Carbon nanotubes based photonics: towards the laser

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Abstract

Semiconducting single wall carbon nanotubes (s-SWNTs) have generated a growing interest for several years due to their extraordinary optical properties. A strong enhancement of the photoluminescence properties has been obtained thanks to the extraction of s-SWNTs. These advances led to the first demonstration of optical gain in carbon nanotubes and are a precursor to obtain nanotube-based laser. Finally, we will present the integration of s-SWNT in silicon photonic structures, and experimentally demonstrate light emission in silicon waveguides. These results constitute a significant milestone towards the development of carbon nanotube based laser sources in silicon.

1. Introduction and description

Semiconducting single wall carbon nanotubes (s-SWNT) are one-dimensional objects with remarkable electrical1-3 and optical properties. Recently, carbon nanotubes have proved to be promising material for nanophotonics and optoelectronics. Due to the possibility of tuning their direct band gap and controlling excitonic recombinations in the near-infrared wavelength range, s-SWNT can be used as efficient light emitters. However, the presence of metallic nanotubes and impurities in raw samples of carbon nanotubes reduces the potentialities of such materials in photonics. Recently, a process to selectively extract s-SWNT has been developed [1]. We show that a removal of metallic nanotubes leads to an enhancement of the photoluminescence properties by a factor of 6 (figure 6) and a chirality selectivity [2].

We will then report on the first experimental demonstration of a optical gain using the variable strip length (VSL) method (figure 2) on a thin layer containing only s-SWNT. Special emphasis will be put on the s-SWNT extraction, as optical gain could not be achieved in a raw or lowly enriched sample due to interactions with remaining m-SWNT [3]. Figure 3 presents a 30 % linewidth narrowing (FWHM from 63 to 45 nm) of the photoluminescence of (8,7) nanotube at 1300 nm, and linewidth narrowing of 28 % (FWHM from 44 to 32 nm) for the (8,6) nanotube at 1200 nm. This characteristic is one of several demonstration of optical gain in carbon nanotubes.

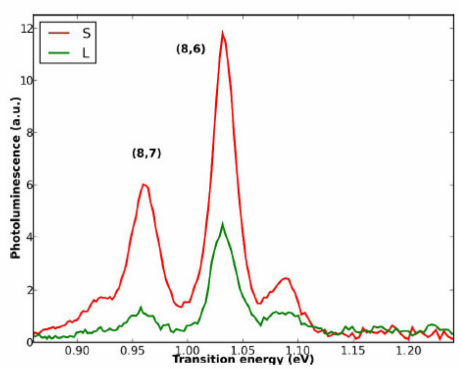

Figure 1: Photoluminescence enhancement of (8,6) and (8,7) s-SWNT for successive s-SWNT extraction.

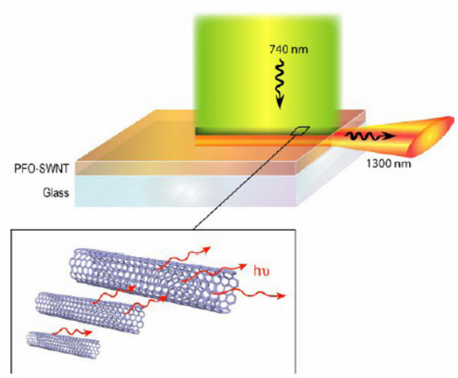

Figure 2: Schematic representation of a variable strip length experiment.

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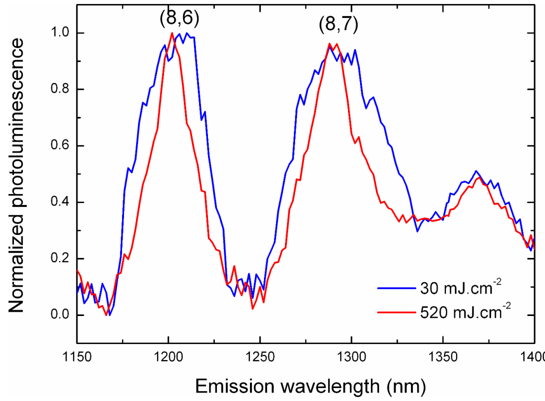

Figure 3: Amplified Spontaneous Emission as a function of emission wavelength at low and high pump fluences for an excitation wavelength of 740 nm.

2. Conclusion

We present the promising results to use carbon nanotubes for photonics and it a significant milestone towards the development of carbon nanotube based laser sources, and open promising perspectives for future high performance integrated circuits.

3. Acknowledgments

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4. References

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