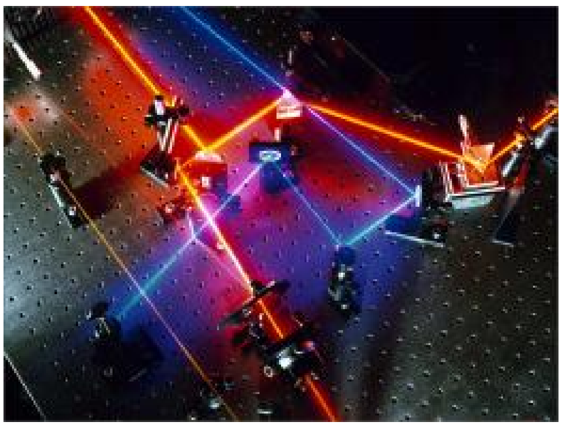
NREL Finds a Way to Give LEDs the Green Light

April 5 2010, by Bill Scanlon



NREL's Solar Energy Research Facility is the site of experiments using lasers to probe the light-emitting properties of gallium indium phosphide alloys for making light-emitting diodes. Credit: NREL file photo

(PhysOrg.com) -- Light bulbs that last 100 years and fill rooms with brilliant ambiance may become a reality sooner rather than later, thanks to a National Renewable Energy Laboratory discovery.

NREL scientists found a way to generate a tricky combination of green and red that may just prove to be the biggest boost for illumination since Edison's light bulb.

Green isn't just a symbol of environmentalism, it is a real color, and a desperately needed one for researchers looking for a way to light homes, streets and buildings at a fraction of today's costs.

LEDs — light-emitting diodes — are the promise of the future because unlike tungsten bulbs or compact fluorescent bulbs, they deliver most of their energy as light, rather than heat. An extra plus is that they don't contain dangerous mercury.

The era of LEDs is fast approaching. The U.S. Department of Energy expects to phase out tungsten bulbs in four years and compact-fluorescents in 10 years. That will leave LEDs with virtually 100 percent of the market.

To make an LED that appears white, researchers minimally need the colors red, green and blue. The white light from the sun is really all the colors of the rainbow. Without at least red, blue and green from the spectrum, no lighting device will be practical for home or office use.

Red proved easy to generate, and about 15 years ago, Japanese scientists found a way to generate blue, thus providing two of the key colors from the spectrum of white light.

But green has been elusive. In fact, the $10 LEDs that people can buy now are made to look white by aiming the blue light at a phosphor, which then emits green. It works OK, but the clunky process saps a big chunk of the efficiency from the light.

NREL Jumps into LED Research via Solar Cells

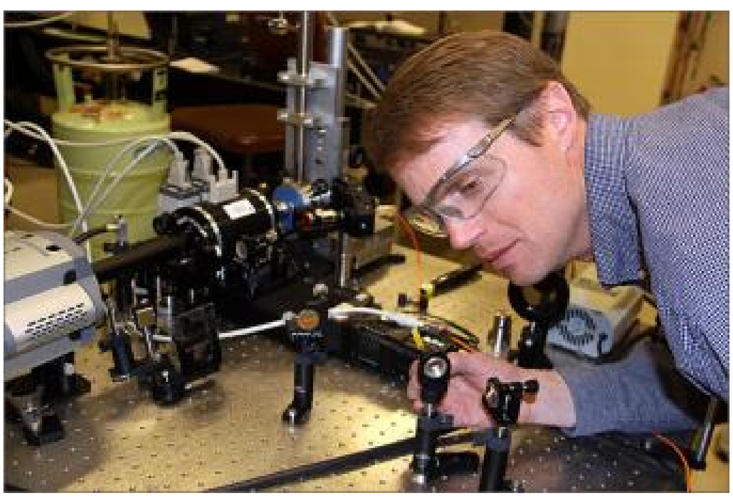
Along came NREL, a world leader in designing solar cells, but a neophyte in the lighting realm.

NREL scientist Angelo Mascarenhas, who holds patents in solar-cell technology, realized that an LED is just the reverse of a solar cell. One takes electricity and turns it into light; the other takes sunlight and turns it into electricity.

"We'd been working with solar cells for 30 years," Mascarenhas said. "Could we find some device where we could just reverse the process of making solar cells?"

Indeed, Mascarenhas found it. NREL had won major scientific awards with its inverted metamorphic solar cells, in which the cells are built by combining layers of different lattice sizes to optimally capture solar energy. In fact, an NREL-produced IMM cell set a world record by converting 40 percent of absorbed sunlight into electricity.

Along the way, "We had already developed some of the know-how to capture sunlight in this green spectral region," Mascarenhas said. They hadn't reached there, because solar cells don't need a green, but they had begun to understand the challenges of getting to a green.



NREL Senior Scientist Brian Flugel adjusts mirrors to set up an experiment aimed at testing the quality of a green LED. Credit: Bill Scanlon

Solving a Decade-Old Conundrum

For a decade, LED researchers had tried and failed to make a reliable efficient green light by putting indium into gallium nitride.

"All signs indicated an impasse," Mascarenhas said. "When you come across an impasse, you don't just bang your head against the wall. You end up breaking your head, not the wall.

"Instead, you move away from the wall, you find a different path."

He and his fellow solar-cell researchers had dealt with the same problem trying to build a solar cell with gallium indium nitride. The problem with trying to make a green on gallium nitride is that the indium phase separates and cracks. When the lattices created by molecular gases don't match up with the lattices of the layer below, "It can't grow well and the efficiency is very, very poor," Mascarenhas said.

NREL's solar cell experts found a way around that. They put in some extra layers that gradually bridge the gap between the mismatched lattices of the cell layers.

"The approach is to grow a different material with an in-between lattice," Mascarenhas said.

The researchers deposited layers that had lattice patterns of atoms close to, but not exactly matching, the layers below. The tiny gap in size was at the so-called "elastic limit" of the material — close enough that the lattices bonded to each other and impurities were deflected away.

Then, add a third layer, this one again at the precise "elastic limit" of the one below. After about seven microns of layering, the result is a solar cell with a firm bond and almost no impurities.

Why not try that same process, only in reverse, to make a reliable deep-green LED using gallium nitride and indium?

A Deep Green on the Very First Try

Astonishingly, once the concept was understood, Mascarenhas's team produced a radiant deep green on their very first try — without any money backing the effort.

The aim now is to provide a fourth color to make that white light even whiter.

NREL plans to use a slightly deeper red and a lemony green, which would then be combined with a blue and a very deep green made using the gallium nitride based technology.

In three years, NREL should have a bi-colored device that when teamed with blue and deep green can produce a sterling LED with a color-rendering index well over 90, Mascarenhas said.

"It will give you one of the finest color-rendering white lights" and the manufacturing costs shouldn't increase, he said.

"We have a patent on a device that will provide these two colors, as one unit, to industry," Mascarenhas said. "They will arrange them like the mosaic in a fly's eye — our units side by side with the blue and deep green combination, alternating in a pattern."

"From afar, it will look like white. You won't be able to see the individual colors of the mosaic structure."

"We have full confidence that this is achievable," Mascarenhas said.

"The technical things will be solved," he said. "This is practical science, not pie-in-the-sky science."

The resulting white light LED will be intelligent. "We'll be able to electronically control the hue of the lamp," he said. "We can vary the combination of intensities of these four colors on an electronic circuit. By slightly increasing the blue, we can make it more suitable for daylight. By turning down the blue and increasing the reddish yellow, we can make it softer, more suitable for night. We can smoothly control the hue throughout the day like nobody has imagined. "

And, by the way, the move toward all LEDs all the time will save some $120 billion in electricity between now and 2030, the Department of Energy forecasts. Not to mention tens of millions of tons of greenhouse gases.

"This is reality," Mascarenhas said. "This is going to happen."

Provided by National Renewable Energy Laboratory