MERIT Long-term Overseas Dispatch Report

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Dispatch information

I had an opportunity to stay at Prof. Klaus J. Boller's laboratory at the University of Twente in the Netherlands for 1 month from September 4th to October 4th 2023. My work was focused on numerical investigation of using a double-injection microring resonator (DIRR) to convert amplitude modulation (AM) to frequency modulation (FM) mode locking and vice versa, and I also had a chance to participate in experiments with hybrid integrated GaAs diode lasers. In addition, I visited various laboratories in the Applied Nanophotonics (ANP) cluster, including laboratories of Prof. Marpaung (NLNP), Prof. Vos (COPS), Prof. Pinkse (AQO), and Dr. Renema (AQO), and gave a talk about my work at the University of Tokyo at the monthly ANP colloquium.

Motivation and background information

My PhD research is in hybrid integration of quantum-dot (QD) single-photon source (SPS) for scalable quantum information processing. One important challenge to consider for future practical application or commercialization is how to excite the SPS. Currently, the SPS is excited optically with an external laser, requiring bulk optics on an optical table. This can be solved by integrating a mode-locked laser for on-chip excitation of SPS [1]. Therefore, I am eager to learn more about hybrid lasers and decided to join Prof. Boller's group as a visiting student. The group is working on hybrid-integrated semiconductor lasers with feedback circuits which have gained a lot of attention thanks to advancement in linewidth reduction, power increment, and stable operation in a compact package [2].

Research

Mode locking consists of multi-mode oscillations with certain phase relations (phase locked) among them. For AM mode locking, the intermodal phase difference is zero (the absolute phase is linear in frequency), which results in a train of short pulses in the time domain. On the other hand, the intermodal phase difference of FM mode locking is linear in frequency (the absolute phase is parabolic), making the time response of output power quasi-constant [3]. This means that it would be possible to modify the mode locking to be more like AM or FM by changing the intermodal phase, if one could find a spectral filter that modifies the phase spectrum without changing the amplitude spectrum.

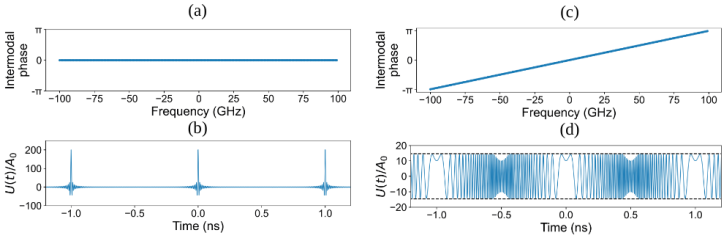


Figure 1 Illustration of mode locking for a laser with 201 longitudinal modes with equal amplitudes. (a) Intermodal phase, AM. (b) Electric field as a function of time, AM. (c) Intermodal phase, FM. (d) Electric field as a function of time, FM. [3]

Devices that can potentially be used for this purpose and be integrated on chips are microring resonators if they exhibit a constant amplitude frequency response while the phase response can be tailored.

Of particular interest are double-injection microring resonators, DIRRs [4,5], which can utilize self-compensation of loss in a 2x2 network structure. I was investigating the possibility of using the device to adjust the intermodal phase of mode locking from a diode laser; thereby, changing the output to behave more AM or FM.

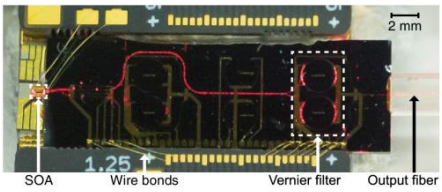
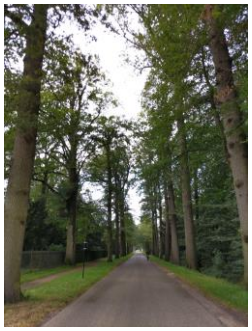


Figure 2 Photograph of a hybrid laser with an AlGaInP optical amplifier butt-coupled to a Si_3N_4/SiO_2 feedback chip. [6]

I also had a chance to join experiments on GaAs hybrid integrated diode laser, of which the gain chip is connected to a SiN circuit chip. The circuit has been shown to improve laser operation, i.e., it enables a large tuning range and linewidth reduction [7].

Life in Twente

During my visit, I had the opportunity to experience life in the Twente region, particularly in Hengelo and Enschede. I also traveled to Borne and Delden. People here were very nice and hospitable. Moreover, staying here enabled me to be close to nature. Serene countryside and ample green spaces allowed me to connect with the natural world in a way I seldom can in my bustling hometown of Bangkok or while studying in Tokyo. Life in these small towns offered a refreshing change of pace from the hustle and bustle of city life, which I found quite appealing. Twente left a lasting impression on me, and I'm grateful for the memorable experiences I had during my brief but enriching stay.



Pictures I took when (left) cycling to the university and (right) visiting Twickel Castle

References

[1] Mahmudlu, H. *et al.* Fully on-chip photonic turnkey quantum source for entangled qubit/qudit state generation. *Nat. Photonics* **17**, 518–524 (2023)

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[4] Cohen, R. A., Amrani, O. & Ruschin, S. Response shaping with a silicon ring resonator via double injection. *Nat. Photonics* **12**, 706–712 (2018)

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[6] Franken, C. A. A. *et al.* Hybrid-integrated diode laser in the visible spectral range. *Opt. Lett.* **46**, 4904–4907 (2021)

[7] L. Winkler *et al*., Tunable Hybrid-Integrated Diode Laser at 637 nm, *2023 CLEO/Europe-EQEC*, Munich, Germany, pp. 1-1 (2023)

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