Transition metal dichalcogenides: Two-dimensional materials for next generation semiconductor lasers

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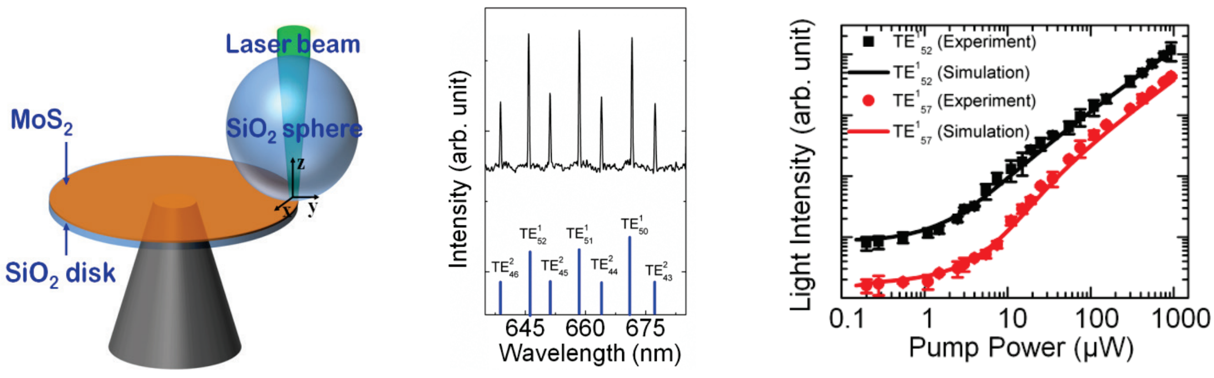
Abstract

Ultralow threshold, highly stable semiconductor lasers that can be monolithically integrated on Si or other foreign substrates are urgently needed for the emerging chip-level optical communications and flexible displays. Compared to conventional III-V compound semiconductors, two-dimensional (2D) transition metal dichalcogenides (TMDCs) can be readily grown on low-cost Si/SiO_2 substrates. 2D TMDCs also possess the advantages of quantum well lasers, namely the large differential gain associated with their 2D density of states. In this context, we have investigated the use of 2D MoS_2 as a new class of materials for laser operation. By embedding 2D MoS_2 at the interface between a free-standing microdisk and microsphere, shown in Figure 1(a), we have demonstrated, for the first time, room-temperature lasing from 2D TMDCs [1]. The devices exhibit multiple lasing peaks, illustrated in Figure 1(b). The threshold is measured to be ~ 5 μW under continuous wave operation at room temperature, shown in Figure 1(c). No saturation in the output power is measured for pump powers more than two orders of magnitude larger than the threshold. The superior performance is attributed to the large gain of 2D TMDCs and the strong coupling between the 2D MoS_2 gain medium and optical modes in the unique optical cavity. The carrier dynamics and exciton kinetics, as well as the role of Auger recombination on the performance characteristics of the emerging 2D TMDC lasers will also be discussed [1,2].

References

[1] O. Salehzadeh, M. Djavid, N. H. Tran, I. Shih, and Z. Mi, Nano Lett., ASAP. **DOI:** 10.1021/acs.nanolett.5b01665.
[2] O. Salehzadeh, N. H. Tran, X. Liu, I. Shih, and Z. Mi, Nano Lett., vol. 14, 4125, 2014.

Figures



(a) (b) (c)

Figure 1. (a) Schematic illustration of the coupled free-standing microsphere/microdisk optical cavity with the incorporation of 2D MoS_2. (b) Emission spectra measured at an excitation power of 100 μW. The calculated mode positions from Mie's theory are also shown (blue lines). (c) Variations of the light intensity vs. excitation power for lasing modes TE^1_{52} (black square) and TE^1_{57} (red diamond). The solid curves are simulated results based on the rate equation analysis.