The Warsaw PhD School in Natural and BioMedical Sciences
and the Institute of High Pressure Physics PAS cordially invite you to
a **SPOTLIGHT TALK**

Surface-emitting lasers

given by

Prof. Åsa Haglund

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on September 13th, 2024, 10:30 a.m.

at the IHPP PAS New Technologies Building,
Al. Prymasa Tysiąclecia 98, seminar room, 2nd floor
Duration: 60+ min

and online via Zoom:

https://us02web.zoom.us/j/8352053896?omn=83819726011

All Warsaw-4-PhD students (and others) are very welcome!

Abstract

The continued development of semiconductor lasers in the UV-B (280-320 nm) and UV-C (<280 nm) faces many challenges compared to visible lasers, including high defect densities, low electrical and thermal conductivity, low electrical injection efficiency, low reflectivity mirrors, and higher sensitivity to surface roughness. Despite this, there is a global effort working to tackle these problems and to devise innovative solutions to circumvent the more fundamental material limitations. Thanks to progress in many of these areas we have now seen, in both UV-B and UV-C, the first electrically driven edge-emitting lasers, optically pumped vertical-cavity surface-emitting lasers (VCSELs) and, more recently, optically pumped photonic crystal surface emitting lasers (PCSELs). UV lasers are now on the move.

In this talk I will focus primarily on surface-emitting UV lasers: VCSELs and PCSELs. VCSELs,

because of their small active areas (<10 µm diameter), have the potential to deliver optical output powers in the mW range with beam divergence ranging from a few up to 10°, with a low threshold current below 1 mA. PCSELs, on the other hand, are large area devices (>100 µm), resulting in high potential output powers in the Watt range and beam divergence of less than 1°, but with consequently large threshold currents in the range of 1 A. VCSELs and PCSELs have many similarities, notably that they both rely on photonic crystals; a one-dimensional photonic crystal form the distributed Bragg reflector in a VCSEL, while a two-dimensional photonic crystal is employed in a PCSEL. Additionally, both devices require very precise spectral control over the resonance since modal gain strongly depends on the overlap between the gain peak and the sparsely placed modes of low loss. In a VCSEL, this resonance is set by the distance between the DBRs, and in a PCSEL by the photonic crystal parameters.

Here we will show that for VCSELs, using a special lift-off technique based on photo-assisted electrochemical etching, we obtain excellent cavity length control with deviations between devices of <1%. Moreover, in PCSELs, we will demonstrate how we can select the desired lasing mode by controlling the photonic crystal parameters, thereby obtaining high-quality far-fields with beam divergence of <1°. Looking towards electrically driven UV VCSELs, a first step towards overcoming the problem of poor hole conduction and current spreading has been taken in the form of a tunnel-junction based resonant-cavity light-emitting diode, in which a tunnel junction enables the use of an n-doped layer for current spreading on the p-side of the device. Thus, while UV surface-emitting lasers still face significant challenges, they are nonetheless inching closer and closer to becoming technologically and societally useful devices.

Åsa Haglund's research interests encompasses III-nitride lasers and light-emitting diodes in the visible and ultraviolet wavelength regions. The focus is on nanostructuring for new optical functionality and thin-film devices realized by electrochemical etching which enables vertical-cavity surface-emitting lasers (VCSELs) and photonic crystal surface-emitting lasers (PCSELs). Åsa has a Master's Degree in Physics from Gothenburg University and received a PhD degree in Electrical Engineering in 2005 from Chalmers University of Technology. She has been a visiting researcher at Ulm University in Germany and Lund University in Sweden and is since 2018 a Professor at Chalmers University of Technology. She is a recipient of for example the European Research Council's consolidator grant (2020), the Swedish Research Council's consolidator grant (2019), and the Swedish Foundation for Strategic Research's young research leader award (2014).