DACNA

Dense Assemblies of Colloidal Nanoplatelets: toward record high optical gain

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Project context and objectives:

Colloidal semiconductor nanoplatelets (NPLs) are quasi two-dimensional nanocrystals offering favorable optical and material properties making them promising for light-emitting and -harvesting applications. Prior to this seed project, our project team has shown the first time lasing in the NPLs with record high optical gain coefficients ever reported in the colloidal nanocrystals at the time. Later, continuous wave pumped optical gain and lasing has been also accomplished in the NPLs representing an important breakthrough for the colloidal semiconductors. To date, effects of the solid-film assemblies of the NPLs on the optical gain performance have not been studied nor understood. Such a control will be crucial for optimizing the optical gain related parameters in these novel materials. In this project, we propose to control the stacking of the NPLs in their solid-films towards enhanced optical gain performance.

Brief description of the main results:

In this seed project, we first investigated the excitonic properties of the controllably stacking NPLs. We have revealed that highly ordered stacks of the NPLs promotes ultra-fast exciton transport among the NPLs causing strong quenching of the photoluminescence due to trapping of the excitons by the non-emissive NPLs within the NPL population. At the same time, we have attempted to develop aerogel-based three-dimensional solids of the NPLs as enhanced optical gain media. However, the initial trials have not been successful since it was not possible to preserve the photoluminescence of the NPLs due to severe ligand loss and oxidation. Alternatively, we have developed spin-coated solid-films of the well-controlled stacked and non-stacked NPLs that showed substantially enhanced optical gain performance. With these, we have achieved both the state-of-the-art stimulated emission thresholds and unprecedented optical gain coefficients in the colloidal NPLs (breaking our previous record prior to starting this project).

Potential impact and challenges:

The NPLs offer high potential as optical gain media among the all colloidal semiconductor nanocrystal structures. Our demonstration of ultra-low threshold lasers and record-high gain coefficients indicate that the NPLs, which are solution processed quantum wells, can compete with their epitaxial counterparts, which are today the mature material technology behind the laser diodes. There remain still some challenges. These include the need for further reduced stimulated emission thresholds and further larger optical gain coefficients to enable colloidal lasers using cheap and feasible optical pump sources or even under electrical injection pumping. Such colloidal NPL based lasers will provide the ease of large scale fabrication using cheap solution processing techniques.