Exciton States in a New Monolayer Semiconductor

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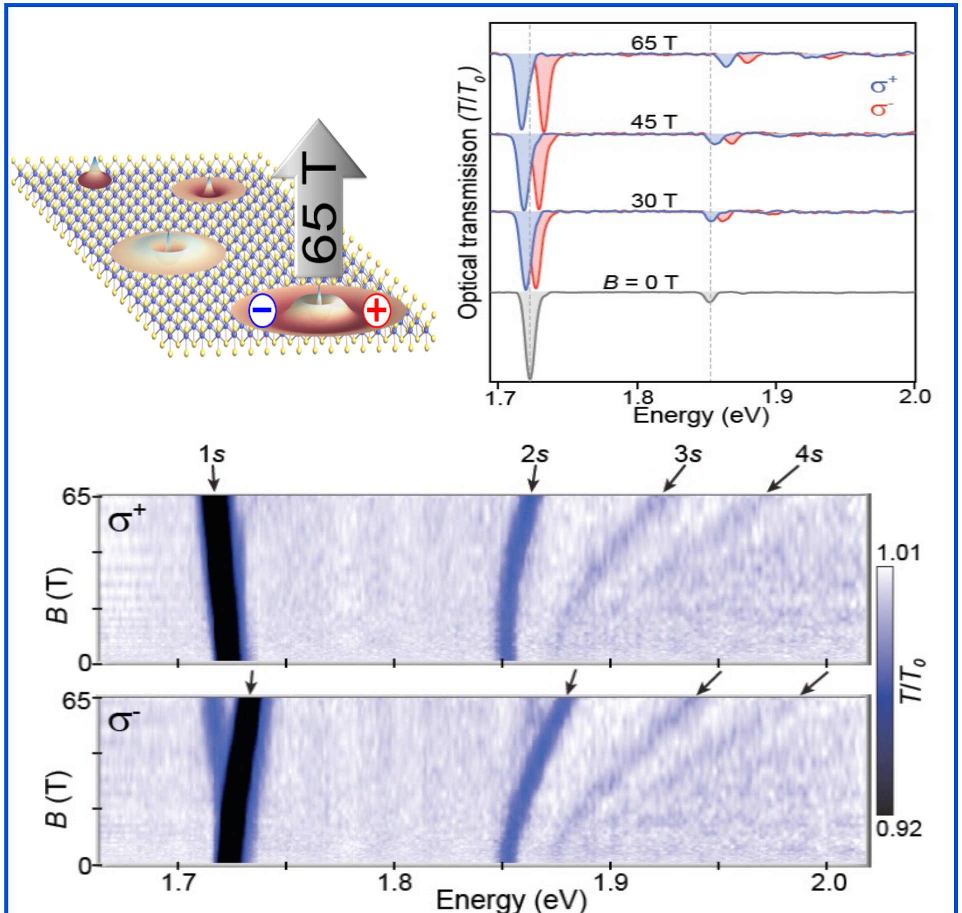
The monolayer transition-metal dichalcogenides, such as WSe_2 or MoS_2, are members of a new class of *atomically-thin direct-gap semiconductors* exhibiting very strong coupling to light, making them interesting materials for future ultrathin and efficient optoelectronics. However, in order to rationally design such devices, fundamental material properties such as the mass of electrons, holes, and excitons must be determined.

Historically, fundamental semiconductor properties such as exciton mass, spin, size, and dimensionality have been revealed via laser spectroscopy as a function of magnetic field. In the new monolayer semiconductors, *extremely* high fields (>50T) are needed to compete with the very large Coulomb interactions of these materials. Researchers encapsulate very clean monolayers of WSe_2 in hBN (hexagonal boron-nitride) a position the sample over the core of single-mode optical fibers. They then measure the polarized transmission spectra in pulsed magnetic fields to 65T. The energy and magnetic field dependence of the resonances revealed for the first time the size and binding energy of the first four Rydberg states of the neutral exciton (*1s*, *2s*, *3s*, *4s*).

Crucially, the nearly-linear shift of the *3s* and *4s* Rydberg states at high field directly reveals the exciton's reduced mass (m_r=0.20m_e), a fundamental material parameter that will help guide not only theoretical models but also the rational design and engineering of future optoelectronic devices based on this new class of two-dimensional semiconductors.



Circularly-polarized optical spectra from 0-65T of monolayers of WSe_2. The magnetic field dependences of the *1s*, *2s*, *3s*, and *4s* Rydberg states of the neutral exciton reveal fundamental excitonic parameters of importance to future optoelectronic applications of this new ultra-thin semiconductor.

Facilities and instrumentation used: NHMFL Pulsed Field Facility, Los Alamos National Laboratory; 65 Tesla capacitor-driven magnet.

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