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Efficient Electron Spin Orientation and Nonlinear Spin Response in a Room-Temperature All-Semiconductor Spin Amplifier

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Semiconductor spintronics and opto-spintronics promise non-volatile information processing, storage and communication with a minimum inter-task lag time. However, the lack of non-magnetic semiconductors that allows efficient spin generation at room temperature has so far limited its application. Recently, spin filtering and amplification has been demonstrated in III-V dilute nitride GaN_xAs_{1-x} at room temperature, which managed to generate spin polarization up to 60% [1-2]. However, the inherent disorder induced by the nitrogen incorporation and the poor spin-to-photon helicity conversion of the material have put forward a fundamental obstacle for further improvement and limit its applications in quantum spin-photon interface, spin-LEDs, spin-lasers, etc. Here, we designed and implemented a remote defect spin-filtering mechanism in the nanostructure of GaNAs/QD which amplifies the InAs quantum-dot (QD) electrons spin polarization through the adjacent tunnelling-coupled GaN_xAs_{1-x} room-temperature spin amplifier (figure **a**). By such construction, we manage to achieve over 90% QD electron spin polarization at room temperature (figure **b**) [3]. Furthermore, we show that the spin response of the room-temperature spin amplifier has an inherent nonlinearity. In the GaNAs/QD nanostructure, we showcase the higher-order harmonic generation of spin signal by converting the low-frequency modulation of the excitation polarization to the higher-frequency oscillation of the QD emission intensity and polarization (figure **c**). The nonlinear spin response in such all-semiconductor nanostructure is expected to be faster than 1 GHz and can be explored for novel nonlinear spintronic applications which are often elusive for materials with weak magnetic interactions. These results establish convenient schema for integration of room-temperature spin amplification functionality as well as new application arenas for spintronic/opto-spintronics.

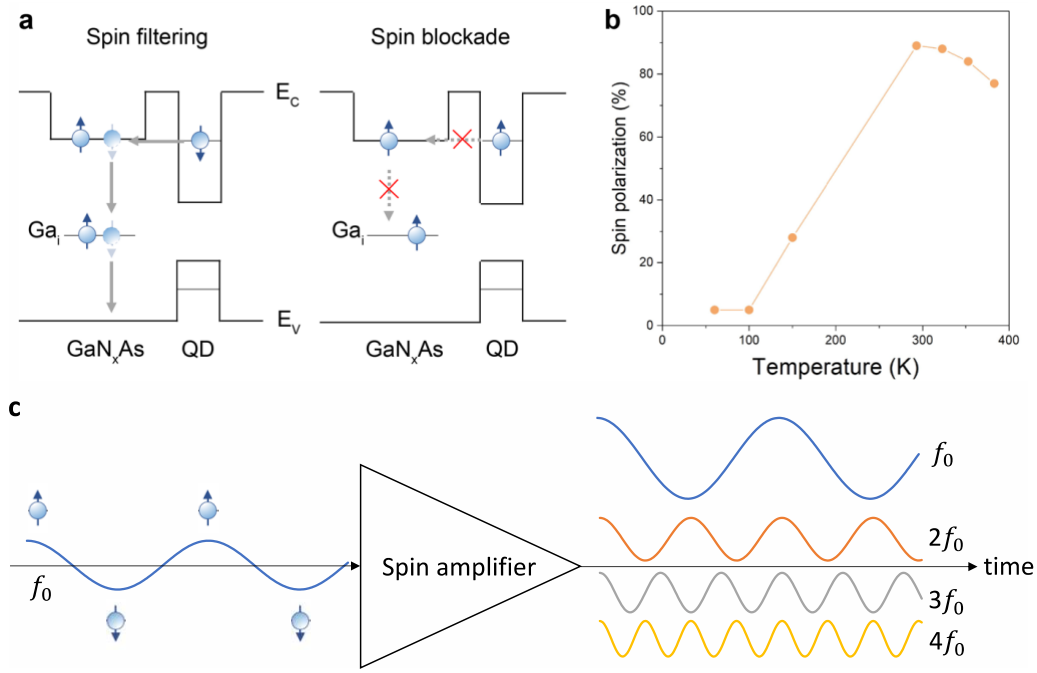

Figure **a,** schematic illustration of remotely filtering the minority spin in QD via the interstitial defect (Ga_i) in the adjacent GaNAs layer, while the majority spins are in the Pauli blockade condition. **b,** Temperature dependence of the steady-state spin polarization generated in the GaNAs/QD structure. **c**, Illustration of the harmonic generation from a modulation signal of spin with frequency of f_0 in the room-temperature spin amplifier.

Reference

[1] Wang, X. J. *et al. Nat. Mater.* **8**, 198–202 (2009).
[2] Chen, S. *et al. Nat. Commun.* **9**, 3575 (2018).
[3] Huang, Y. *et al. Nat. Photonics* **15**, 475–482 (2021).