Photonic Crystal Surface Emitting Lasers over the Entire Visible Spectrum based on Colloidal Nanocrystals

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Silicon photonics has emerged as a robust, low-loss, integrated, particularly through the use of silicon nitride (SiNx), which offers excellent properties for visible-light applications. By now, losses as low as 1 dB/m are achievable, allowing for quality factors (Q) above 1 million.[1] SiNx's compatibility with standard CMOS fabrication processes further enhances its appeal for integrated photonic devices. However, despite its potential as a passive platform, the lack of efficient light emission from SiNx limits its wider application.

In this context, the integration of solution processable colloidal nanocrystals (cNCs) onto SiNx presents a transformative approach for achieving the desired enhanced functionality. As cNCs are obtained as an ink, they are processable from a solution phase allowing for cost-effective and straightforward methods for integration onto photonic chips, such as spin coating. Using their broadband and size-tunable absorption, efficient optical gain metrics have been demonstrated, [2,3] which is critical for the development of the highly desired on-chip laser sources mentioned above. Several demonstrations in literature indicated the potential for lasing on the nitride platform, both in the green and red part of the visible spectrum under quasi-CW optical excitation.[2,3] In these demonstrations, two-dimensional photonic crystal cavities were used – due to the ease of processing, as they consist of a single lithography step followed by depositing the active NC layer on top. Furthermore, these Photonic Crystal (PhC) surface-emitting laser implementations benefit from efficient collection of the collimated out-of-plane emission, allowing for quick demonstrations of lasing in proof-of-concept experiments across the visible and near-infrared spectrum. While PhC - based laser structures combined with NCs have been presented in the past, they are typically not explored in-depth from a purely photonic perspective and more used as a means to an end.

Here, we demonstrate lasing from cNC/SiNx PhC devices across the visible spectrum by using two different materials, and their far-fields are measured. These were both spin coated from a colloidal dispersion on similar SiNx chips, underscoring the versatility of the hybridization approach. Next, the photonic band structures of these low refractive index contrast SiNx/NC systems are simulated using the Finite Element Method (FEM). The simulations allow to identify and label the various possible modes and their energy dispersion.[4] Finally, through 2D Fourier Imaging, the band structures are measured and compared to theory, showing excellent agreement.

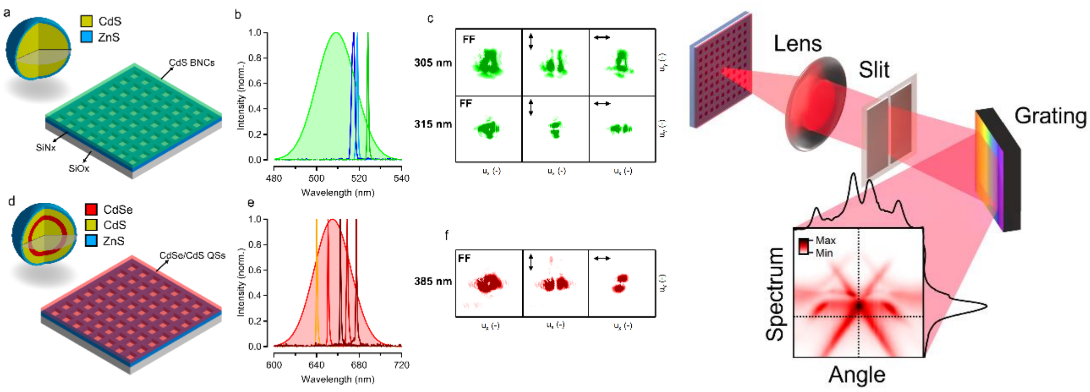

Fig. 1 PhC surface emitting lasers based on green– and red emitting cNCs. (a) and (d) show schematics of the materials and devices. (b) and (d) show the normalised PL spectra and lasing peaks for various device periods. (c) and (f) show the (polarised) far fields. On the right, the 2D Fourier Imaging technique is displayed, used to directly measures photonic band structures.

References

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