Program for the computation of conductance and shot noise in a t-stub transistor in the presence of a magnetic field

This program computes the normalized conductance (with respect to the conductance quantum) and the shot noise power spectral density at low frequency (normalized with respect to the full shot noise power spectral density given by Schottky’s theorem\cite{schottky}) for a T-stub transistor\cite{t-stub} threaded by a magnetic field perpendicular to the plane of the device.

The computational approach that we have used is based on the recursive Green’s function technique, with the inclusion of the effect of magnetic field by means of a Peierls phase factor. The recursive Green’s function technique is described in detail in Refs.\cite{t-stub} and\cite{recursive_green_function}: it is based on partitioning the device into transverse slices, within each of which the potential can be considered longitudinally constant. We then evaluate the analytical Green’s functions for each slice, assuming Dirichlet boundary conditions at the boundaries on both ends. The Green’s function of a section obtained by joining two slices (and removing the Dirichlet boundary condition between them) is computed via the Dyson equation. The other slices are attached recursively, until the Green’s function of the whole structure has been computed, from which the transmission and reflection matrices are obtained.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{t-stub_diagram.png}
\caption{Diagram of a t-stub transistor with a magnetic field $\vec{B}$ applied.}
\end{figure}

The magnetic field is included considering a Landau gauge with the vector potential having a nonzero component only along the transverse direction ($\vec{A} = [0 \ Bx \ 0]^T$). With this choice of gauge\cite{landau_gauge} the transverse wave functions are unchanged with respect to the case without magnetic field, except for the addition of a Peierls phase factor $\exp[-i(q/\hbar)A_y(x)y]$, where $q$ is the electron charge and $\hbar$ is the reduced Planck constant. The longitudinal component of the Green’s function is not affected, therefore the only change in the recursive Green’s function method (with respect to the case with no magnetic field) is in the overlap matrices between the transverse modes of adjacent slices, which become complex.

It is essential, for the numerical error to be kept under control, that the magnetic flux threading each slice is smaller than a flux quantum. Therefore, depending on the intensity of the magnetic field and on the width of each section, the length of the section must be chosen in such a way as to satisfy this condition. This is taken care of automatically by the program, which determines the discretization step that guarantees that the above mentioned condition is satisfied in each slice.

The input quantity defined “discretization step” is the discretization step used for the calculation of the analytical Green’s functions of each section, it is not the length
of a slice, which is usually much greater and is expressed, within the code, as an
integer multiple of the discretization step.
The overall Green’s function is evaluated between two positions \((x_a \text{ and } x_b)\), outside
the active device area, where there is no magnetic field: this simplifies the evaluation
of the transmission matrix from the Green’s function, since the usual relationships
for \(B = 0\) can be used. The magnetic field is ramped linearly from 0 to the required
value \(B_0\) over a “dummy section” that extends from one of the initial slices to the
beginning of the active area of the device; then, past the active area, it is ramped
down, reaching a zero value near the last slice. The number of mesh points (“dummy
points”) over which this variation of the magnetic field is performed can be chosen
by the user: typically 40 points are sufficient.

The user can specify the relative dimensions of the stub, in units of the wire width;
the stub width is intended as the total width, including the wire.
The parameters defining the energy scan are the lower and upper bound (normalized
to the threshold for propagation in the wire) and the number of energy values for
which the calculation should be performed.
The number of points in the transverse direction is the one used for transverse dis-
cretization within the wire (in the stub they will be increased proportionally to the
stub width). In principle one could consider as many transverse eigenvalues as the
number of transverse discretization points, but usually a smaller number is sufficient,
corresponding to the propagating modes plus a number of evanescent modes. These
two numbers (discretization points and number of eigenvalues) should be determined
running a few tests and checking when further increasing them leads to no visible
change in the solution. Clearly the smaller these numbers, the faster the execution
of the code.

References