Research Trip Summary Report

Task 2. Foreign mobility of WUST doctoral students

I. Data of the doctoral student

1.Full name: Monika Mikulicz

2.Year of studies: 4

3. Educational discipline: Physical Sciences

II. Foreign research trip (research visit)

1. Research institute in which the foreign research was implemented: Technical University of Denmark

2. Name and surname of the host person (mentor): Prof. Kresten Yvind

3. Dates of the research trip: 20.10.2023 – 20.11.2023

4. Title and date of a seminar delivered during the research trip: Electrically pumped VCSEL – Results of measurements, 24.10.2023

5. Description of work carried out during the research trip:

The initial phase of the internship focused on receiving training in cleanroom safety and the operation of the VCSEL characterization setup, essential for undertaking independent tasks. Throughout the internship, various skills were acquired, including the use of Atomic Force Microscope (AFM), Scanning Electron Microscope (SEM), ellipsometer, and chemical-mechanical polishing machine. The subsequent task involved modifying the VCSELs characterization setup by integrating a new sample holder with a thermoelectric cooling system and nitrogen purging. The development of custom LabVIEW programs enabled the temperature control of the system and automated the input/output power measurements of the optically pumped HCG MEMS VCSELs. Characterization of numerous devices allowed the identification of optimal performance cases for future investigations at DTU. Following this, a new batch of electrically pumped HCG MEMS VCSELs underwent thorough optical and electrical characterization, followed by SEM analysis of the high-contrast grating mirror (HCG) in selected devices.

6. Description of the main results obtained:

The measurements conducted on optically pumped HCG MEMS VCSELs included testing the impact of cooling on lasing, input/output measurements, DC and AC tuning. The devices exhibiting the best performance were selected for further coherence investigations at DTU. Exemplary results, such as the emission spectrum and input/output curve with clear threshold was presented in Figure 1.

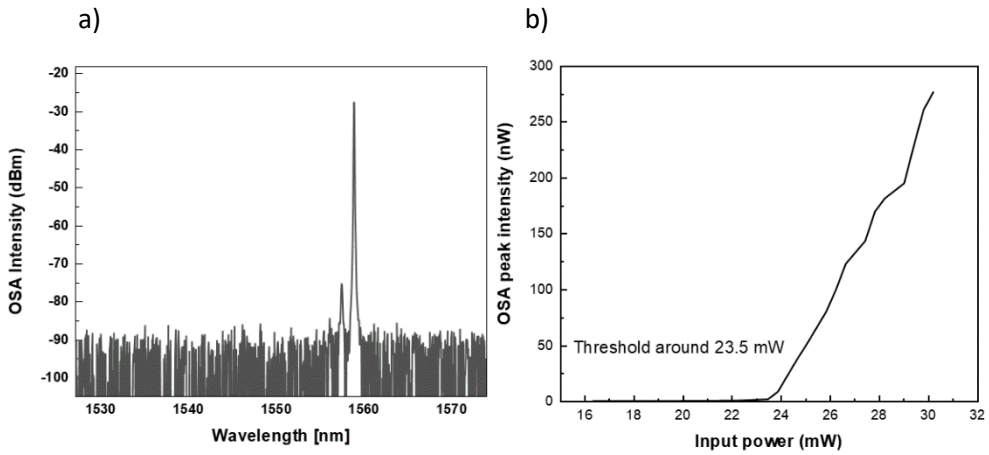

Figure 1. a) Emission line from optically pumped VCSELs and b) input/output curve measured with custom software

The investigation of electrically pumped VCSELs enabled the observation of the influence of oxidation mesa size and HCG design on the performance of HCG MEMS VCSELs. A mesa size that is too small resulted in rapid device overheating, while an excessively large mesa led to undesirable multimode emission due to weak spatial signal filtering. Regarding HCG design, improved performance was noted in devices with a new focusing HCG, characterized by a lower threshold and higher output power, attributed to reduced mirror and material losses in the optimized structures. SEM analysis of electrically pumped devices facilitated the direct determination of the duty cycle (ratio between the thickness of HCG and the period of the structure), allowing for a comparison of experimental results with calculations and providing valuable feedback information for processing purposes. An exemplary SEM photo of an electrically pumped MEMS VCSEL is presented in Figure 2.

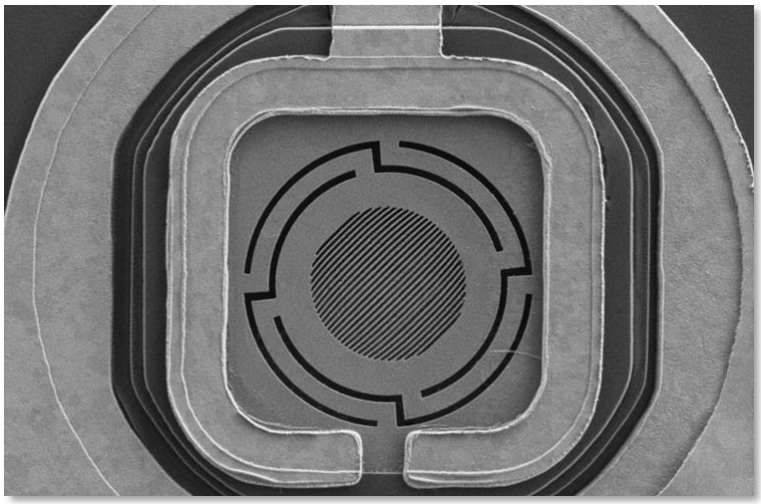

Figure 2. SEM image of electrically pumped VCSELs

7. Future collaborations (if applicable):

Discussing obtained results during online meetings and exploring the potential for scientific publication.

8. Title and date of a seminar presenting the results of the trip delivered at Wroclaw University of Science and Technology after returning from the research trip: Tunable high contrast grating vertical-cavity surface-emitting lasers, 28.11.23

III. Doctoral student's signature

…….. (Date)

……. (doctoral student's signature)

IV. Confirmation and information from the host

1. Confirmation of compliance of the information contained in the report: I CONFIRM / DO NOT CONFIRM. (*In justified cases, the confirmation of the host may be sent by e-mail to the Dean's Office of the Doctoral School email: interdocschool@pwr.edu.pl*)

2. Additional information and comments

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…… (Date)

…… (signature(s) of Host)