Nanocrystal Optoelectronics: From Solution – Processed Quantum Dots to Wells

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Colloidal semiconductor nanocrystals have been attracting increasingly greater interest in photonics including color conversion and enrichment in quality lighting and display backlighting [1]. Optical properties of these nanocrystals can be conveniently tuned by controlling their underlying excitonic mechanisms [2]. Their rational design and excitonic control provide us with the ability to make efficient light-emitting diodes [3] and optically-pumped lasers [4]. In this talk, we will introduce this emerging field of colloidal nanophotonics using solution-processed quantum dots to wells. In particular, we will present a new concept of all-colloidal lasers developed by incorporating nanocrystal emitters as the optical gain media intimately into fully colloidal cavities [5]. As an extreme case of solution-processed tightly-confined quasi-2D quantum structures, we will also show that atomically flat nanocrystals analog of epitaxial thin-film quantum wells allow for record high optical gain and ultralow lasing threshold among all colloids. In addition, we will discuss that controlled stacking of these colloidal quantum wells uniquely enables us to fine-tune and master their excitonic properties [6]. We will also show that doping such nanoplatelets leads to extraordinarily large Stokes shift, accompanied with near-unity quantum efficiency and high absorption cross-section, ideal for luminescent solar concentrators [7]. Furthermore, advanced heterostructures of these nanoplatelets make it possible to target other applications such as remote temperature sensing [8]. Given the recent accelerating progress in nanocrystal photonics, solution-processed quantum materials hold great promise to challenge their conventional epitaxial counterparts.

[1] HVD et al., *Nano Today* 6, 632 (2011); TErdem and HVD, *Nature Photonics* 5, 126 (2011)

[2] BGuzelturk et al. HVD, *Laser & Photonics Reviews* 8, 73 (2014); *J. Phys. Chem. Lett.* 5, 2214 (2014) and *Advanced Functional Materials* 26, 8158 (2016)

[3] XYang et al. XWSun and HVD, *Advanced Functional Materials* 24, 5977 (2014); *ACS Nano* 8, 8224 (2014) and *Advanced Materials* 24, 4180 (2012)

[4] YWang et al. HVD and HSun, *Advanced Materials* 27, 169 (2015) and *Nano Letters* 17, 2640 (2017) and YGao et al. HSun and HVD, *J Phys. Chem. Lett.* 7, 2772 (2016)

[5] BGuzelturk et al. HVD, *Advanced Materials* 27, 2741 (2015)

[6] BGuzelturk et al. HVD *ACS Nano* 8, 6599 (2014) and *ACS Nano* 8, 12524 (2014); M. Olutas et al. HVD, *Advanced Functional Materials* 26, 2891 (2016) and O. Erdem, et al. HVD *J Phys. Chem. Lett.* 7, 548 (2016)

[7] MSharma et al. HVD *Advanced Materials*, in press (2017)

[8] YKelestemur et al. HVD, *Advanced Functional Materials* 26, 3570 (2016) and *Chemistry of Materials*, in press (2017)