDs ▪ Low system efficiency ▪ Complex optical and electrical design ▪ Costly packaging, binning and integration	▪ Optically-optimized single chip for each color ▪ Simple, efficient collection optics and circuitry ▪ Lower assembly and system costs - superior BOM over lamp based solution

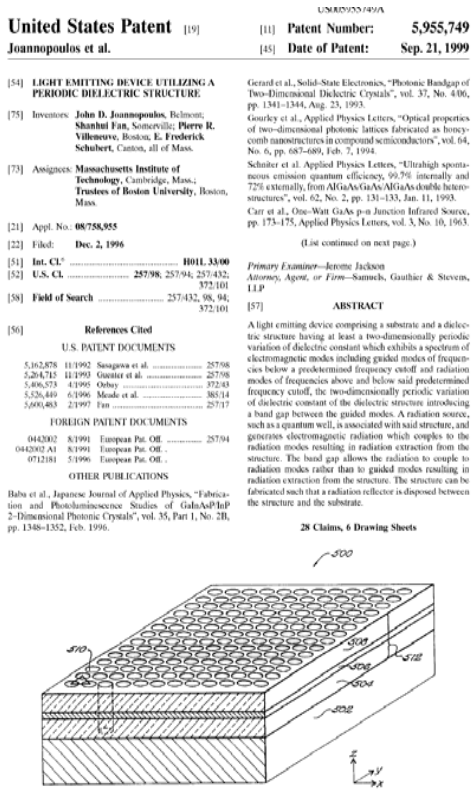




Luminus has swiftly commercialized PhlatLight by an early focus on manufacturability

1995

Invented at MIT



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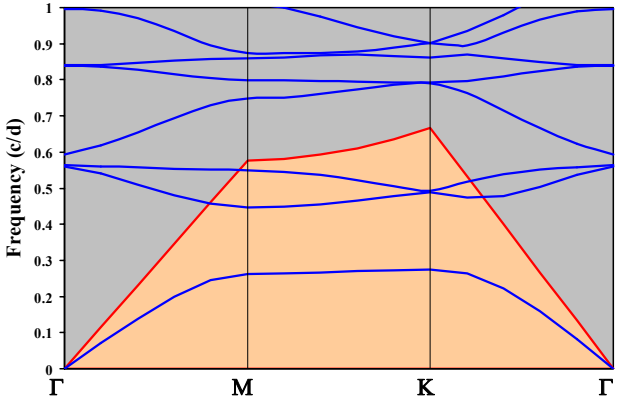
28 Claims, 6 Drawing Sheets

2002

Designed for Manufacturing



- Supercomputer simulations
- Robust, process tolerant designs
- Standard mfg equipment

Nearly 100 more patents filed

2006

Commercial Products

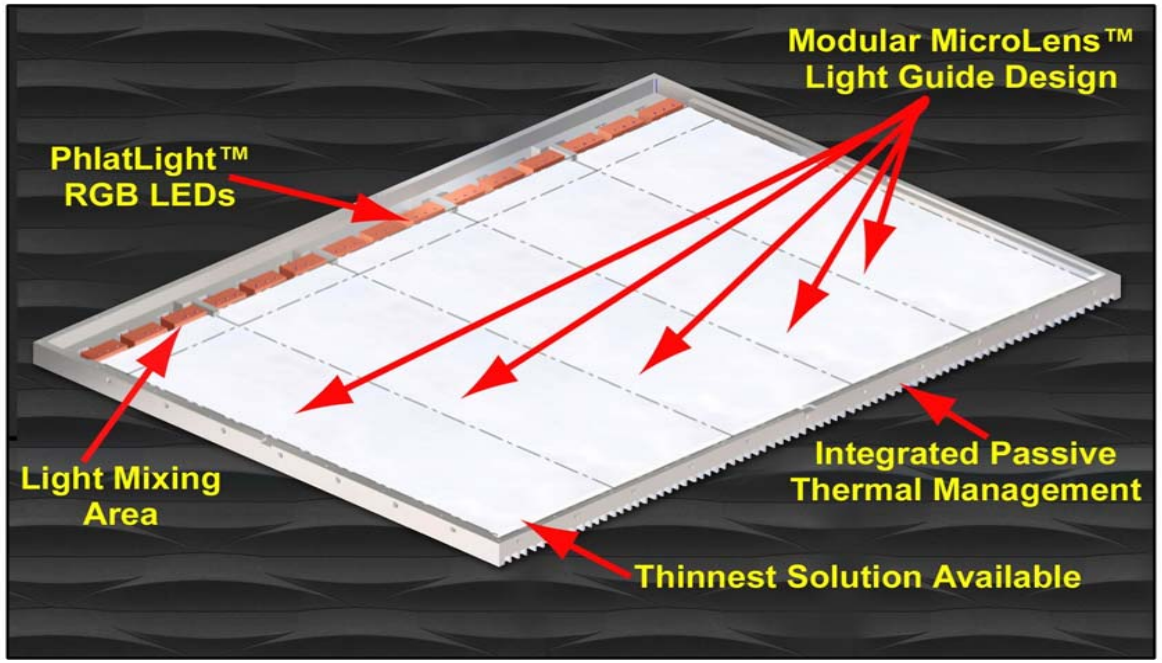
PhlatLight

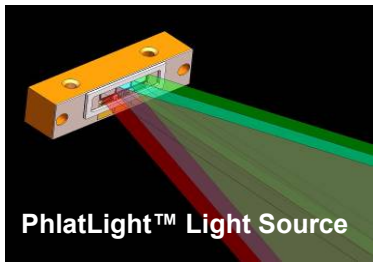
Luminus' goal with PhlatLight™ LEDs is to help MD-TV industry win back market share from plasma and LCD

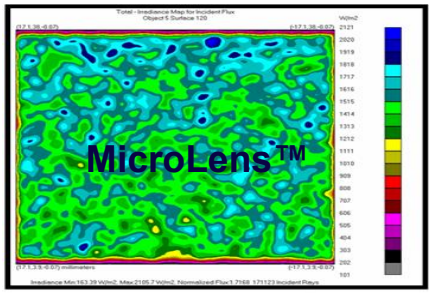
- Replace all MD-TV (e.g. DLP) arc-lamps with PhlatLight™ by 2008
- Rapid price reduction with growing economies of scale
  - Expansion of application portfolio
  - Various MD-TV screen sizes
  - Home-theater
  - Higher brightness pocket projectors
  - LCD BLU (edge lighting)

➔ Utilize the introduction of solid state light sources to revitalize the consumer perception of MD-TVs ("rear-projection" TVs)

The next big thing for PhlatLight: Backlight Unit for LCD-TV







- High Brightness 8,500+ cd/m²
- Fewer LEDs
- Thinnest Design Available
- Modular Light-Guide Design
- Passive Thermal Management
- Optimal Color Mixing
- Very Small Footprint
- Scalable to Any Size

GLOBAL LIGHTING TECHNOLOGIES INC.

PhlatLight

The next big thing for PhlatLight: Backlight Unit for LCD-TV

- Best new BLU at SID 2006

24” diagonal demo