Giant Excitonic Faraday Rotation in 2D Semiconductors

B. Carey[1,2], N. K. Wessling[1,3], P. Steeger[1], R. Schmidt[1], S. Michaelis de Vasconcellos[1], R. Bratschitsch[1], and A. Arora[1,4,*]

[1]Institute of Physics and Center for Nanotechnology, University of Münster, Wilhelm-Klemm-Strasse 10, 48149 Münster, Germany

[2]School of Mathematics and Physics, The University of Queensland, St Lucia, Queensland 4067, Australia

[3]Institute of Photonics, Department of Physics, University of Strathclyde, 99 George Street, G1 1RD Glasgow, UK

[4]Department of Physics, Indian Institute of Science Education and Research, Dr. Homi Bhabha Road, 411008 Pune, India

Faraday rotation is a fundamental effect in the magneto-optical response of solids, liquids and gases. Materials with a large Verdet constant find applications in optical modulators, sensors and non-reciprocal devices.

We measure Faraday rotation spectra around the neutral and charged exciton lines in hBN-encapsulated monolayers of WSe_2 and $MoSe_2$, and bilayers of MoS_2 under moderate magnetic fields ($B < 1.4$ T) [1] (see Fig. 1). For WSe_2 and $MoSe_2$ monolayers, the plane of polarization rotates by several degrees around exciton lines, resulting in a giant Verdet constant of $-1.9 \times 10^7 \mathrm{deg\ T^{-1} cm^{-1}}$ and $-2.3 \times 10^7 \mathrm{deg\ T^{-1} cm^{-1}}$, respectively. This is the largest measured Verdet constant in the visible/near-infrared regime. The giant Faraday rotation is due to the large oscillator strength and high g-factor of the excitons in monolayers. In comparison to monolayers, the Verdet constant reverses its sign for interlayer excitons in bilayer MoS_2 ($V_{\mathrm{IL}} \sim +2 \times 10^5 \mathrm{degT^{-1} cm^{-2}}$). We deduce the complete in-plane complex dielectric tensors of these materials, which is vital for the prediction of Kerr, Faraday and magneto-circular dichroism spectra of 2D heterostructures. For our measurements, we used a charge-coupled device-based Faraday rotation spectroscopy method for performing temperature-resolved spectroscopy on 2D materials on the microscale [2]. This method is about two-to-three orders of magnitude faster than state-of-the-art modulation magneto-spectroscopy methods, while providing a similar performance.

Finally, our results pose a crucial advance in the potential usage of two-dimensional materials in ultrathin optical polarization devices.

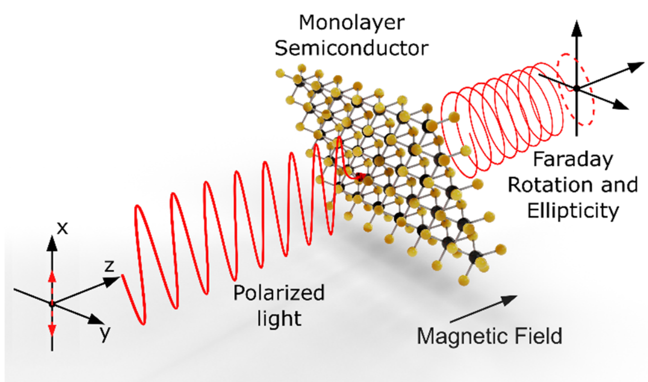

Figure 1: Schematic drawing depicting how linearly polarized light passes through an atomically thin semiconductor under a magnetic field and acquires Faraday rotation and ellipticity.

Acknowledgements

The authors acknowledge the financial support from the German Research Foundation (DFG project nos. AR 1128/1-1 and AR 1128/1-2), the Alexander von Humboldt foundation, and NM-ICPS of the DST, Government of India through the I-HUB Quantum Technology Foundation (Pune, India), Project No. CRG/2022/007008 of SERB (Government of India), and MoE-STARS project No. MoE-STARS/STARS-2/2023-0912 (Government of India). Fruitful discussions with Thorsten Deilmann and Mukul Kabir are gratefully acknowledged.

References

[1] B. Carey, N. K. Wessling, P. Steeger, R. Schmidt, S. Michaelis de Vasconcellos, R. Bratschitsch, and A. Arora, *Nat. Commun.* **15**, 3082 (2024).

[2] B. Carey, N. K. Wessling, P. Steeger, C. Klusmann, R. Schneider, M. Fix, R. Schmidt, M. Albrecht, S. Michaelis de Vasconcellos, R. Bratschitsch, and A. Arora, *Small Methods* **6**, 2200885 (2022).

*Email: ashish.arora@iiserpune.ac.in