High Frequency Behavior of the Datta-Das and Resonant Spin Lifetime Transistors

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Monte Carlo simulations of spintronic devices is a well known technique [1]; but, usually, no attention is paid to the spin-dependent electron injection process, limiting the validity of the simulations to the time-independent regime. We have recently developed an injection model [2] that allows the simulation of AC devices, and which we have used to study the ultimate limiting factors on the maximum operating frequency (ω_c) of two types of spin field-effect transistors; namely the Datta-Das (DDST) [3] and the non-ballistic resonant spin lifetime transistor (RSLT) [4, 5].

We have found [6] that, for the DDST, ω_c is determined by the transit time of electrons through the channel, rather than by intrinsic parameters of the spin such as the Larmor frequency or the spin lifetime. Thus, ω_c of the DDST will be similar to that of the analogous high electron mobility structure (HEMT), possibly not providing any significant advantage in terms of operating speed.

Our studies of the RSLT show similar results, with ω_c again determined by the transit time through the channel. We also analyzed the influence on the spin lifetime of $\mathcal{O}(k^3)$ terms in the Rashba spin Hamiltonian [7]. These cubic terms, never considered before the present work, have been seen to dramatically affect both the current characteristics and the dynamic behavior of the device, and thus they must be considered for a complete description of the RSLT.

Our findings should call for a reevaluation of the high speed operation prospects for spin-based transistors.

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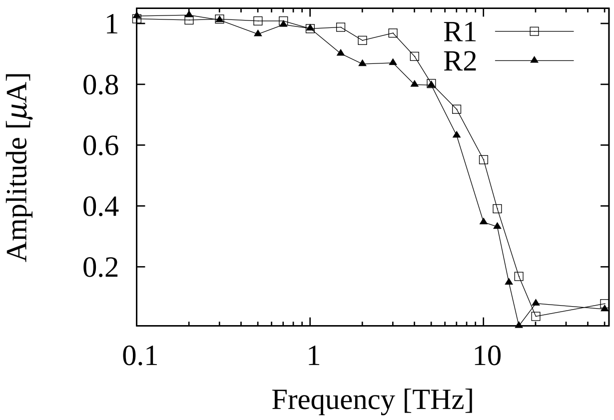

FIG. 1: Amplitude of the current for several Rashba modulating frequencies. R1 and R2 correspond to two different range of modulation of the Larmor frequency. A cutoff frequency of 7.2 THz (6.1 THz) is observed for the range R1 (R2).

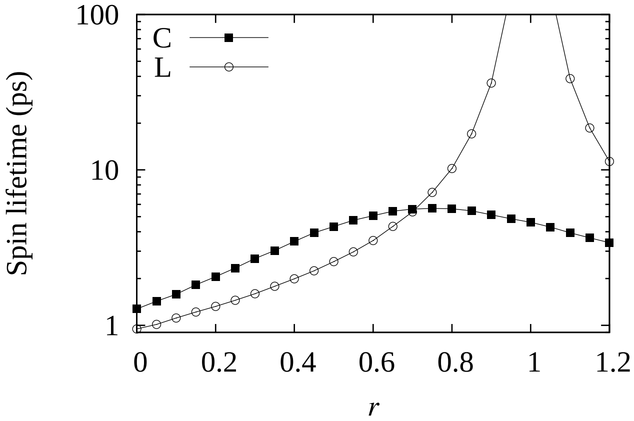

FIG. 2: Spin lifetime calculated using $\mathcal{O}(k^3)$ terms in the Rashba spin Hamiltonian (C) and with only $\mathcal{O}(k)$ terms (L).