Mechanism of Pure Circular Polarization Electroluminescence from a GaAs-based DH Spin-LED

° H. Munekata, R.C. Roca, K. Nishibayashi, and N. Nishizawa
Institute of Innovative Research, Tokyo Institute of Technology
E-mail: hiro@isl.titech.ac.jp

As disclosed recently in the manuscript [1], we have found very surprising experimental results of pure circular polarization electroluminescence (CP-EL) at *room temperature* with no external magnetic fields by sending a spin-polarized current of 100 A/cm^2 or higher in the n-AlGaAs/p-GaAs/p-AlGaAs semiconductor double heterostructure (DH) through a ferromagnetic-metal/oxide-tunnel-barrier contact consisting of Fe and crystalline γ-AlO$_x$ layers [2]. The results suggest the appearance of some spin-dependent non-linear processes that lead to recovering and even enhancing the injected, initial spin information. Considering that the CP-EL arises due to the annihilation of minority-helicity EL component, added with the fact that no apparent narrowing in EL spectra takes place in the region 100 A/cm^2 ≤ J ≤ 250 A/cm^2, we speculate that occurrence of spin-polarized lasing [3] is remote at the present J region. Instead, we infer the occurrence of spin-dependent re-absorption and/or amplified emission (stimulated emission without a resonant cavity) in the present J region. The former process involves the J-induced enhancement in the rate of absorption for minority-helicity photons (σ+), whereas the later involves the contribution of stimulated emission due to the majority-helicity electromagnetic field (σ−). In view of microscopic pictures, the former process is quantitatively possible when the valence band of the active layer is spin polarized ($-P_V$) oppositely to the conduction band ($+P_C$) (Fig. 1), whereas the later process becomes significant when the rate of radiative recombination between minority-spin electrons and light-holes (the σ′− transition in Fig. 2) is enhanced by the stimulated process. We infer that combination of these two processes results in the observed pure CP-EL. Results using spin-polarized rate equations will be discussed at the time of .presentation.

[1] N. Nishizawa, *et al.*, arXiv. 1606.06834 // Prog. Nat. Acad. Sci. USA (2017), in press.
[2] N. Nishizawa and H. Munekata, J. Appl. Phys. **114**, 033507 (2013).
[3] C. Gøthgen *et al.*, Appl Phys Lett **93**, 042513 (2008).

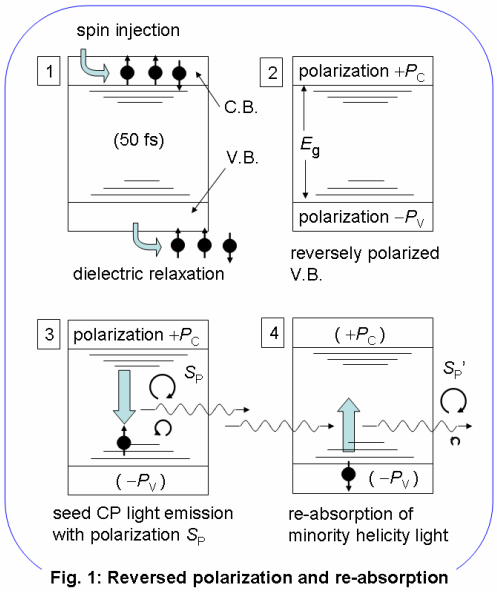

Fig. 1 (1) spin injection in the conduction band (C.B.) and subsequent spin extraction from the valence band (V.B.) due to the dielectric relaxation; (2) dynamic polarization of the C.B. and V.B.; (3) radiative relaxation of electrons; and (4) re-absorption of minority helicity light.

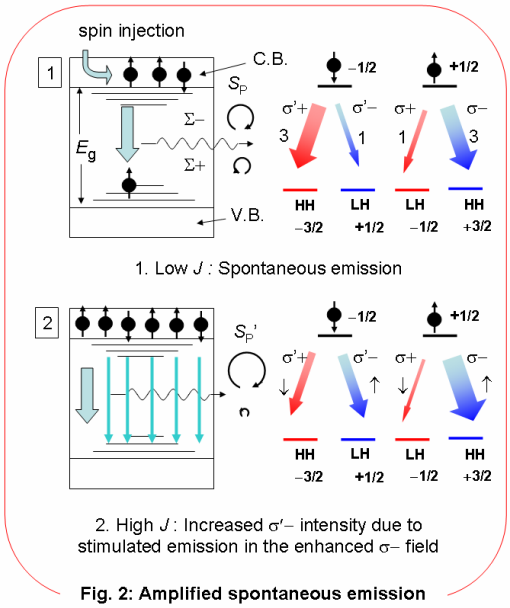

Fig.2 (1) spontaneous emission (a thick arrow) that is governed by the spin-dependent optical selection rule; and (2) stimulated emission (narrow arrows) that is induced when σ+ light propagates through the active layer. This enhances the −1/2 → LH +1/2 relaxation.