Cathodoluminescence excitation spectroscopy of 2D materials

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Fast electrons spectroscopies have had huge success for nano-optics [1]. For phase-locked excitations (e. g. surface plasmons) electron energy loss spectroscopy (EELS) is an optical extinction analogue and cathodoluminescence (CL) that of optical scattering [2]. For "incoherent" excitations, EELS also measures optical extinction for atomically thin materials [3,4,5], while CL measures spectra similar to off-resonance CL [3]. Despite clear benefits (link to structural and chemical information, atomic-scale spatial resolution and broadband excitation), electron spectroscopies have some penalties which limit applications to nano-optics: lack of resonant excitation and polarization degrees of freedom and still limited spectral resolution (EELS). In this contribution, we will discuss how temporally resolved spectroscopies can mitigate some of these issues, specifically for 2D materials, as h-BN and TMD heterostructures.

The lack of excitation energy control can be circumvented by measuring the energy lost by each electron in time coincidence EELS-CL experiments. This has been achieved using a nanosecond-resolved direct electron detector (Timepix3) [6], correlation electronics and a PMT. The information retrieved here is analogous to that of photoluminescence excitation spectroscopy (PLE), hence we name it cathodoluminescence excitation spectroscopy (CLE) [7]. With it, we explored the relative quantum efficiency of different excitation energies and decay pathways towards 4.1 eV defect photon emission in h-BN flakes [7] (Figure 1). We observe a higher quantum efficiency towards light emission of energies just above the optical band gap of h-BN. Our future experiments will aim at understanding the excitation mechanisms leading to light emission in transition metal dichalcogenide monolayers encapsulated in thin h-BN flakes [3].

References

[1] F. J. García de Abajo, Rev. Mod. Phys. 82, 209, 2010.
[2] A. Losquin, et al., Nano Lett. 15, 1229, 2015.
[3] N. Bonnet, et al., Nano Lett. 21, 10178, 2021.
[4] F. Shao, et al., Phys. Rev. Mater. 6, 074005, 2022.
[5] S. Y. Woo, et al., accepted, 2022.
[6] Y. Auad, et al., Ultramicroscopy 239, 113539, 2021.
[7] N. Varkentina, et al., Sci. Adv., 2022.

Figures

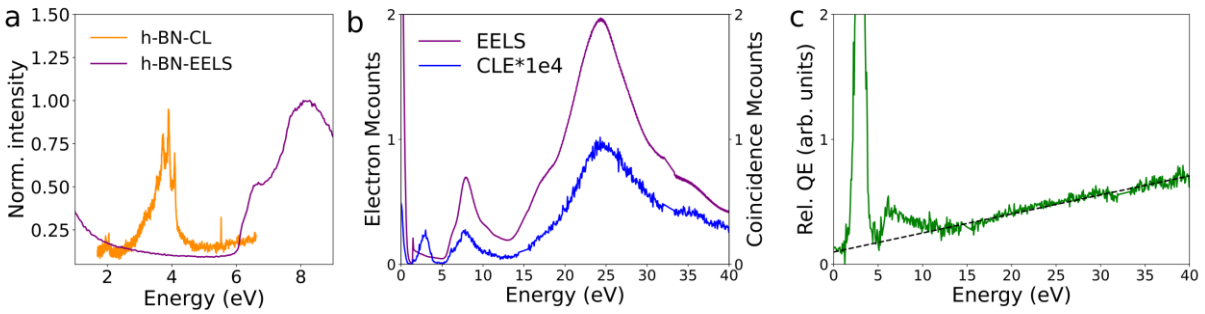

Figure 1: a Average CL an