Optoelectronic properties of nanostructured devices

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Optoelectronic devices are components of optical technologies with applications in daily life. Their large scale use, e.g. in optical networks for the internet, has raised the need for reduced power consumption as a contribution to global energy savings. The demands of internet and computation technology rise to a level, where in the very near future we will need an introduction of new devices, to increase the bandwidth while reducing energy consumption. To this end, optical interconnects, operating with smaller (nanoscale) lasers are needed, that nevertheless are able to operate at higher modulation speeds and greater temporal and spectral precision. I will discuss the prospects of semiconductor nanostructures for novel optoelectronic devices on two examples:

Semiconductor Quantum Dots (QD) are tailor-made structured, possessing tree-dimensional carrier confinement. Therefore, the emission wavelength of devices based on QDs can be tuned, e.g., via their material composition. Such QDs can be integrated with nanocavity devices that enhance the spontaneous emission and allow for lasing with only few QD emitters as active material. We discuss the prospect of such devices regarding their dynamical properties. In recent years, so-called tunnel injection (TI) QD structures have shown record high small signal modulation bandwidth up to 15 GHz and also QDs emitting at the technologically relevant 1.55 μm band were reported, which shows the enormous application potential for high-speed optical communication networks. The optimal design of future TI lasers benefits from a detailed understanding of the physics and the interplay of various interaction processes involved in such devices. We investigate theoretically the carrier and laser dynamics in TI structures, sheding light on the underlying tunneling processes.

Atomically thin transition-metal-dichalcogenides (TMDs) are an appealing system for optoelectronic applications such as LEDs or lasers, as they combine great physical strength with high carrier mobility and an direct optical band gap with a large exciton binding energy. Optoelectronic applications depend on the dynamics of excited carriers, that is governed by the carrier-carrier Coulomb interaction and by the carrier-phonon interaction. We investigate the carrier relaxation dynamics in TMD monolayers as well as the optical properties of nanostructures build out of two-dimensional materials.

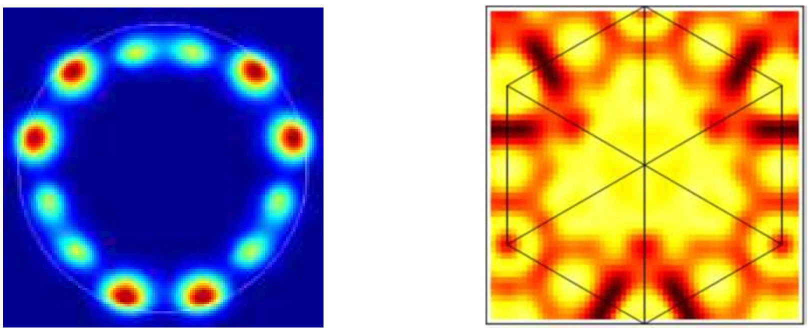

Figure 1: Left: Wavefunction of a TMD based Nanobubble; Right: Electron population in MoS_2, 400 fs after optical excitation