Transconductance spectroscopy on self-assembled dots: Beyond the ensemble average

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We have recently developed a so-called transconductance spectroscopy (TCS), which is an all-electrical preparation and probing method for non-equilibrium (excited) states in an ensemble of self-assembled quantum dots (QDs) [1,2]. We demonstrate here the scalability of the measurement technique down to about 100 QDs with the future vision of an all-electrical single dot measurement; a necessary requirement for preparation and control of quantum states in self-assembled QDs for quantum information processing.

The device is a high electron mobility transistor (HEMT) with an embedded layer of InAs QDs, separated by a tunneling barrier from a two-dimensional electron gas (2DEG). The 2DEG is used as a sensitive charge detector as well as a reservoir for electrons in the QD states. This device offers time-resolved charge detection via a transconductance measurement as well as ideal scaling properties. Therefore, electron beam lithography has been used to define a gated channel containing only $\sim$ 100 QDs, see Fig. 1(a). The equilibrium TCS of the present device shows enhanced energy resolutions in Fig. 1(b) with clear signatures of the s- and p-shell for the displayed blue line. Reducing gate pulse amplitude and source drain voltage further increases the resolution, allowing us to observe reproducible, sharp peaks that can be attributed to the many-particle states for smaller subsets within the QD ensemble, see red line in Fig. 1(b).

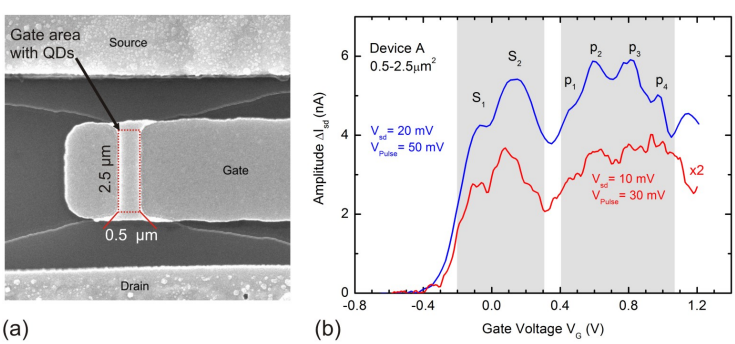

Figure 1: (a) HEMT device containing $\sim$100 QDs in the active gate region. (b) Transconductance spectroscopy of the device in (a), where the inhomogeneous broadening splits up into discrete lines of QD sub-ensembles.

[1] B. Marquardt et al., Nature Commun. **2**, 209 (2011).
[2] B. Marquardt et al., Appl. Phys. Lett. **95**, 22113, (2009).