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Optically induced spin electromotive force in ferromagnetic-semiconductor quantum well structure

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Hybrid structures combining ferromagnetic (FM) and semiconductor constituents have great potential for future applications in the field of spintronics. The fundamental interest in such systems is associated with the presence of new spin-spin interactions, which exist upon bringing the FM and semiconductor into contact. In this case, the FM proximity effect arises, i.e., the spin polarization of the charge carriers in a semiconductor in the vicinity of a ferromagnet [1-3].

Here, we present a systematic approach for studying the magnetic proximity effect by combining the optical and electrical detection of the spin-dependent electron transfer with nanoscale spatial resolution. We study GaMnAs/GaAs/InGaAs heterostructure uponresonant optical excitation of the InGaAs quantum well (QW) located at a distance of only 5–10 nm from the FM GaMnAs layer. We determine the two conditions that should be fulfilled to unambiguously isolate the tunneling spin transfer in such hybrid structures. First is the choice of the FM where the magnetic circular dichroism is absent. The second is resonant excitation of the QW. In our case QW embedded into the structure near the interface sets the nanometer scale depth resolution of proximity magnetic effect, provided that the QW is excited resonantly [3].

Spin-dependent transfer is manifested in three spectacular effects: (i) PL circular polarization under unpolarized excitation, (ii) dependence of the PL intensity from the QW on the circular polarization degree of the excitation, and (iii) spin-dependent photo-voltage across the junction. We show that all the three parameters demonstrates similar non-linear magnetic field dependences with hysteresis loop saturating in ~100 mT. This indicates the interaction of charge carriers in the QW with the FM, i.e. the FM proximity effect.

[1] V. L. Korenev et al. Nature Commun. **3**, 959 (2012).
[2] V. L. Korenev et al. Nature Physics **12**, 85 (2016).
[3] V. L. Korenev et al. Nature Commun. **10**, 2899 (2019).