Challenges and new concepts of semiconductor light emitters

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The switch to high efficiency lighting is enabling to tap a huge reservoir of energy, but it requires light emitting diodes (LEDs) to reach efficiencies higher than the dominant fluorescents lamps, to have a lower *cost of ownership*. Beyond efficiency, major demands on LEDs are full visible spectrum coverage and low cost.

To achieve this, LEDs have to perform at the physical limits of electricity-to-light conversion efficiency, requiring mastering of the *intrinsic electrical and optical* properties of the materials, and of the *electromagnetic* properties of the device structure. Today's LEDs operate in the blue range with both 90%+ internal quantum efficiency (IQE) and light extraction efficiency (LEE).

The progress in the past decade has been remarkable, in particular on LEE, with solutions based on *geometrical optics or wave optics* to overcome the issue of total internal reflection at the semiconductor-air interface. IQE, however, is still not at the desired level: the 90%+ performance is only obtained in the blue/violet spectral range at relatively low carrier injection. The required operation at high current densities, a prerequisite to lower lamp costs, leads to nonlinear phenomena which diminish the IQE. Many measurements point to an Auger non radiative recombination mechanism as the main cause of droop. The "green gap" of high efficiency performance in the green-yellow spectral range presents major hurdles, related to crystal growth conditions and defect formation at high In contents. Increasing strain with In contents also induces fundamental limitations related to large internal electric fields in c-plane grown LEDs.

While the bulk of LEDs produced today are based on the progress of c plane QW LEDs grown on sapphire substrates, a concept originating in the mid-nineties, it is desirable to explore other avenues to reach performance beyond that materials system. I will introduce some of the paths under study: designing better LED structures leading to diminished carrier densities at high current injection, avoiding c-plane limitations by new substrates (semipolar and non polar GaN), using new concepts of active materials (quantum wires, QWRs, quantum dots, QDs), relying on lasers as alternatives to LEDs, switching to large Si substrates, ...