Deriving spin-orbit parameters by single frequency analysis in diffusive transient spin dynamics

千葉大院工[1], 東北大院工[2], 徳島大院工[3] ○志田 博貴[1], 川口 晃平[1], 齋藤 康人[1],
高澤 一朗太[1], 深澤 俊樹[1], 飯笹 大介[2], 斎藤 隆仁[2], 北田 貴弘[3], 石谷 善博[1],
好田 誠[2], 森田 健[1]

Chiba Univ.[1], Tohoku Univ.[2], Tokushima Univ.[3] ○H. Shida[1], K. Kawaguchi[1], Y. Saito[1],
I. Takazawa[1], T. Fukasawa[1], D. Iizasa[2], T. Saito[2], T. Kitada[3], Y. Ishitani[1], M. Kohda[2], K. Morita[1]

E-mail: morita@chiba-u.jp

Spin-orbit (SO) magnetic fields arising from the spin-orbit interaction (SOI) effect on the mobile electron spins which has a wave vector in semiconductors. In III-V semiconductors two kinds of SO-fields are significant. One is the Rashba and the other is Dresselhaus SO-field. Spins also precess about diffusive motion induced SO-fields and Rashba (α) and Dresselhaus (β) SO parameters derivation are established [1-3]. When spins are locally excited at the spot size of σ_0, much smaller than the spin precession length, spins diffuse with the diffusing constant D_s and precess about SO-fields. The precession frequency $\Omega_{\mathrm{R(D)}}(r,t)$ induced by Rashba (Dresselhaus) field at a specific position r is given by

$$\Omega_{\mathrm{R(D)}}(r,t) = -\frac{2m\alpha(\beta)}{\hbar^2[t+\sigma_0^2/(2D_s)]}r, \tag{1}$$

which decreases with time t [2, 3]. This decrease is clearly observed in time regime of $t\sim\sigma_0^2/(2D_s)$ referred as transient regime. Kawaguchi *et al.* examined spin dynamics in this regime and established a method for deriving accurate SO parameters α and β by extracting the time-independent factor in $\Omega_{\mathrm{R(D)}}(r,t)$ [3]. In this method, commonly used single-frequency (SF) analysis with the fitting function $S_z(r,t) = S\exp(-t/\tau_s)\cos[\Omega(r)t]$ is not adopted since $\Omega_{\mathrm{R(D)}}(r,t)$ depends on t. Here, τ_s is spin relaxation time. However, SF analysis is still attractive for deriving α and β since it is easier to handle due to fewer fitting parameters.

In this study, SO parameter derivation using the SF analysis is performed in the diffusive spin dynamics in the transient regime. Spin dynamics is measured by scanning time-resolved Kerr rotation microscopy. $In_{0.53}Ga_{0.47}As/In_{0.53}Al_{0.47}As$ multiple quantum wells is used for the sample whose SO parameters were derived as $\alpha\ (\beta) = 2.39\ (0.80)$ meVÅ by the time-dependent analysis [3]. Monte-Carlo (MC) simulation is also performed to reproduce the measurements and evaluate α and β. One problem of comparing the measurements and MC simulations is that τ_s obtained by SF analysis is different in two $S_z(r,t)$ for experiments and MC simulations. Thus, we multiply the MC simulated $S_z(r,t)$ by the adequate exponential function and intentionally adjust MC simulated τ_s to the measured τ_s. In Fig. 1, red (blue) filled circles show $\Omega_{\mathrm{R+D(R-D)}}(r)$ from the experiments with SF analysis, where $\mathrm{R+D\ (R-D)}$ indicates the sum (difference) of Rashba and Dresselhaus SO-fields. The red (blue) solid line was $\Omega_{\mathrm{R+D(R-D)}}(r)$ obtained from the MC simulations with $\alpha+\beta\ (\alpha-\beta) = 3.19\ (1.59)$ meVÅ. This consists with $\alpha\ (\beta) = 2.39\ (0.80)$ meVÅ obtained by the time-dependent analysis [3]. We found that accurate SO parameters can be derived by the SF analysis of comparison between measurements and MC simulations with τ_s adjustment.

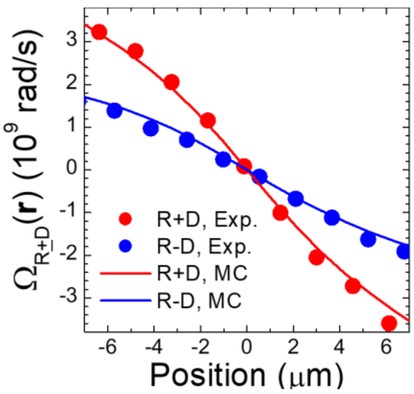

Fig. 1. $\Omega_{\mathrm{R\pm D}}(r)$ from the experiments and MC simulations.

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