Charge cloud simulations, status report

SRH generation 6M pairs, 7.5ns
Outline

- Short recapitulation
- Status of the computations
- Preliminary comparison with measurements
- Deliverables and next steps
- Cooperation agreement DESY/XFEL–WIAS signed in June
- Essential goals:
  - Improve 3d device simulations for detector design goals based on math
  - Couple simulations with experiments for XFEL detector development
Van Roosbroeck’s Equations

\[-\nabla \cdot \epsilon \nabla w = C - n + p, \quad (1)\]

\[\frac{\partial n}{\partial t} + \nabla \cdot \mu_n n \nabla \phi_n = R, \quad (2)\]

\[\frac{\partial p}{\partial t} - \nabla \cdot \mu_p p \nabla \phi_p = R, \quad (3)\]

in \( S \times \Omega, \ S = (0, T), \)
\( \Omega \subset IR^N, \ 2 \leq N \leq 3, \) a bounded polyhedral domain,
\( \partial \Omega = \Gamma_D \cup \Gamma_N, \ \Gamma_D \) closed, positive surface measure.

Boundary conditions:
hom. Neumann on insulating parts,
Dirichlet on Ohmic contacts,
and gates: hom./inhom. Neumann \( \phi/w \)
\( (\partial w/\partial \vec{\nu} + \alpha(w - w_\Gamma) = 0, \ \vec{\nu} \) outer normal vector).
Very short summary: analytic results

1) thermodynamic equilibrium boundary conditions: the free energy decays for any initial data along trajectories (exponentially) to its equilibrium value, the thermodynamic equilibrium is unique;

2) existence of bounded steady state solutions (smoothness assumptions on data, models and domains, space dimensions), uniqueness close to equilibrium;

3) time dependent problems: existence and uniqueness for finite time intervals (avalanche blow up), in special cases global in time (no 'easy' bounds far from steady state, non trivial attractor dimensions);

4) 1d unipolar problem: unique, bounded steady state solution.

Discrete counterparts:
On boundary conforming Delaunay grids 1) ... 4) (up to exponential decay) can be proved, too!
Byproduct of proofs: possible averages for \( \mu(x, n, p, |\nabla \phi_i|) \), ... resulting in positive solutions.
Meeting at Berlin July 28, 2008 (Uni-HH, HLL, WIAS):
Discussion of
– the experimental setup at Uni-HH,
– which measurements will be done,
– device specification,
– simulations to start with,
– additional topics related to XFEL detector development.
Status of the computations: pin Diode

hight 280µm, diameter 100µm, laser spot sizes: \( \sigma_{rad} = 10µm, 1.9µm \), vert. absorption length 3.0µm, 1.8, 0.9, 0.09M pairs in a full cylinder, code 'as is'.

The grid:
pin Diode: doping and source shape

doping (left), source shape ($\sigma_{rad} = 10\mu m$, right)
pin Diode: cloud deposition

4ps: all pairs created, electrons (left), holes ($\sigma_{rad} = 1.9\mu m$, right)
pin Diode: cloud distribution

1\text{ns}: electrons (left), holes ($\sigma_{rad} = 1.9\mu m$, right)
**pin Diode: cloud distribution**

4 ns: electrons (left), holes ($\sigma_{rad} = 1.9 \mu m$, right)
pin Diode: cloud distribution

Potential differences $4\text{ps}$, $1\text{ns}$, $4\text{ns}$ ($\sigma_{rad} = 1.9\mu m$)
pin Diode: unfiltered results

Wider spots are less dense, hence faster

BOTTOM\_30V
BOTTOM\_40V
BOTTOM\_50V
BOTTOM\_60V
BOTTOM\_80V
BOTTOM\_100V
BOTTOM\_200V

BOTTOM=-30 \ldots 200V, TOP=0V, tau\_SRH=0.001s, 1.8M pairs,
mu\_ele*0.66, spot sigma 10um, lines spot sigma 1.9um

Wider spots are less dense, hence faster
pin Diode: unfiltered results

Rescaled to equal charge: different numbers of pairs at different applied voltages.

BOTTOM=200V, TOP=0V, tau_SRH=0.001s, 1.8, 0.9, 0.09M pairs,
mu_ele*0.66 scaled to equal charge (0.9M pairs), spot sigma 1.9um
pin Diode: unfiltered versus filtered results

RC filtered computations: information losses at small times

BOTTOM=-30 ...-200V, TOP=0V, 1.8M pairs, mu_ele*0.66,
spot sigma 10um, lines: filtered with resp. experiment (9.5pF, 50Ohm)
pin Diode: filtered versus measurements

RC filtered computations: marker; measurements 2.5GHz: lines; $\sigma_{rad} = 10\mu m$
pin Diode: filtered versus measurements

RC filtered computations: marker; measurements 2.5GHz: lines; $\sigma_{rad} = 1.9\mu m$
Deliverables and next steps

Next steps:

- discussion of the preliminary results,
- re-computation for a selected set of experiments,
- set up of a strip counter computational model,
- mobility models \( \mu_j = \mu_j(n, p, C, |\nabla \phi_j|) \),
- meeting 'how to use the code'.
Deliverables and next steps

Deliverables: 3 CDs (for HLL, Uni-HH, RAL) with

- N.N.x86, N.N.64x86 (Linux) + additional code,
- preliminary documentation,
- the pin diode example with all data and,
- all commands ’from grid coordinates to IV, I(t) curves’.
Final question

Who is missing his anorak? (hint: the bakery, Apr. 17)