Universität Münster

Aktuelle Fragen
der Nanophysik

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R87, Wilhelm-Klemm-Str. 10

Faraday and Kerr effects on 2D excitons and trions: layered semiconductors vs quantum wells

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Magneto-optical spectroscopy on 2D materials is traditionally performed by magneto-photoluminescence and magneto-reflectance spectroscopy methods. These techniques provide vital information on various aspects of 2D semiconductors and magnets such as spin-valley-layer-resolved band structure, circularly-polarized excitons and trions, magneto-valley polarization, valley coherence, and single-photon emission [1]. However, one normally needs large magnetic fields such as $B > 5\,\mathrm{T}$ for a reasonable signal-to-noise ratio. For measurements under low magnetic fields ($B < 1\,\mathrm{T}$), differential magneto-optical spectroscopy such as Faraday and Kerr effect spectroscopy is highly desirable.

In this talk, I will discuss our recent developments on establishing some of these techniques (Faraday rotation [2,3] and spectroscopic ellipsometry). We overcome the bottleneck of long measurement times in these methods, and enhance the speed of data acquisition by two-to-three orders of magnitude using our innovations [3]. I will describe our first results of Zeeman spectroscopy of intra- and interlayer excitons, and trions in 2D materials such as MoS_2, $MoSe_2$, WS_2 and WSe_2 using Faraday rotation spectroscopy [3]. For the first time, we are able to extract the complete dielectric tensor of these 2D materials [2]. Furthermore, I will discuss our recent discovery of the excited state of a bound 3 particle complex (a trion) in a GaAs quantum well using Kerr spectroscopy under moderately large magnetic fields up to $6\,\mathrm{T}$ [4]. Here we solve a four-decades old problem on the existence of excited trions in a quantum well.

Our works open new paradigms to explore new spin-valley physics in 2D semiconductors and magnets using sensitive magneto-optical spectroscopy.

[1] Check reviews at: a) A. Arora, J. Appl. Phys. **129**, 120902 (2021) and b) Glazov et al., MRS Bulletin **49**, 899 (2024)
[2] Carey et al., Nature Communications **15 (1)**, 3082 (2024)
[3] Carey et al, Small Methods **101 (6)**, 2200885 (2022)
[4] Jain et al., submitted (2025)