De-trapping of moiré-localized interlayer excitons in $WSe_2/MoSe_2$ heterostructures

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Moiré superlattices in heterostructures (HSs) of semiconducting Transition Metal Dichalcogenides can act as a promising potential landscape for the creation of ordered arrays of quantum emitters [1], or for the formation of Bose-Einstein condensates [2] and highly correlated exciton states at elevated temperatures [3].
Here, we address up to what extent moiré excitons (MXs) can be truly considered localized, upon temperature and photogenerated carrier density increase. To this end, we study the photoluminescence properties of a $WSe_2/MoSe_2$ HS under steady-state and transient conditions, also under a magnetic field [4]. The exciton dynamics and emission lineshape evolution with temperature show clear signatures that MXs de-trap from the moiré potential and turn into free interlayer excitons (IXs) for Ts above 100 K (Fig. 1.a and Fig. 1.b). The MX-to-IX transition is also apparent from the exciton magnetic moment reversing its sign when the moiré potential is not capable of localizing excitons at elevated temperatures (Fig. 1.c). Concomitantly, the exciton formation and decay times reduce drastically. Furthermore, the increase of photogenerated carrier density at low temperature allows the population of MX states with different local atomic registry, as apparent from the gyromagnetic factor of different exciton transitions.

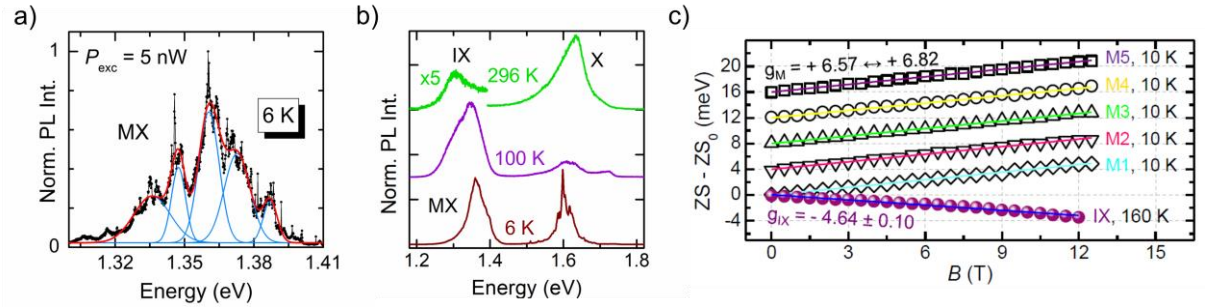

Figure 1: a) Micro-PL spectrum of a moiré-trapped interlayer exciton band (MX). The evenly spaced gaussian peaks are centered around the moiré potential energy levels. b) Micro-PL spectra at different temperatures, featuring the emission of the moiré-trapped interlayer exciton (MX), the free interlayer exciton (IX) and the intralayer excitons of the two constituent layers (X). c) Zeeman splitting (ZS) of five moiré-trapped excitons (M1-M5) at 10 K and the free interlayer exciton (IX) at 160 K for magnetic fields up to 12 T. The exciton gyromagnetic factors are extracted by performing linear fits, showing a distinctive sign-reversal.

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[2] Z. Wang *et al.*, Nature **574**, 78-80 (2019).
[3] Y. Xu *et al.*, Nature **587**, 214–218 (2020).
[4] E. Blundo *et al.*, Nat. Commun. (in press) (2023).