Spotlight on Optics

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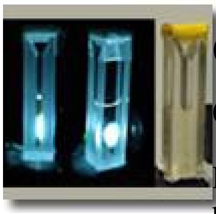

Observation of white-light amplified spontaneous emission from carbon nanodots under laser excitation

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Spotlight summary: Light sources have an indispensable role in everyday life. From the first lamp using animal fat around 70,000 BC, to modern light sources, these have been widely used and developed for diverse applications going much beyond night lighting. For example, light-emitting diodes (LEDs) have been extensively utilized in illumination, e.g. as backlight for various mobile units (such as laptop displays and mobile phones). A key component of modern light sources (LEDs and lasers) is the gain material, emitting photons when electrically or optically pumped. Thus far, this has been mainly based on traditional semiconductors: blue LEDs rely on GaN and InGaN, laser diodes for fiber-optic communications are typically based on InGaAsP.

Organic opto(electronic) materials attract great interest for various applications, because of their low-cost/flexibility in fabrication/integration. Recently, low-dimensional carbon-materials, such as fullerenes, nanotubes, graphene, nano-diamonds, nano-dots, have emerged as potential candidates for various photonic and optoelectronic applications (e.g. bio-imaging, ultrafast lasers, photodetectors, displays and solar cells). Photoluminescence has been reported for all these.

Zhang et al. demonstrate white-light amplified spontaneous emission from carbon nano-dots (C-dots) fabricated by irradiating a mixture of graphite powder and N-Methylpyrrolidone (NMP) with a pulsed laser (10ns, 10Hz, Nd:YAG at 1064nm) for around 30 minutes. The generated C-dots range from 1.5 to 3.5 nm. The dispersion was diluted to reduce fluorescence quenching, so to maximise the optical-to-optical conversion efficiency.

Strong white-light emission was observed due to amplified spontaneous emission, when pumping with a 266nm laser. The emission wavelength (with 120nm bandwidth) was in the visible spectral range, peaking at~450nm. The net optical gain was 16cm-1, for an input peak pump power of 0.27MW.

The authors reported that the solvent used to disperse the C-dots enhances their light emission efficiency. An energy-transfer mechanism from NMP to C-dots was suggested, considering the close match between the NMP peak emission wavelength (295nm) and the C-dots absorption (300nm). Compared to evaporated C-dot thin films on quartz, the optical gain and efficiency of C-dots in NMP were improved by 39%.

These results, although preliminary and in need of further studies, show great promise for various applications (e.g. bio-imaging) due to the easy fabrication process, broad emission spectral range and non-toxicity. However, the optical-to-optical efficiency is still very low, as indicated by the high peak power pump (e.g. 0.21MW pump threshold for amplified spontaneous emission). Further investigations, e.g. focussing on the recovery time and C-dot size control, may lead to a significant improvement of the conversion efficiency, with a consequent reduction of the pump threshold. This could be the first step towards all-carbon based devices, that could combine graphene based transparent conductors and C-dots-based gain materials, for flexible opto(electronics) applications.

--Zhipei Sun and Andrea C. Ferrari

ToC Category: Nanomaterials

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