Multi-junction distributed-feedback laser diodes - synergy of high optical power and single-mode operation

GaN-based technology is revolutionizing the semiconductor market. Light emitting diodes and laser diodes (LDs) based on GaN have reached maturity and can be found in applications such as general lighting, displays, illumination, projection, medical and many others. Despite this tremendous success, there still are emerging applications to which only GaN-based devices could be used, because only they can cover the blue and green spectrum. Many such applications are based on distributed feedback (DFB) LDs. These devices offer unprecedented spectral purity in a compact system, which will find applications in "last mile" telecommunication based on plastic fibers, Li-Fi, Light Detection and Ranging (LIDAR) systems, underwater communication, strontium-based atomic clocks, gas sensing and environmental monitoring.

In this project we plan to develop a completely new optoelectronic device - a multi-junction DFB LD, which is shown schematically in Figure 1. Multi-junction LDs have several pn junctions interconnected with tunnel junctions (TJs). The advantage of this scheme, compared to single junction devices, is that for the same current flow, the recombination occurs in each of the quantum wells (QW). In principle, one can expect an *N*-fold increase in output power of the multi-junction LD with *N* sections. This results in differential efficiency (photons per injected electrons) higher than 100%, which comes at the cost of additional voltage required for each section. The DFB grating placed on the surface of the device, as shown in Figure 1, will ensure strong coupling to the optical mode and lasing at only one wavelength – the one that matches the grating.

The demonstration of visible multi-junction DFB LDs will open a new field of GaN-based devices and stimulate new research directions.

The project will be conducted in collaboration between Institute of High Pressure Physics Polish Academy of Sciences (IHPP PAS), CEZAMAT Warsaw University of Technology and group of Prof. Ulrich Theodor Schwarz from Technische Universität Chemnitz (TU Chemnitz). At IHPP PAS the technology of GaN-based LD is being developed for over 20 years. The CEZAMAT laboratory offers state-of-the-art lithographic technologies, in particular electron beam lithography, which will be used to make surface diffraction grating on top of the mesa structure. The group of Prof. Schwarz specializes in the spectroscopic investigation of the physical properties of semiconductor devices.

We expect that work performed within this project and close collaboration between the three groups will allow for the first demonstration of multi-junction DFB LDs in the world.

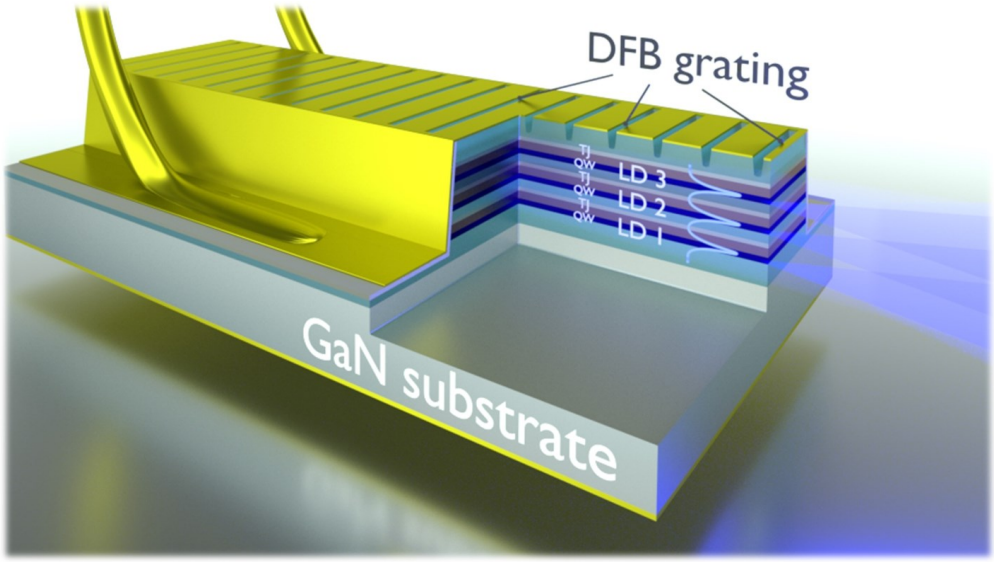

Figure 1. A schematic showing the concept of a multi-junction distributed feedback laser diode composed of three sections interconnected with tunnel junctions (TJ). The third order optical mode is drawn with maxima in the three quantum well (QW) regions. The light propagating in the device couples to the DFB grating that is placed on the surface and ensures lasing in a single mode.