New way to extract light from semiconductors could lead to ultra-high efficiency LEDs

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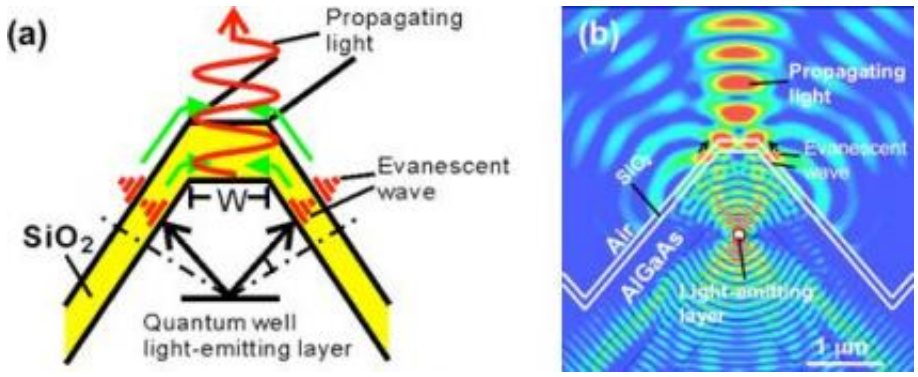

The illustration in (a) shows evanescent waves coupling at two interfaces on the flat planes of a ridge. Figure (b) shows the simulated electromagnetic field intensity of the structure. Image credit: AIST.

(PhysOrg.com) -- By fabricating ridges coated with silicon dioxide (SiO_2) on the surface of a semiconductor, scientists from the National Institute of Advanced Industrial Science and Technology (AIST) in Japan have shown how to extract light from a semiconductor with an extremely high efficiency. The new technique could lead to the development of low-cost, ultra-high efficiency LEDs for lighting and display applications. With the widespread use of LEDs, researchers estimate that global electricity consumption could be reduced by 10% or more, which could save about $120 billion over the next 20 years.

As the researchers explain, the key to improving an LED's energy-conversion efficiency lies in extracting the light generated in the semiconductor with the highest efficiency possible. However, the strong internal reflection in the semiconductor makes efficient light extraction very difficult, since light tends to remain inside the semiconductor. Most techniques to improve the light extraction efficiency have high production costs, but finding a highly efficient, low-cost light extraction technique is essential for popularizing LED lighting.

The AIST researchers, XueLun Wang and Mutsuo Ogura, were able to design a semiconductor to take advantage of the effects of evanescent waves for improving light extraction efficiency. As the scientists explain, evanescent waves are a special kind of light existing only near a reflection interface. When two evanescent waves meet, they are efficiently transformed into light.

In their experiments, the researchers fabricated a GaAs/AlGaAs nanostructure with V-shaped grooves and even smaller ridges between the grooves. They then deposited a 150-nm-thick layer of SiO_2 onto the nanostructure. This design enabled evanescent waves to form and couple at the semiconductor-SiO_2 and SiO_2-air interfaces on flat planes at the tops of the ridges, resulting in an increase of the amount of light that could be extracted.

Photoluminescence studies revealed that the SiO_2-coated semiconductor's light-emitting layer at the ridges was enhanced by a factor of 1.7. According to a press release, the light-extraction efficiency builds upon and exceeds the 50% efficiency of a similar technique, although the exact efficiency of the current design is not mentioned. In contrast, uncoated light-emitting semiconductor materials deposited on flat substrates only enable a few percent of the light generated in the semiconductor to be extracted; for example, GaAs has only a 2% efficiency.

One advantage of the new design is that it doesn't require any significant changes to the conventional LED fabrication process, which should keep fabrication costs low. The method could also be used with other materials, such as indium tin oxide or zinc oxide as the coating, and AlGaInP-based and GaN-based semiconductor materials, which can be used to develop visible LEDs with ultra-high light extraction efficiency.