Orbitons and orbital correlations in vanadates studied by RIXS and optics

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The $3d^2$ vanadates RVO_3 (R = Y or rare earth) display a variety of orbitally and/or magnetically ordered states, and orbital exchange interactions as well as orbital fluctuations are expected to be strong. We have studied the orbital excitations via RIXS and infrared absorption, and investigated the orbital correlations via ellipsometry.

Using high-resolution RIXS we aim at the first unambiguous observation of a novel kind of elementary excitations in a solid, namely orbitons, propagating orbital excitations. We have observed orbital excitations in YVO_3 and $GdVO_3$ at the V L edge and the O K edge. Due to the excellent resolution of 60 meV, we have been able to resolve two different features at low energies, which we interpret as one-orbiton and two-orbiton excitations. For both features, the results are in good agreement with infrared absorption data. In RIXS, the one-orbiton peak displays a clear momentum dependence. We discuss whether this reflects a matrix-element effect or the sought-after dispersion. The two-orbiton excitation is attributed to the exchange of orbitals between adjacent sites. These results establish that superexchange is relevant for a quantitative understanding of the orbital excitations in RVO_3.

Using ellipsometry, we study the excitations from the lower to the upper Hubbard band. We obtain a consistent description of the multi-peak structure in terms of the different d^3 multiplets, solving the discrepancy between different data sets reported in the literature. The optical spectral weight of the different absorption peaks shows a strong temperature dependence, which reflects nearest-neighbor spin-spin and orbital-orbital correlations. A comparison of our data with theoretical predictions based on either 'classical' orbital order or strong orbital fluctuations shows that the latter can be ruled out.