Thermal effect of InP/InAs Nanowire Lasers Integrated with Optical Waveguides

NTT Basic Research Lab[1], NTT Nanophotonics Center[2], NTT Device Technology Labs[3]
(B) E. Frandsen[1], M. Takiguchi[1,2], G. Zhang[1,2], H. Sumikura[1,2], T. Tsuchizawa[2,3], A. Shinya[1,2], H. Gotoh[1] and M. Notomi[1,2]

E-mail: frandsen@ualberta.ca, masato.takiguchi.mg@hco.ntt.co.jp

Nanowire lasers have been studied for the past few years because of their small size and versatile nature. Until recently it has been difficult to achieve telecom-band nanowire lasers at room temperature [1]. With these recent successes, considering silicon's utility in electronic devices and its telecom-band transparency, it is beneficial to utilize these properties. Therefore, the fusion of the telecom nanowires and silicon photonics would be innovative for on-chip devices. These devices would be able to reach certain levels of light confinement in subwavelength nanowires by integrating them with other photonic circuits such as photonic crystals (PhC) to achieve desired optical properties. They can be further fine tuned with slight changes in the lattice of the PhC or waveguide based on its placement [2]. Similarly, the temperature of a nanowire can significantly affect its lasing properties. This study focuses on estimating the thermal effects on InP/InAs nanowire laser oscillations as well as the integration and implementation of these nanowire lasers [1] over various waveguides (Si and SiN) and substrates (Au and Si) using a microgripper to adjust their positions (Fig. 1a).

Our nanowire lasers operate at wavelengths around 1.3 um [1]. Using the microgripper, selected well-lasing samples are picked out from a group that was scattered over a substrate and dropped at the desired position, with some variability in the orientation, on an optical waveguide. The nanowire laser is measured in a typical PL set up at room temperature. Lasing oscillation was estimated using a 1064 nm pulse laser at 250, 500 and 1000 kHz pulse frequency, and 13 ns pulse width. The pump power was increased until a maximum of approximately 1.38 mW (averaged pulse power) to avoid burning the samples. Figure 2 shows an example of the lasing spectrum obtained from the top and the side through certain waveguides. The emission reading from the top was relatively stronger than the reading from the side, however, there remained significant evidence of strong coupling with the waveguide (Fig. 2a, 2b). Furthermore, lasing was achievable at all tested frequencies with the emission scaling with the laser input power. When the input power approached the lasing threshold of the sample, the nanowire laser experienced a sharp blue shift in the emitted wavelength before experiencing a gradual red shift after passing the lasing threshold, seemingly ignoring any thermal effects. Eventually, the measurements began to exhibit a plateau which subsequently turned into a downturn in most 1 MHz samples (Fig. 3). This plateau suggests significant thermal effects are acting on the nanowire. The surrounding material compounds these effects and either increases or decreases transmission, with the emission being typically higher for the high conducting material (Au) and lower for the low conducting material (SiN) in our tests. This research is being supported by grant JSPS KAKENHI Grant Number 15H05735.

References:
[1] G. Zhang et al., Sci. Adv., 5 (2019) [2] B.-S. Song et al., Nature Mat. 4, 207–210 (2005)

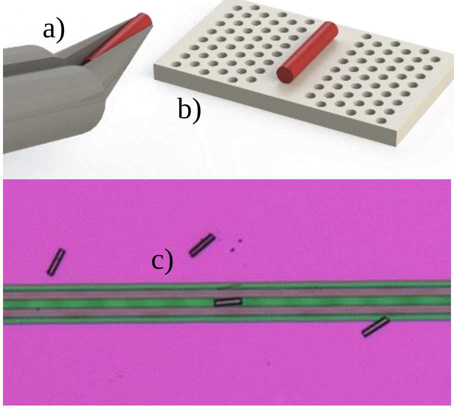

Fig. 1: a) Schematic of the gripper holding a nanowire and b) a nanowire on a waveguide. c) Image of InP/InAs nanowire placed on a SiN waveguide.

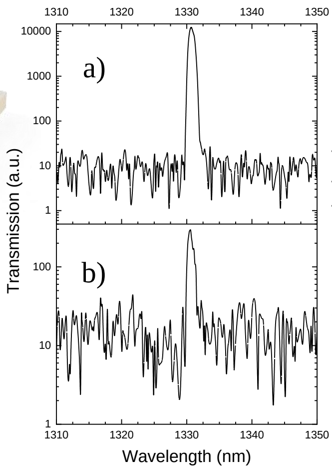

Fig. 2: Emission from a InP/InAs nanowire on a SiN waveguide with a 500 kHz and 0.69 mW incident laser, measured from a) the top and b) the side.

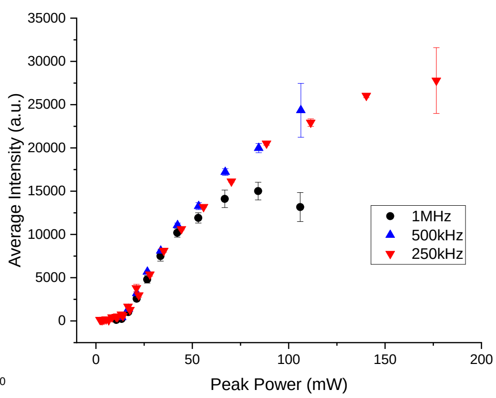

Fig. 3: L-L curve of the emission from a nanowire plotted against the laser input power on a SiN waveguide. Showing the plateau and downturn from thermal effects.