

Magnons and plasmons in Vanadium-based dichalcogenides

W. Rudziński,¹ M. Jafari,¹ J. Barnaś,¹ and A. Dyrdał¹

¹*Faculty of Physics and Astronomy, ISQI,*

Adam Mickiewicz University in Poznań,

ul. Uniwersytetu Poznańskiego 2, 61-614 Poznań, Poland

Magnon-plasmon interaction in 2D magnetic crystals is of current interest due to specific plasmon modes that enable magnon-plasmon hybridization. More precisely, plasmon energy vanishes in the center of the Brillouin zone (zero wave-vector, $k=0$). We have analyzed the spectra of plasmons, spin waves (magnons), and coupled magnon-plasmon hybridized modes [1] in monolayers and bilayers of the Vanadium-based transition-metal dichalcogenides (TMDs), VX_2 ($X=S, Se, Te$) [2]. The Vanadium atoms within individual atomic layers are coupled ferromagnetically, while the exchange coupling between V atoms located in different planes is either ferromagnetic or antiferromagnetic, depending on the stacking type of individual layers. Both, symmetric exchange and Dzyaloshinskii-Moriya (DM) interactions are taken into account. For all numerical calculations, the intra- and interlayer exchange parameters, the magneto-crystalline anisotropy constants, and most of DM parameters have been evaluated using first-principles methods based on the density functional theory (DFT) [3].

The spin-wave dispersion relations have been derived analytically within the spin-wave theory (SWT), in terms of the Holstein-Primakoff transformation combined with the Bogolubov diagonalization scheme. To obtain analytical solutions, we assumed a collinear magnetic ground state, which is achieved when the magnetic anisotropy and DMI parameters obey certain conditions. The spin-wave spectra have also been simulated using the atomistic spin dynamics (ASD) package. We have found that the results obtained within the ASD method in the linear-response regime and for a collinear ground state coincide very well with those derived from the SWT. In turn, for the nonlinear regime and/or noncollinear ground state, the ASD is more reliable as it includes the effects omitted in the linear SWT.

In antiferromagnetic TMD bilayers, the system undergoes a field-induced transition to the spin-flop phase [4], which evolves into a saturated ferromagnetic phase for sufficiently strong magnetic fields. The existence of different phases depends on material parameters, particularly on the interlayer exchange parameters and anisotropy constants.

References:

- [1] W. Rudziński, M. Jafari, J. Barnaś, and A. Dyrdał, *Phys.Rev. B* 113, (2026) 035437
- [2] H.-R. Fuh, Ch.-R. Chang, Y.-K. Wang, R. F. L. Evans, R. W. Chantrell and H.-T. Jeng, *Sci. Rep.* 6, (2016) 32625
- [3] M. Jafari, W. Rudziński, J. Barnaś, and A. Dyrdał, *Sci. Rep.* 13, (2023) 20947
- [4] W. Rudziński, J. Barnaś, and A. Dyrdał, *Phys. Rev. B* 109, (2024) 035412