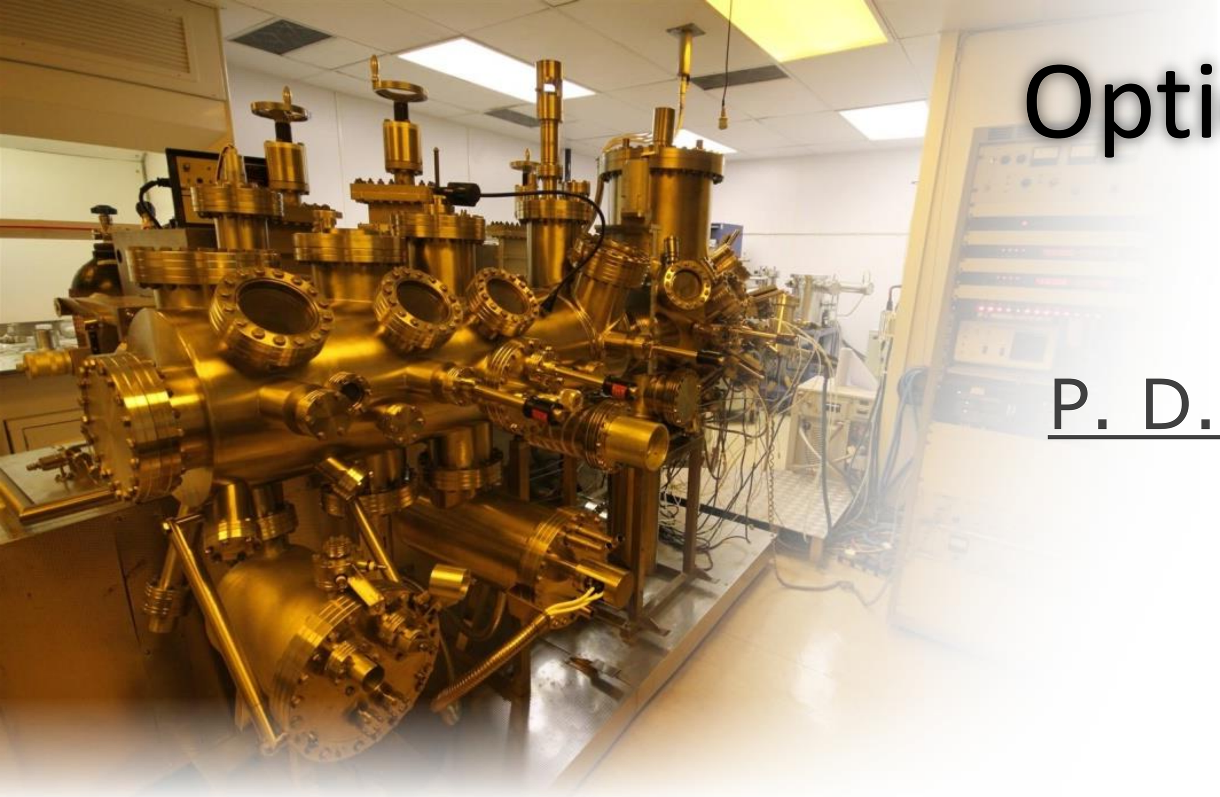

Optically-induced charge depletion in type-II GaSb/GaAs quantum dots and rings

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i. Introduction

The results presented here are for a molecular beam epitaxy (MBE) grown GaAs/GaSb self-assembled quantum ring (QR) sample.

Transmission electron microscopy has revealed the presence of both quantum rings and quantum dots in the sample [1].

The GaAs/GaSb system has a type-II band alignment, leading to interesting effects

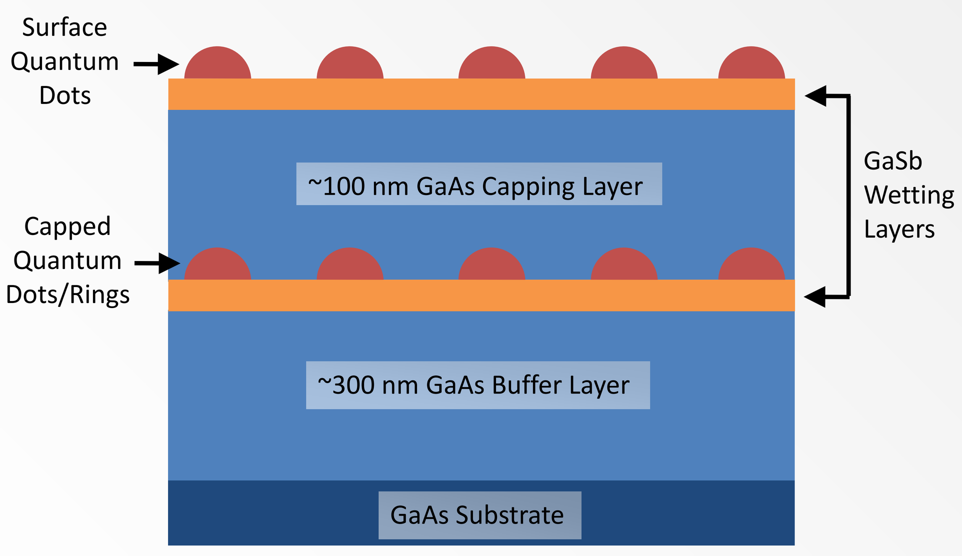
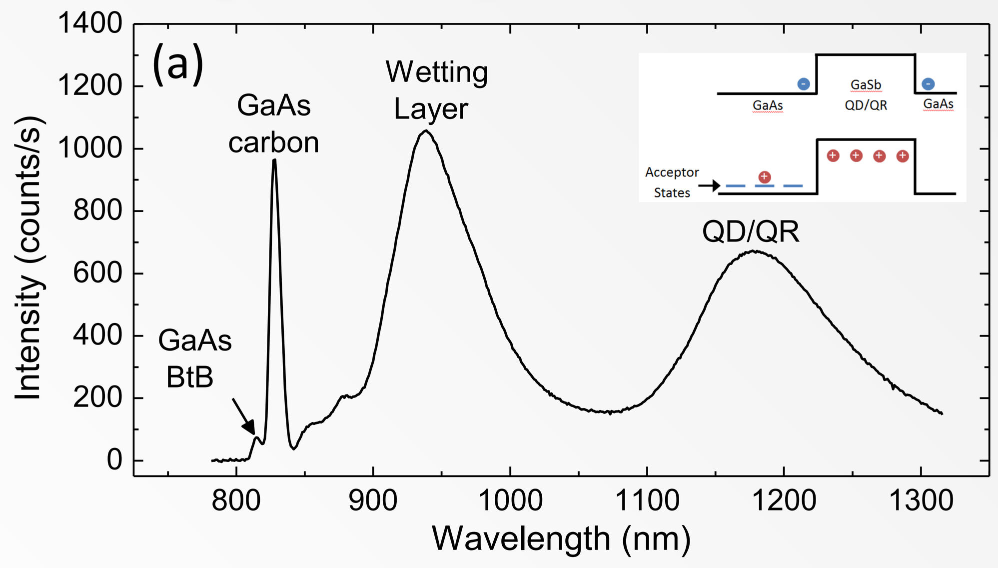


Figure 1. Schematic diagram of sample structure.

The spatial separation of carrier species offers considerable potential for applications such as memory storage devices [2] and solar cells.

But first it is important to understand how carriers migrate through a QD/QR system as a function of temperature.

ii. Optically Induced Charge Depletion



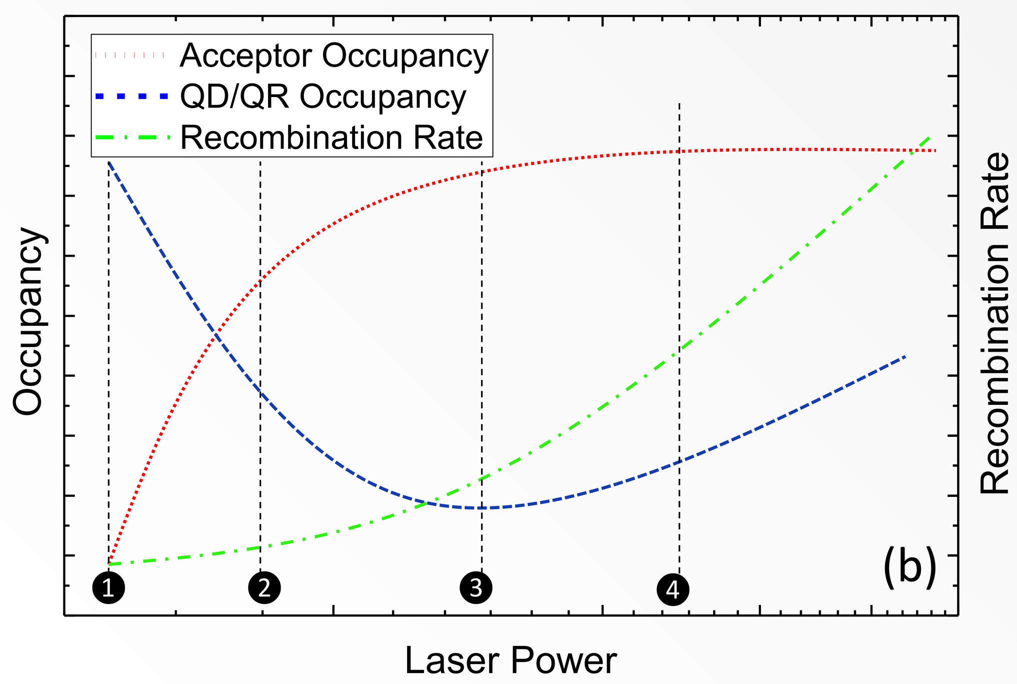


Figure 2. (a)Typical PL emission emission spectrum from GaAs/GaSb QRs at 2K.
(b) Illustrates how OICD occurs, see main text for details.

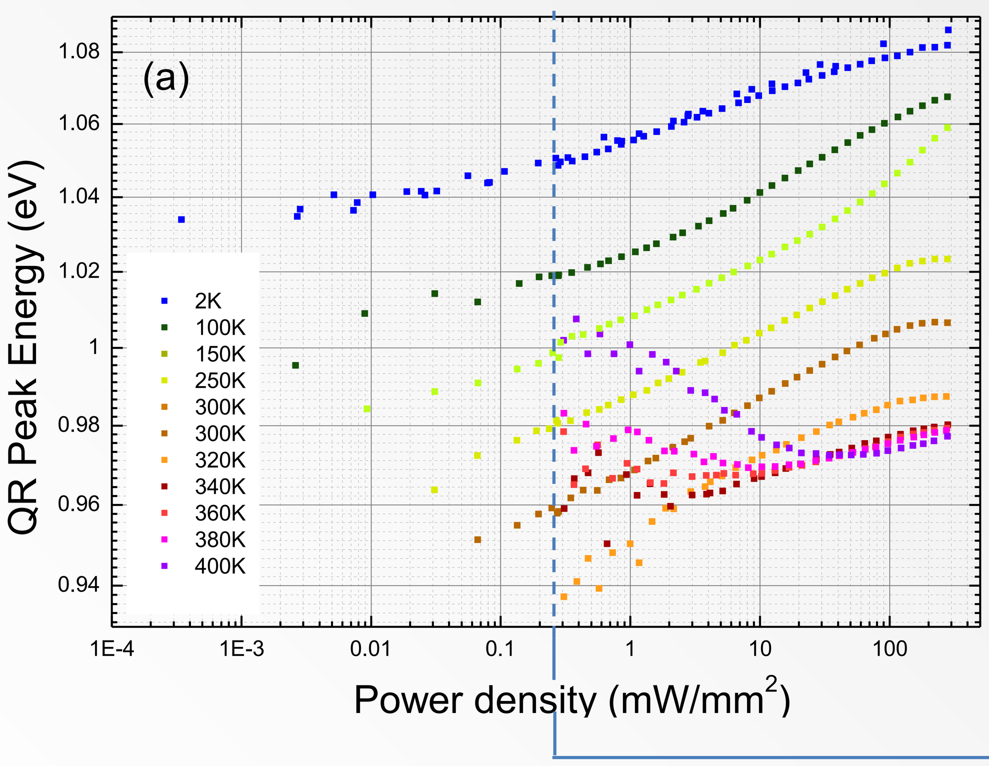
Optically induced charge depletion (OICD) results in the discharging of quantum dots as the incident laser power is increased in a photoluminescence (PL) measurement.

OICD requires the presence of dopants, such as carbon, in the sample. Unintentional carbon doping is common in MBE [3] and is clearly present in our sample [GaAs Carbon peak in Fig. 2(a)].

Fig. 2(b) illustrates how OICD can occur:

1. Zero laser power:
   - acceptor holes preferentially occupy the QRs
2. Low laser powers:
   - acceptors become populated, preventing holes from reaching the QRs
   - recombination rate increases as number of electrons increases, so the QRs discharge.
3. Mid laser power:
   - Acceptor states become saturated
   - Photogenerated holes spill into QRs
4. High laser power:
   - High density of photogenerated carriers charge the QRs

iii. Results – Quantum Rings



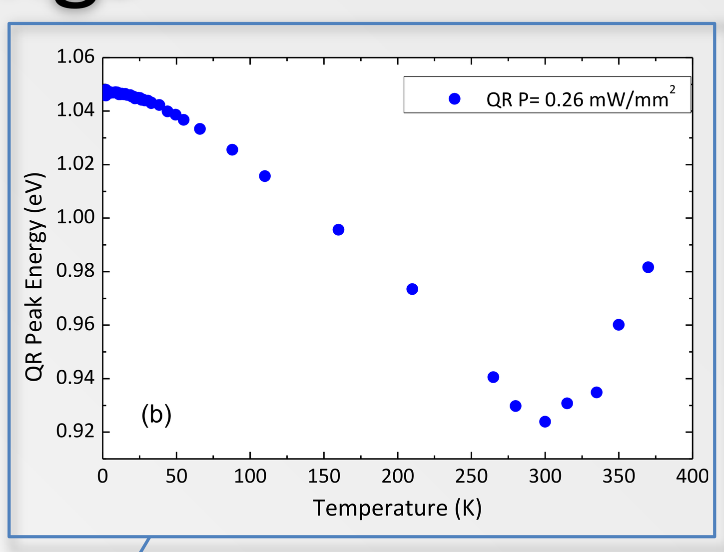
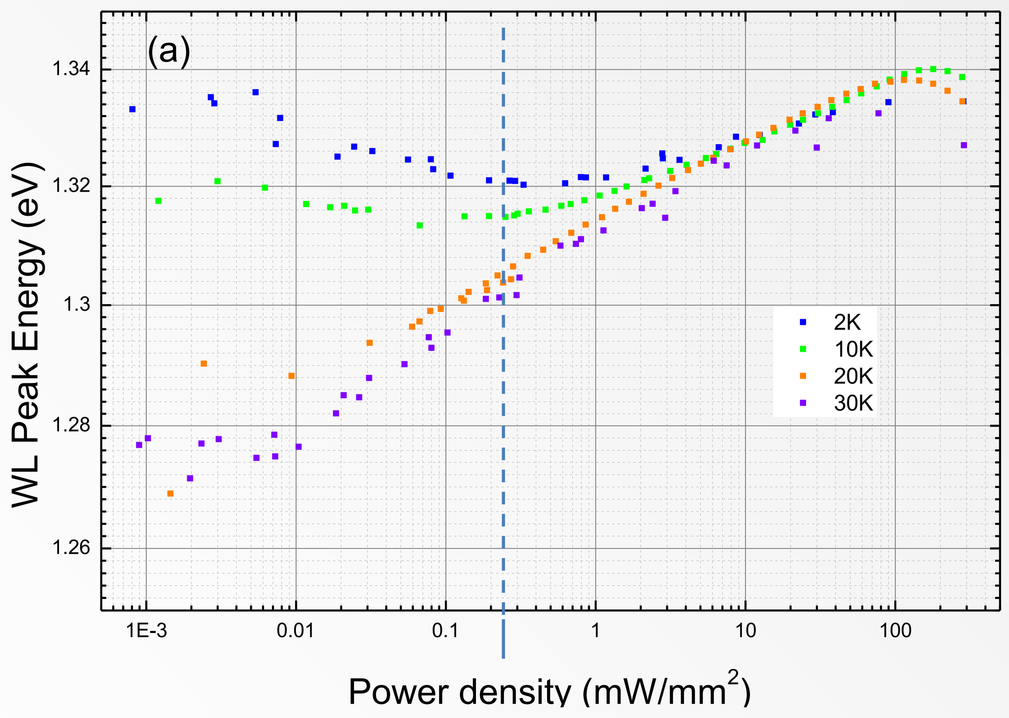


Figure 3.(a)QR peak energy as the laser power is varied at fixed temperatures.
(b)QR peak energy at different temperatures.

At temperatures less than 320 K the QR peak shows a monotonic blueshift with increasing laser power. This is characteristic of type-II systems, where multiple hole occupation of dots leads to capacitive charging [4] and band bending [5] (see my other poster).

Above 320 K an initial redshift is observed, this is caused by OICD. The magnitude of the redshift is greater at higher temperatures, indicating more acceptor holes occupy the dots as the temperature is increased.

iv. Results – Wetting Layer



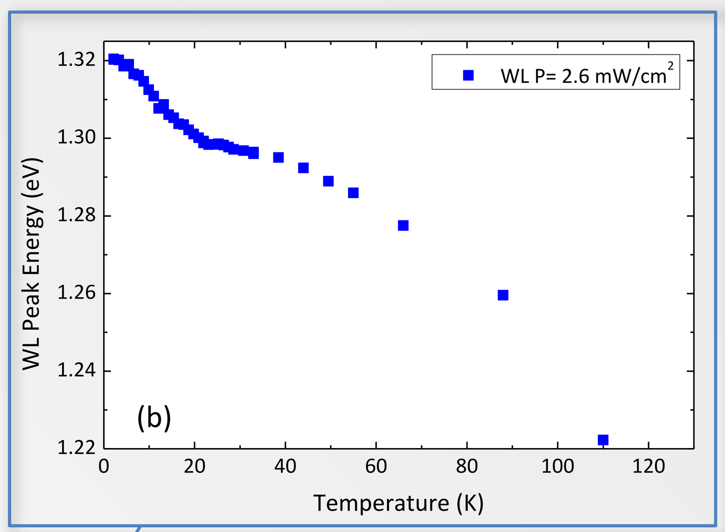


Figure 4.(a)WL peak energy as the laser power is varied at fixed temperatures.
(b)WL peak energy at different temperatures.

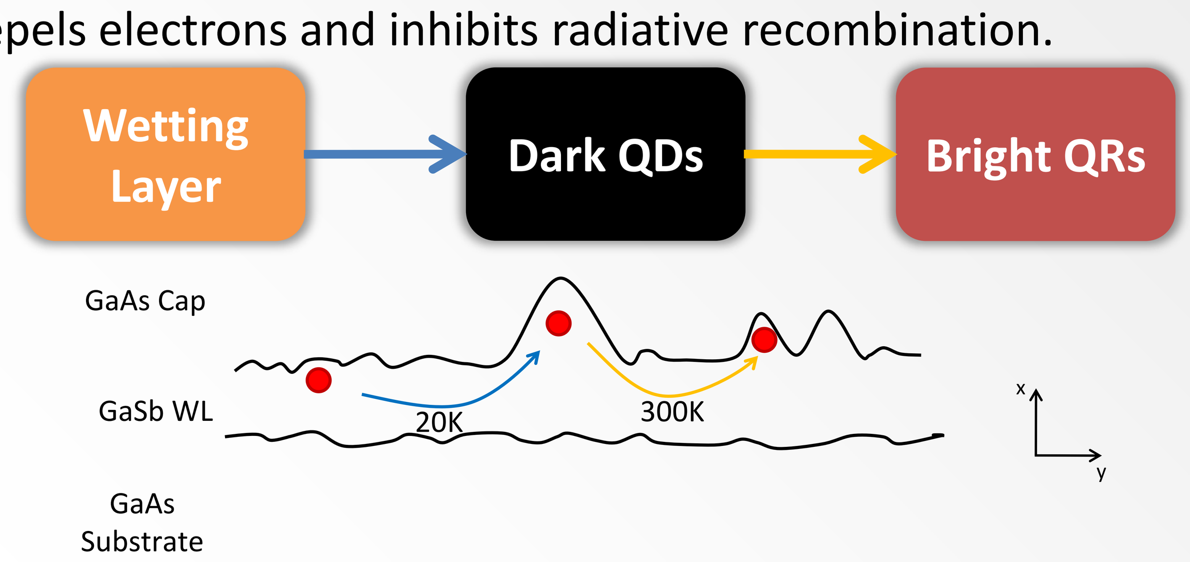
Again an initial redshift of the emission energy with increasing laser power, due to OICD, is observed. However the WL shows the opposite OICD behaviour to the QRs.

OICD is only seen below 20 K. The magnitude of the redshift is greater at lower temperatures, indicating that the WL discharges of acceptor holes as the temperature is increased.

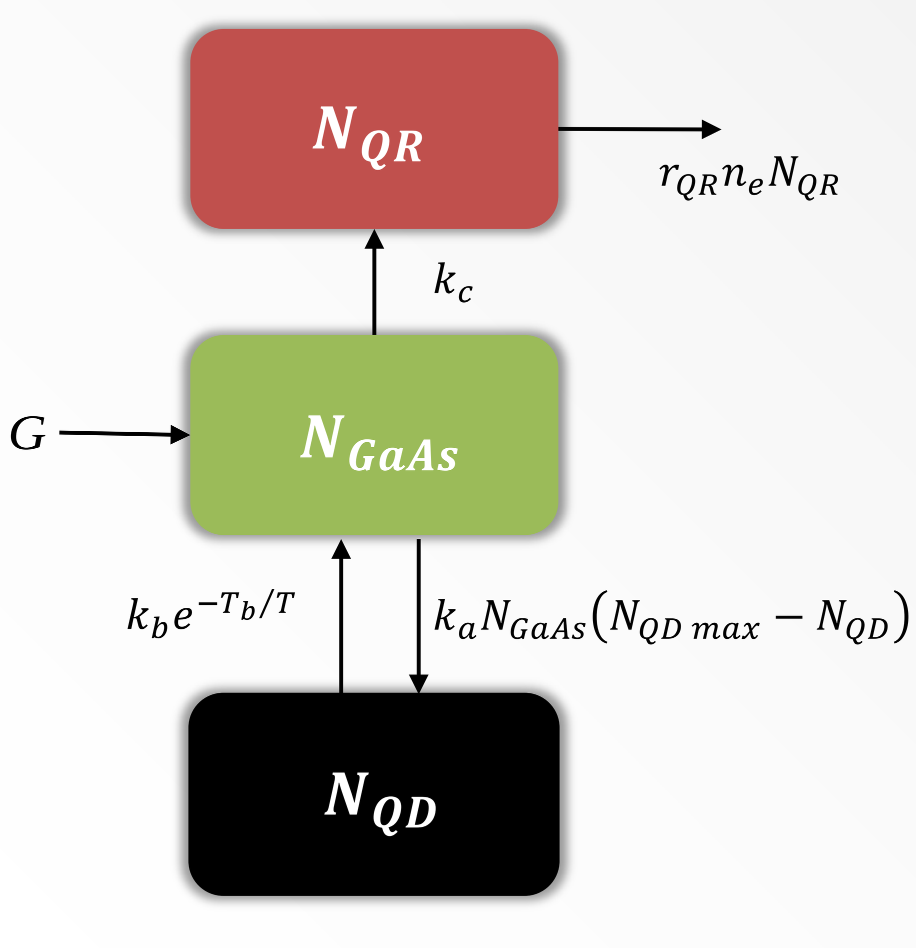
v. Discussion

Our results show that the acceptor holes are trapped in the WL at low temperatures, possibly by composition fluctuations. They escape at 20 K and aren't observed again until the temperature is above 320K, where they appear in the QRs.

We believe that the acceptor holes occupy highly strained QDs at the intermediate temperatures. The strain in these structures repels electrons and inhibits radiative recombination.

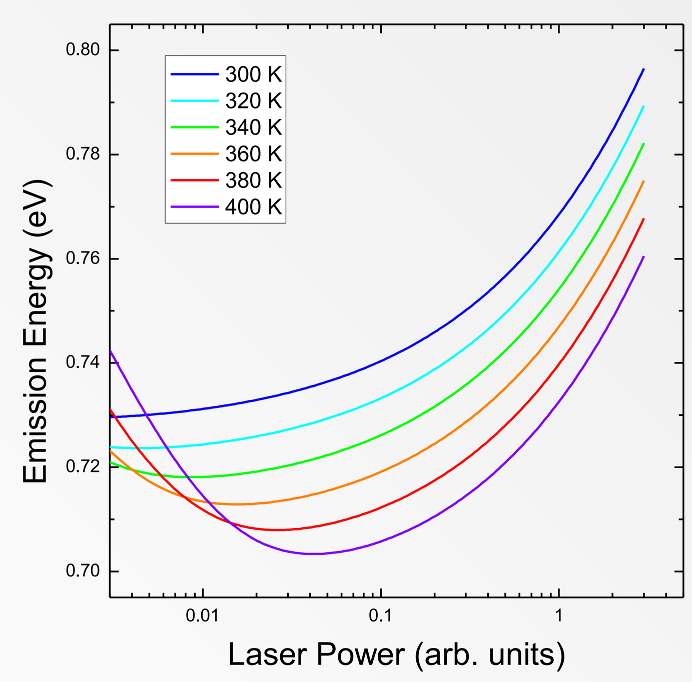


vi. Modelling



The model calculates the hole population in 3 regions: the GaAs, dark QDs and bright QRs.

The energy shift of the QR emission per additional hole from capacitive charging is 24 meV [6].



The model successfully replicates the OICD effect observed in the QRs. (Compare with Fig. 3(a) at temperature > 300 K)

The model does not currently include the WL, as this adds extra complexity without describing any new physics

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