Supplemental Document:

# Determination of optical properties and band structure parameters of MBE-grown InAs and InAsSb bulk and InAs/InAsSb and InGaAs/InAsSb superlattices from photoluminescence lineshape

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The impact of disorder on the band structure of MBE-grown InAs, InAsSb, and InAs/InAsSb is examined below using the lineshape of temperature and excitation dependent photoluminescence measurements and is shown in the following figures. The measurement temperatures range from 12 K to room temperature and the pump powers range from 0.4 to 200 mW. The lineshape model is fit to the resulting families of spectra for each material, with the 100 K results shown in Fig. 1, where at this temperature the pump powers range from 4 to 200 mW. The quasi-Fermi level separation $\Delta F$, which is the chemical potential of the photoexcited electron-hole population, is also indicated in the figure. Note that for the constant range of pump powers in Fig. 1, the range of the chemical potential $\Delta F$ decreases moving left to right, because the lifetime decreases as the material disorder increases.

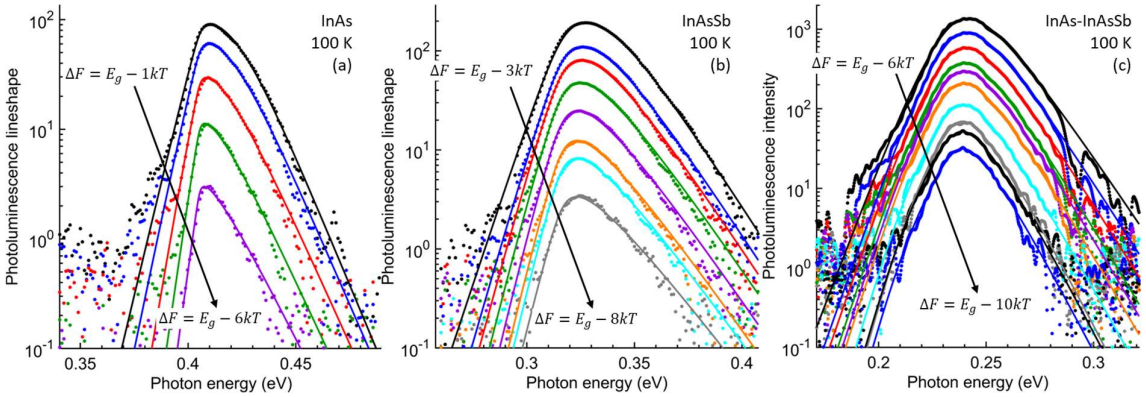


Fig. 1. Excitation-dependent photoluminescence spectra (filled circles) for InAs (left panel a), InAsSb (middle panel b), and InAs-InAsSb superlattice (right panel c), measured at temperature 100 K. The solid lines are fits of the model to the measured lineshape. The quasi-Fermi level separation $\Delta F$ is shown from the highest to the lowest excitation (pump powers 200 mW to 4 mW). The x-axis range is the same for all plots to display the progressing degree of broadening of the lineshape.

The lineshape model predicts the so-called S-shape behavior of the peak position as a function of temperature and excitation. The S-shape behavior typically occurs at low temperatures, where for the carriers in disordered materials, the width of the Urbach tail in the density of states exceeds the width of the thermal Fermi occupation tail. This causes the lineshape to red shift, with an increasing magnitude in the shift as the electron-hole chemical potential is reduced. As the temperature is reduced further, the chemical potential for a given excitation density increases, thereby blue-shifting the lineshape peak back towards the bandgap, thus completing the S-shape. The S-shape is a typically prominent feature in the bismide alloys [1,2].

The S-shape behavior is clearly shown in Fig. 2 panels b and c, for the InAsSb bulk alloy and the InAs/InAsSb superlattice. For the InAsSb alloy, the first part of the S-shape is observed. However, for the superlattice, the reversal of the red-shift in the S-shape is observed at the lowest temperatures. As the alloy disorder increases (left to right), binary InAs, ternary InAsSb, and InAs/InAsSb superlattice, the width of the Urbach tail increases (see Fig. 3) as illustrated by the strong red shift in the peak at low temperatures. Furthermore, for the superlattices that have the largest density of tail states, the peak position drops below the bandgap at the lowest excitation levels indicating that almost all of the emission comes from the tail states. Temperature and excitation dependent Urbach parameter, which is the characteristic energy of the lineshape tail, is shown in Fig. 3.

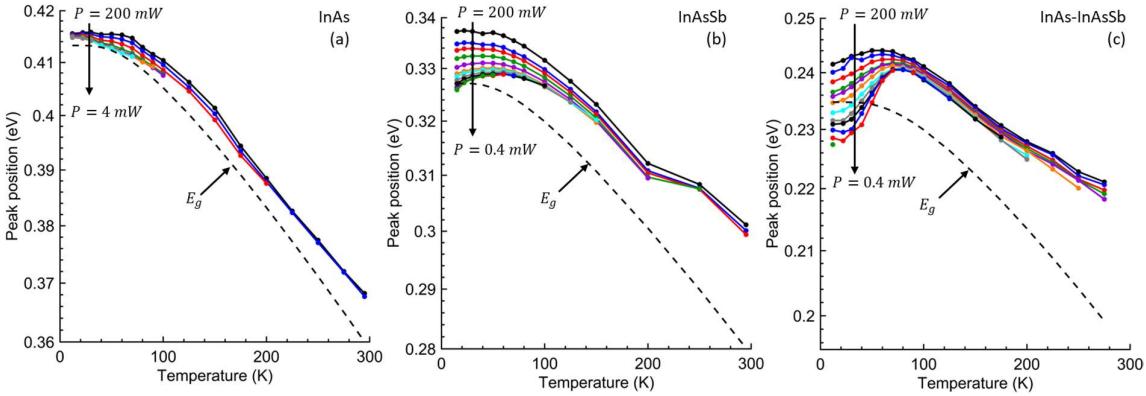


Fig. 2. Temperature and excitation dependent lineshape peak positions (filled circles with solid connecting lines) for InAs (left panel a), InAsSb (middle panel b), and InAs-InAsSb superlattice (right panel c). The bandgap inferred from a global fit of the lineshape model to the measurements as a function of temperature is show as a dashed line. The range of the photoexcitation is shown in terms of pump power.

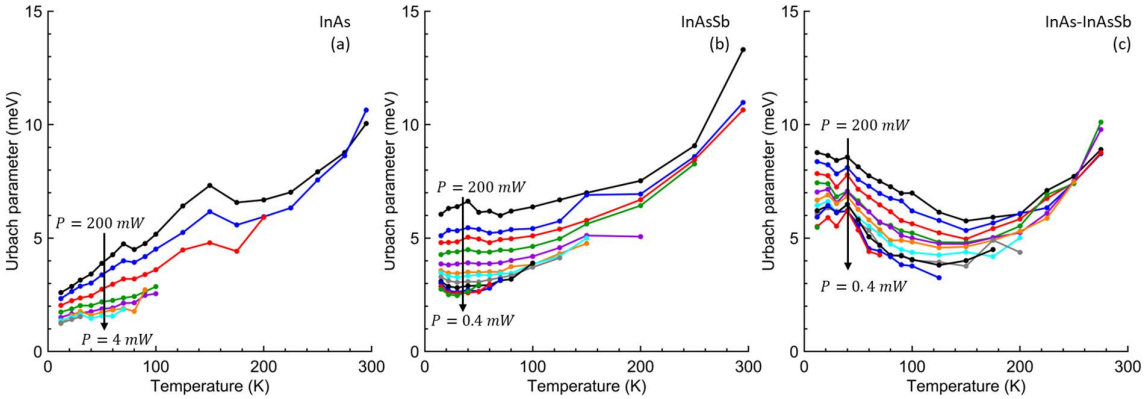


Fig. 3. Temperature and excitation dependent Urbach parameter (filled circles with solid connecting lines) for InAs (left panel a), InAsSb (middle panel b), and InAs-InAsSb superlattice (right panel c). The range of the photoexcitation is shown in terms of pump power.

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