Determination of the exciton binding energy and effective masses for methylammonium and formamidinium lead tri-halide perovskite semiconductors

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1 Supplementary Information

The low temperature spectra of $FAPbBr_3$ and $MAPbBr_3$ are shown in Fig 1. Panel (a) shows the transmission spectra for the FA compound for different magnetic fields. The main peak corresponds to the 1s transition. We can also clearly resolve the 2s state for magnetic fields of 20T and above, marked schematically by red points. The ratioed spectra are shown in panel (b). The first differential feature corresponds to the diamagnetically shifted 1s state and the arrows show the magnetic field induced 2s state and a further minimum corresponding to the excitonic absorption of the n=1 Landau level. For the MA sample by contrast panel (c) shows a significantly broader 1s transition and no 2s feature is detectable. The ratioed spectra in panel (d) show a significantly broader differential feature for the 1s transition and no reliable feature that can be attributed to the 2s state.

The high temperature magneto transmission spectra measured for $FAPbBr_3$ sample are shown in Fig 2(a),(b). Panel (a) shows the results of the measurements performed with the long pulse technique. The transmission spectra exhibit one very strong minimum, which corresponds to the strongest absorption originating from the 1s state of the neutral free exciton. The absorption peak shifts towards higher energies with increasing magnetic field similarly to the results obtained at low temperature. Panel (b) shows the results for monochromatic transmission of different laser wavelengths as a function of magnetic field obtained by using the short pulse technique. The results show strong minima corresponding to the absorption from the 1s free exciton state (2266meV and 2279meV) and from higher Landau levels (2375 meV, 2393 meV and 2410 meV).

The temperature dependence of 1s transition for all samples discussed in the main text is is shown in Fig 3. The energy of the transition increases with the temperature showing characteristic dip around 150K which corresponds to the phase transition between different crystal structures. It is worth noting that the phase transition is sharp and the change in band gap is much larger for $MAPbI_3$ while for the other compounds only a much smaller change in band gap

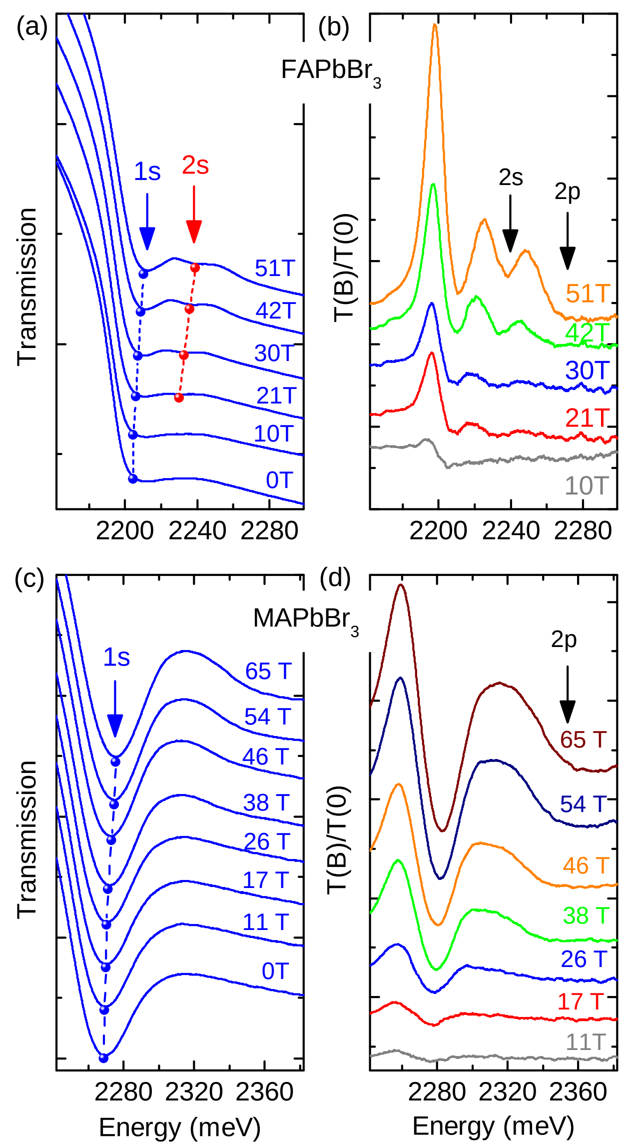

Fig. 1 Low temperature data for $FAPbBr_3$ and $MAPbBr_3$(a), (c) transmission spectra for different magnetic fields, (b), (d) transmission spectra at fixed field ratioed to the zero field spectrum.

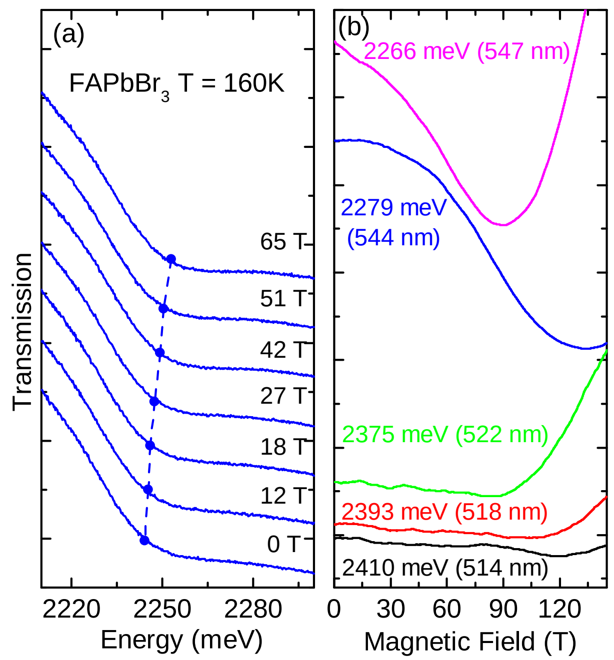

Fig. 2 Typical high temperature (a) transmission data taken using a long pulse technique, (b) monochromatic transmission as a function of magnetic field obtained by using the short pulse technique. The data were taken for $FAPbBr_3$.

is observed and the transition is less abrupt.

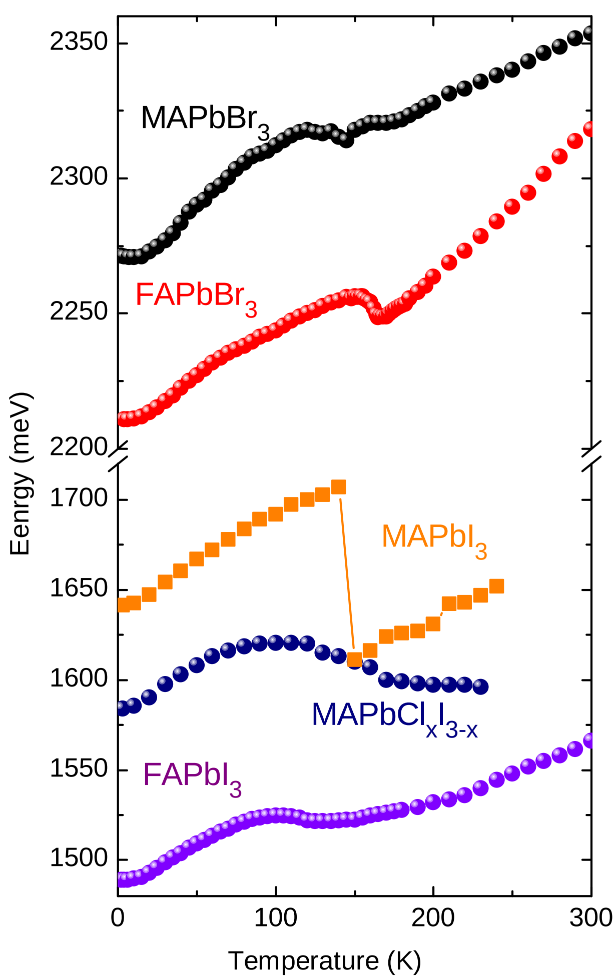

Fig. 3 Temperature dependence of the 1s excitonic absorption energy for all of the compounds discussed in the main text.