Electronically Switched Silicon Raman Lasers

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Raman lasers inherently require optical pumping, hence they are considered a tool for extending the conventional wavelength range of lasers. Nevertheless, the lack of on-chip electronic switching capability casts a shadow over the usefulness of a Raman laser in optoelectronic applications. Recent demonstration of silicon Raman lasers [1] opens the possibility of electronic switching in Raman lasers. The optical loss in silicon is a linear function of free carrier (electrons and holes) density [2] and this can be altered by many orders using a diode. This offers a unique ability to electronically switch the silicon laser output using a diode laser cavity.

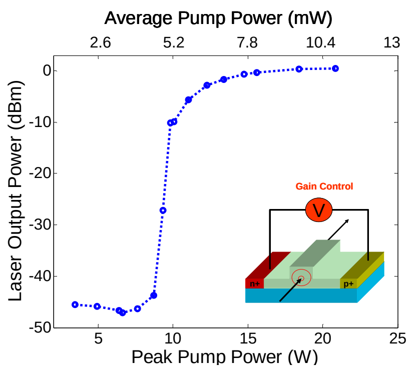

Figure 1. Input-output characteristic of the silicon Raman laser exhibiting a sharp threshold at 9W peak pump pulse power. Inset shows the geometry of the device used in our experiments.

In this paper we report the proof-of-concept demonstration of electronic switching in a Raman laser by using a diode laser cavity. To the best of our knowledge, this is the first such demonstration. In contrast to traditional Raman lasers, this laser can be directly modulated to transmit data, and can be part of a silicon optoelectronic integrated circuit.

The experimental setup is very similar to the previously reported silicon laser by using pulsed pumping [1]. The inset of Fig 1 shows the geometry of silicon waveguide used in the experiment. The observed threshold characteristics of the laser are shown in Fig. 1. Data is plotted in logarithmic scale to elucidate the near threshold behavior. The lower abscissa shows the peak power of pump pulses while the upper abscissa displays the average pump power. Below threshold, the output power is around -40 dBm level and is limited by the noise floor of the optical spectrum analyzer used in the experiment. Once the lasing threshold is reached, there is a sudden 1000 fold (30 dB) increase in the output power. Above threshold the output power increases linearly as expected, and a peak output power of 2.5 W is obtained when the peak pump power is 20 W. The slope efficiency, defined here as the ratio of peak output power and peak pump power, is calculated to be 12.5%.

A key attribute of the silicon Raman laser is its electronic modulation capability. Optical loss in silicon and hence the net optical gain in the laser cavity is proportional to the free carrier density in silicon. The linear dependence of free carrier density on diode forward current provides direct electronic modulation of the intra cavity gain. The laser will be turned off when the loss induced by diode current exceeds the gain per round trip in the cavity. Figure 2(a) shows the switching characteristics of the laser when a digital electrical waveform with 2.5 mA peak current and 200 ps rise/fall time is applied to the diode. The output pulse train of the laser is switched on and off as expected, with a measured turn-on time of 1μs and a turn-off time of 500ns. The turn off time will depend on the rate of carrier injection and hence on the switching time of the diode, whereas the turn on time will depend on the photon lifetime in the laser cavity. Figure 2(b) shows the laser output with 1 MHz modulation applied to the p-n junction diode. While the modulation speed is limited in these experiments, the results clearly demonstrate the electronic switching feature of the silicon Raman laser.

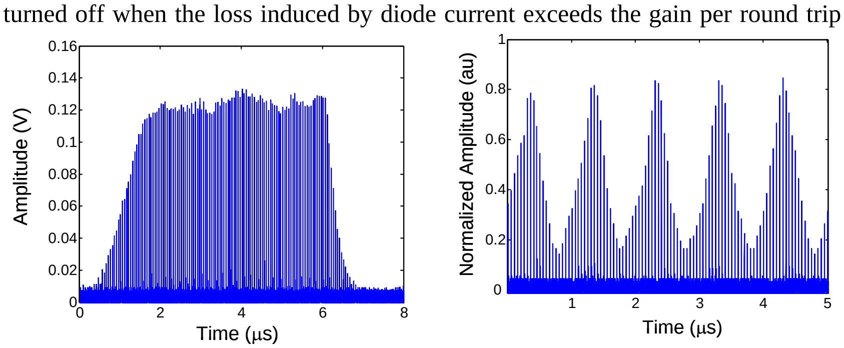

Figure 2. A) Demonstration of electronic switching of the silicon Raman laser. 2.5 mA peak current with 200 ps rise and fall times is applied to the on-chip diode. B) Electronic modulation results of the silicon Raman laser.

References

1. Ozdal Boyraz and Bahram Jalali, "Demonstration of a silicon Raman laser," *Opt. Express* **12**, 5269-5273 (2004).
2. R.A. Soref, B. R. Bennett, "Electrooptical effects in silicon," *IEEE J. Quantum Electronics* **23**, 123-129, (1987).