Next generation visible light sources utilizing photonic crystals

Nowadays we all take advantage of high efficiency light emitting diodes (LEDs) that replaced the well-known Edison's bulbs. The revolution in lighting that is being observed in the recent 10 years allowed for tremendous global energy savings and opened new technological possibilities. Importantly, many times in the history of GaN-based LEDs and laser diodes (LDs) development scientists have been facing very difficult obstacles that required substantial effort to be overcome in order to make progress. The understanding of magnesium compensation, being a problem in a p-type GaN material fabrication, was even awarded a Nobel Prize in 2014. This project is the next step forward in the development of light sources and paves the way to novel construction structures and devices emitting in visible range that are required for much more technologically advanced applications.

The main motivation and ultimate goal of the planned effort is to find a way to fabricate **photonic crystal surface-emitting lasers (PhC SELs)** emitting in visible range. In the project we want to integrate photonic and laser diode structures in order to obtain new class of devices: miniaturized, efficient and with improved light beam properties. A photonic crystal is a two-dimensional structure of nanometer size holes or pillars arranged in specific ordered manner – creating a crystal-like structure, but of larger dimensions than in a real crystal. It couples with the light and alters the propagation of the wave in a desired way. The fabrication of such photonic structure is challenging in nitrides due to small size features requirements, but it can be done by electron beam lithography and etching. The much more severe problem is posed by the need of photonic crystal integration with the laser structure in a monolithic construction. Currently it is not possible in an efficient way because photonic elements are being placed in p-type material and that decreases electric performance of such devices.

The concept of the ultimate project goal – photonic crystal surface emitting laser diode - is presented in Fig. 1. Below the laser diode and a photonic crystal we propose to place the tunnel junction (TJ). In this construction the sequence of p- and n-type layers in the device is inverted and there is n-type material in the top part of the structure. Such structure offers an unmatchable freedom in surface functionalization since the n-type material is highly conductive and allows for further regrowth after patterning. This is in fact the game-changing element and allows to avoid problematic high resistivity in case of p-type regrowth. Moreover, within the project we will use plasma-assisted molecular beam epitaxy for the purpose of epitaxial structure growth that has been proven to be superior in terms of structure quality and electrical properties.

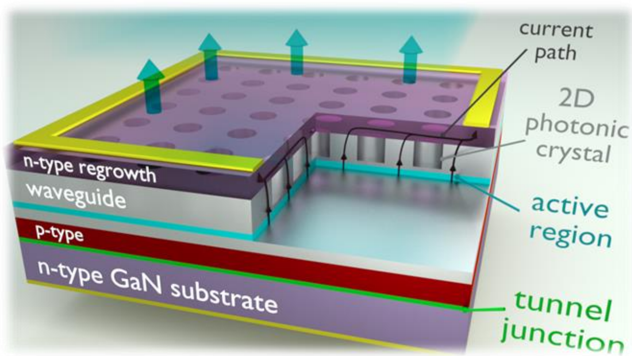

Fig 1. Conceptual image showing a photonic crystal surface emitting laser diode design with a bottom-tunnel junction that is proposed in this project.

We expect that the use of bottom-TJ configuration will allow for a straightforward integration of GaN based emitters with photonic crystals and allow for the construction of high-power, efficient surface emitting lasers with narrow emission spectra, circular optical beam shape and operating at low currents. The next breakthrough in light emitters development seems to be very close.