The BIRS Workshop on
Low-Dimensional Semiconductor Nanostructures:
Section on open problems

This section aims to identify and discuss some of the most important problems to solve in near (and far) future within **Low-Dimensional Semiconductor Nanostructures**.

I. The discussions in this section can be centered on the following points:

(a) Identify critical problems [Open Problems] of major importance that require solution and prioritize them (or identify main obstacles in obtaining better quantum devices),

(b) Summarize most recent experimental achievements in the Open Problem area with associated physical effects and phenomena that require better understanding.

(c) Summarize the state-of-the-art models and computational techniques for modeling LDSNs that can assist further progress related to the Open Problem.

(d) Analyze feasibility of existing mathematical and computational methodologies for the solution of the problem. Can new, more efficient methodologies be developed? Explore promising approaches in addressing identified challenges/Open Problems.

II. Open problems in LDSN (posted by D. G. Austing)

Energy levels of N-electron (small N but greater than 2) double quantum dot molecules as a function of magnetic field (with coupling to BOTH Zeeman and orbital degrees of freedom) AND energy offset between the two quantum dots (equivalently an applied electric field between the two dots OR non-identical quantum dot confinement).

The situation of N=2 with magnetic field coupling to the Zeeman degree of freedom has been instrumental in understanding the influence of hyperfine coupling to nuclei in recent groundbreaking measurements performed at Delft and Harvard on lateral double quantum dot molecules which are of key importance for 1- and 2- qubit operations [F. H. L. Koppens, et al., Nature 442 (2006) 766, and J. R. Petta, et al., Science 309 (2005) 2180].

Vertical double quantum dot molecules also show pronounced effects related to hyperfine coupling in the N=2 spin blockade regime [K. Ono, et al., Phys. Rev. Lett. 92 (2004) 256803, and J. Baugh, et al., Phys. Rev. Lett. 99 (2007) 096804]. However, similar effects including hysteresis and current oscillations have been recently observed well outside of the usual N=2 spin-blockade regime [D. G. Austing et al., arXiv:0710.0884, and S. Amaha et al., (unpublished)]. To understand these effects properly the above mentioned problem needs to be addressed.

III. Other Open Problem Examples (posted by Morten Willatzen):

(1) Knowledge about growth sequence and growth parameters' influence (temperature, concentrations of constituents, growth operating time,…) on the formation of structure geometry [laboratory control of nanostructure geometry]? Can theory help with better recipes for optimizing this process and which are the major problems? Is there a need (from experimental side) for theoretical assistance in specifying the importance of strain and thermal effects for nanostructure device geometry formation and vice versa? Specify detailed theoretical assistance required.

(2) In order to obtain, e.g., fast carrier transport and /or optical communication, it is necessary to achieve high efficiency, low level of noise, high operation bandwidth, etc. One issue is effective overlap between electron states of nanostructures, another is bandstructure engineering, tailoring of energy levels. How can theory assist in proposing effective geometries in order to satisfy ideal criteria? What can be done experimentally in terms of geometry and material composition – guidelines for theoreticians in suggesting useful geometries/structures for experimentalists to grow.

IV.……

V. General questions to address for Open Problems and networking:

(i) Define the problem.

(ii) Why is this problem important?

(iii) Define possible schemes for attacking the problems? List your and your group's strong sides and weak sides in addressing the above problem. Define the necessary competencies needed to address the problem and distinguish whether these competencies are existent today (anywhere?, in your group or among present-day collaborators?)

(iv) Are there any participants present at this workshop that you believe can help provide the competencies you and your group miss? If yes, give their names, e-mail addresses.

(v) By the end of the workshop: Did you, during the workshop, make contact with other workshop participants so as to enhance your group/network's list of competencies relevant for the problem?