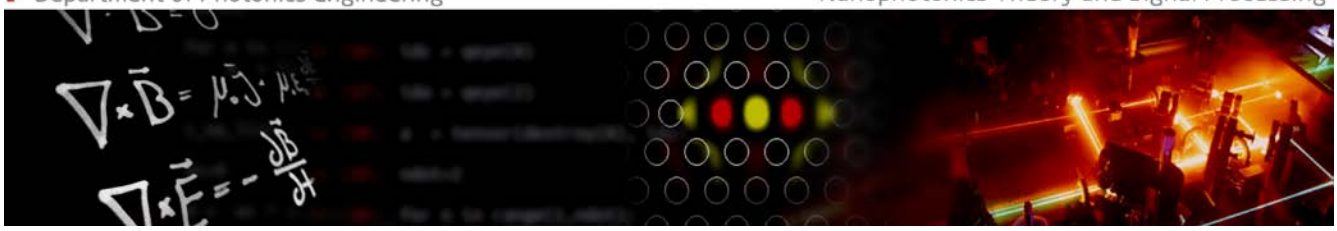


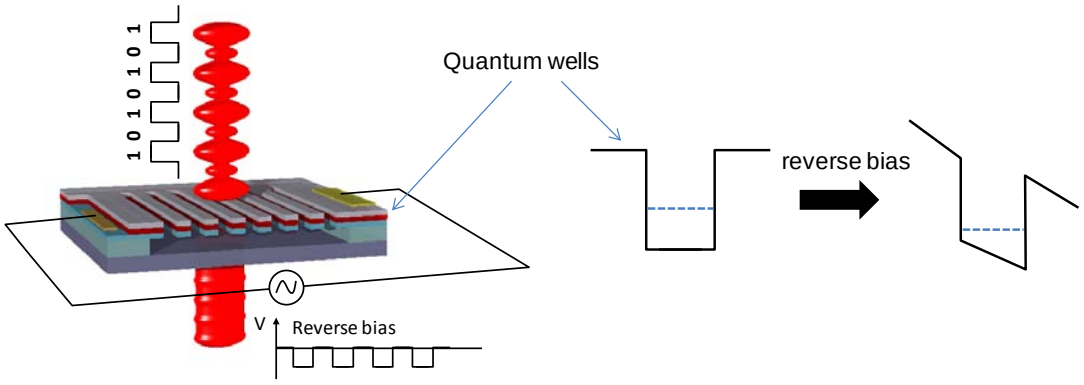
## M.Sc. Thesis Project

# Ultrafast micro reflector

In the context of chip-level optical interconnects and silicon photonics, demonstrating an ultralow-energy-consumption laser with a speed higher than 10 Gb/s, has been one of key scientific and technological challenges during past 5-6 years. The dream energy consumption per sending a bit (energy/bit) is about 10 fJ/bit [1]. The current state-of-the-art laser is a photonic crystal laser with a buried active region demonstrated by the NTT lab [2]. This laser can be directly modulated at 10 Gb/s, the energy/bit is 10-20 fJ/bit, and the output power is about 1 μW. The demonstrated low energy/bit is highly desirable but the output power needs to be increased to 10 μW for feasible signal detection. However, in directly-modulated lasers, increasing the output power without loss of energy/bit is challenging due to fundamental reason; the speed and the energy consumption that is proportional to the current supply are in trade-off relation, as shown in relation for intrinsic bandwidth of a laser diode, $f_{3dB,\,int}$:

$$f_{3dB,\mathrm{int}} \propto \left[\frac{I - I_{th}}{V_P}\right]^{1/2}$$

where I is the applied current, $I_{th}$, the threshold current, and $V_p$ is the modal volume. To overcome this fundamental limit motivates this project.




In this project, you will investigate a grating mirror of which reflectivity can be electro-optically modulated. As schematically illustrated in the figure above, reversely applied voltage through the quantum wells in the grating mirror results in refractive index change, leading to reflectivity of the grating mirror e.g., from 99.9 % to 99.0 % [3]. This reflectivity-modulated grating mirror can work as a monolithically-integrated external modulator when it is integrated with a laser. In this externally-modulated laser, one does not need to increase the injection current in

order to get higher speed: While the light-generating active part can be operated at a low DC current sufficient for an output power higher than 10 μW and the modulation of the light emission will be conducted by the grating mirror. Therefore, this laser can provide ultralow energy consumption, high-speed response, and enough modulated output power. This project comprises of three phases:

- Theory: Perform numerical simulations and understand the physics.
- Processing: Fabricate electro-optically modulated grating mirrors.
- Characterization: Characterize the optical cavity.

Depending on the student's background and interest, the project can be formulated as a combination of theory + characterization, or a combination of processing + characterization. This project is closely related to existing hybrid laser activities and you will get practical help from Ph.D. students. If successful, chance of journal publication is expected.

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**References:**

[1] D. A. B. Miller, "Device requirements for optical interconnects to silicon chips," Proceeding of IEEE, **97**, 1166 (2009).
[2] S. Matsuo, et al., "20-Gbit/s directly modulated photonic crystal nanocavity laser with ultra-low power consumption", Optics Express, **19**, 2242 (2011).
[3] Il-Sug Chung, "Reflectivity-modulated grating-mirror", EP 11166358.9, US 61/486,930