An emerging field of nanocrystal optoelectronics: all-colloidal nanocrystal lasers of quantum dots to wells

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Abstract: Here we will present all-colloidal lasers constructed by incorporating nanocrystal emitters as the optical gain media in fully colloidal cavities. As an extreme case of solution-processed tightly-confined quasi-2D colloids, we will also show that the atomically flat nanocrystals, alternatively known as colloidal quantum wells, uniquely offer record high optical gain coefficients and ultra-low amplified spontaneous emission thresholds.
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Solution-processed semiconductor nanocrystals have attracted great 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 mastering their underlying excitonic mechanisms and can be conveniently controlled by tailoring their shape, composition, and size in an effort to realize high-performance light generation and lasing [2]. Their excitonic control provide us with the ability to make highly efficient light-emitting diodes [3] and optically-pumped lasers [4]. These nanocrystals span different types and heterostructures of colloidal semiconductors in the forms of quantum dots and rods to more recently emerging quantum wells. Based on the rational design of these nanocrystals, it is possible to achieve highly efficient optically pumped lasers.

Here we will present all-colloidal lasers developed by incorporating nanocrystal emitters as the optical gain media in 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 amplified spontaneous emission threshold among all colloids [6].

In addition, we will discuss that controlled stacking of these colloidal quantum wells uniquely enables us to fine-tune and master their excitonic properties. 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 optoelectronics, solution-processed quantum materials hold great promise to challenge their epitaxial counterparts in the near future.

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