The Physics of Photonic Crystals LEDs

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Photonic crystal (PhC) based LEDs display a rare blend of fundamental and applied concepts in semiconductor physics.

This is due to the fact that the properties of PhC-LEDs rely on a mix of *intrinsic optical* properties of the materials (most often nitrides these days) originating from their *electronic* structure and of *electromagnetic* properties of the PhC.

Focussing on the latter, PhC LED studies allow in-depth understanding of properties of PhCs such as determination of their key parameters (real and imaginary dispersion curves of the band structures for instance). This is to be contrasted with studies dealing with the better established confinement properties of PhCs which rely on non-propagating modes in the photonic forbidden bandgap and therefore mainly explore bandgap states, whereas PhC LEDs allow to explore propagating states of the photonic band structures.

In a series of recent papers in the nitride materials system, we have determined band structures of PhC lattices such as triangular[1] and Archimedean tilings[2]. These studies are a clearcut example how physics *in* devices is a powerful tool to extract fundamental properties of matter (here light propagation in periodic structures).

Turning to studies of physics *of* devices led to explore various structures which could pave the way to ultimate efficiency LEDs. We showed[3] in particular that the optimum PhC structures would depend on the materials' index of refraction, being the triangular lattice for nitrides, while lattices with more nearest neighbours, such as Archimedean tilings lattices, are required for GaAs materials due to their higher index of refraction. We also showed that surface PhC structures have some limitations to extract low order guided modes while embedded PhC structures appear to be optimum[4].

Applications are here of major importance: PhC LEDs could be a favoured solution for ultra-high efficiency LEDs to be used in tomorrow's solid state lighting, with foreseen huge energy savings. The challenge is very actual as several states and countries are on the verge of forbidding sales of incandescent light bulbs in favour of higher efficiency solutions, and as today's preferred one is the high efficiency compact fluorescent lamp (CFL) due to its availability and low cost. The challenge to PhC LEDs is to reach efficiencies similar to CFLs or higher, with fabrication technologies allowing large volume production, low cost and high fabrication yield.

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[1] A. David et al. Applied Physics Letters 87, 101107 , 2005

[2] A. David et al., Applied Physics Letters 88 073510 2006

[3] A. David, H. Benisty H and C. Weisbuch, IEEE Journal of Display Technology, **3**, 133-48. 2007

[4] E. Matioli et al., Applied Physics Letters 96 031108, 2010