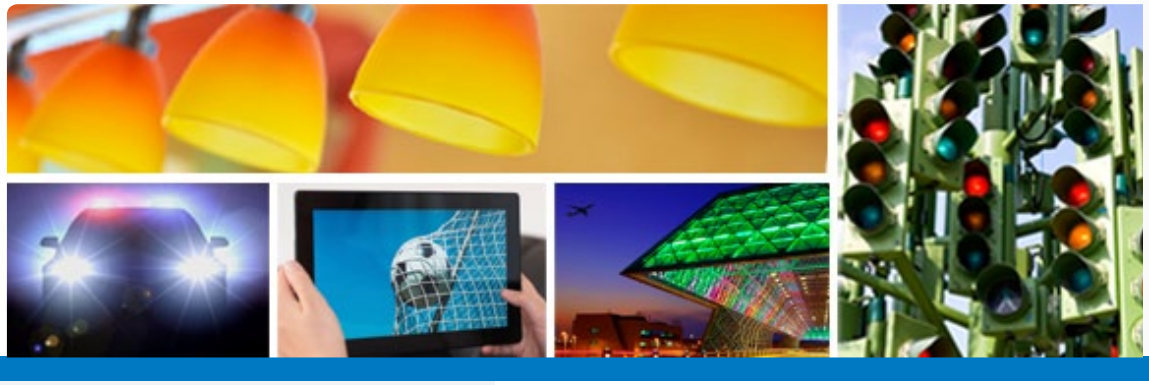
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

New Amber LEDs for High-Efficiency Solid-State Lighting



Technology Licensing Webinar

Tuesday, December 10th
2 p.m. EDT

Be the first to access this game-changing technology for your solid-state lighting business, as NREL commercializes its patent-pending intellectual property.

Register now to attend this webinar, which will include details about:

- How this innovative technology revolutionizes LED lighting
- Its potential impact on the high-growth multi-billion-dollar LED market
- How to apply for a license

Register at: **http://bit.ly/1diFeSe**

Or scan this code with your smart phone to go to the registration site:

NREL is closing the LED "green gap" with a patent-pending technology that allows for easy manufacturing of low-cost amber LEDs that—when combined with red, green, and blue LEDs—produce brilliant broad-spectrum white light more efficiently than current LEDs. This color-mixing technique enables low-cost, easy-to-manufacture white LEDs with improved luminosity.

This novel device architecture achieves greater efficiencies than current amber LEDs. In addition, the color-mixing approach avoids the energy losses associated with producing white light via conventional (phosphor-converted blue) LEDs.

NREL's game-changing innovation could transform the market for solid-state lighting (SSL) for industry, businesses, and consumers. It also will impact the performance of lasers and photovoltaics.

NREL's amber LED technology is available for license.

Benefits

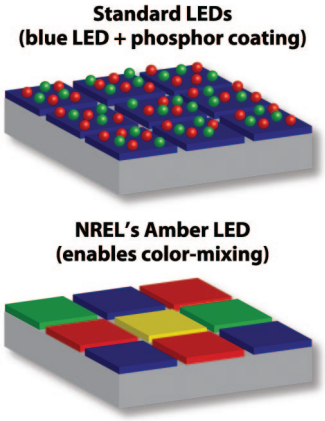
NREL's innovative amber LED technology offers significant advantages over current LED techniques, such as:

- **Proven efficiency increases:** Demonstrates twice the efficiency of current amber LEDs
- **Easy manufacturing:** Can be fabricated simply on a large scale with existing manufacturing equipment
- **Low-cost materials:** Uses the same commercially available substrates as for current amber and red LEDs—gallium arsenide (GaAs)
- **Better white LEDs:** Enables color-mixing white LED architectures that:
  — Emit more white light, with an estimated 20% increase in luminosity
  — Avoid Stokes-shift energy losses while minimizing photocarrier losses
  — Improved color with a color rendering index (CRI) greater than 95

Technology Details

Many existing solid-state LED technologies are built on monochromatic blue or ultraviolet LEDs. The standard process for converting blue light to white light—known as phosphor conversion for its use of a phosphor coating to extend the blue's wavelength (Stokes shift) over a broad spectrum—significantly reduces the LED's efficiency and reduces luminosity by 20%.

Scientists at NREL have developed a portfolio of novel LED technologies that emit in the green-amber regions of the visible spectrum. These technologies enable color-mixing approaches that incorporate red, green, and blue along with NREL's efficient amber LEDs (RGBA) to create white LED lamps that are highly efficient and avoid the Stokes-shift energy losses.



Given its unprecedented efficiencies, NREL's technology will have a major impact on SSL for industry, businesses, and consumers. Device designs utilizing similar material combinations will also impact the performance of lasers and photovoltaics.

How It Works

Combining amber LEDs with red, green, and blue LEDs achieves RGBA color mixing that yields brilliant white light. This use of amber LEDs is a major achievement, since they historically have demonstrated low efficiency and manufacturing difficulties due to fundamental materials issues.

NREL's innovation utilizes high-bandgap AlxIn1-xP alloys to overcome carrier-loss mechanisms that degrade the performance of phosphide-based amber LEDs. It bridges lattice misfit between the device layers and conventional GaAs substrates via compositionally graded buffer layers. Carrier confinement is achieved via engineered ordered/disordered double heterostructures.

Why It Is Better

NREL's amber LEDs enable high-CRI white light to be produced with significantly greater efficiency and luminosity than was previously possible. Furthermore, NREL's high-efficiency amber LED keeps costs low by using standard manufacturing methods, conventional deposition equipment, and commercially available substrates.

Current amber LED technologies suffer from low efficiencies. NREL's amber LED achieves highly efficient luminescence because its high-bandgap semiconductor prevents inter-valley electron transfer losses at emission wavelengths as low at 570 nanometers. NREL's technique also draws on semiconductor physics to engineer innovative cladding layers that are more effective than the materials and techniques currently used by industry to fabricate amber LEDs.

Applications

NREL's amber LED will have a major impact on the trend toward energy efficiency across multiple industries, including:

- SSL
  - —Conventional LED-based solid-state lamps
  - —General lighting, backlighting, etc.
  - —Industrial and residential lighting
  - —Components for automotive, medical, consumer electronics, etc.
- Photovoltaics (PVs)
  - —Ultra-high efficiency solar PVs
  - —Utility-scale and industrial solar PVs
- Lasers

Licensing Opportunities

NREL is offering this technology suite (ROI-10-64 and ROI-09-36) for license. A Dec. 10, 2013, webinar will describe the commercialization process as well as provide detailed information about the technology and its potential markets.

Register for the Technology Licensing Webinar on Dec. 10, 2013

Register at: **http://bit.ly/1diFeSe**

Contact Information

For more information about NREL's amber LED technology and licensing opportunities, contact:

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Please reference ROI-10-64/ROI-09-36 in your communication.

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