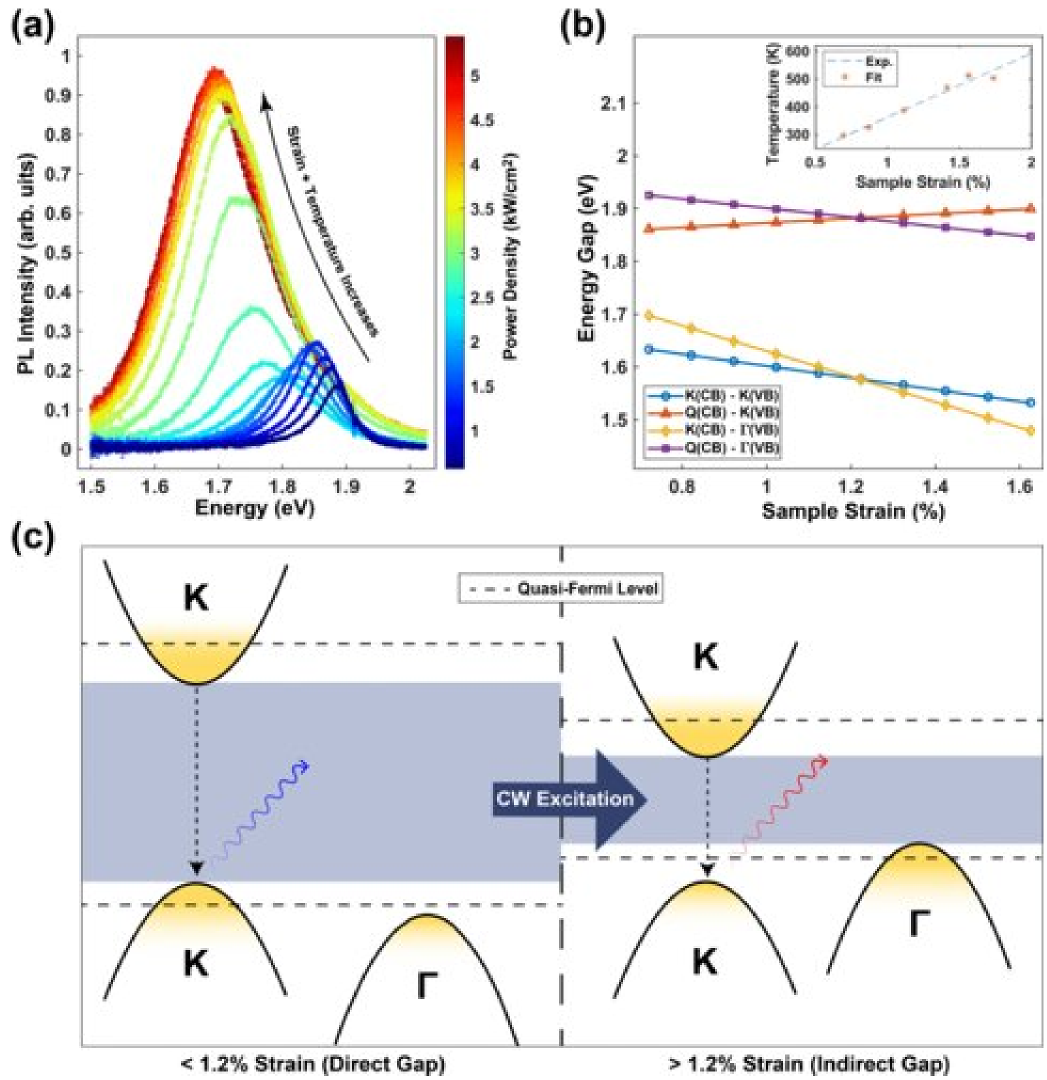
PHYS.ORG

The search for electron-hole liquids gets warmer

February 18 2021, by Ryan Wilmington



(a) Photoluminescence (PL) measurements showing excitonic to electron-hole liquid (EHL) transition and peak intensity increase. (b) Calculated bandgap shifts due to sample strain (referenced to K-VB). Inset shows fit of strain vs temperature based on Raman spectroscopy measurements [10]. (c) Schematic of band structure evolution during lattice expansion. Dashed lines indicate quasi-Fermi levels for electrons-holes. Shaded area shows the bandgap before and after phase transition. Credit: *Physical Review B* (2021). DOI: 10.1103/PhysRevB.103.075416

An electron-hole liquid is a unique collective quantum state formation in semiconductors where free charges can condense into a droplet. These droplets have interesting uses for laser-controlled circuits based on light beams instead of wires. Unfortunately, electron-hole liquids normally only exist in extremely cold environments, and aren't practical for real devices. But what if these droplets could instead form as the material heats up?

Our study predicted that these droplets may be able to condense at temperatures 1,000 degrees (F) hotter than previously thought. We made the prediction by combining several computational models and previous experimental results to be used as ingredients for a new meta-analysis of the electron-hole liquid transition in a 1-atom thin flake of Molybdenum disulfide (MoS_2).

We showed that our first principles analysis matched the physical data we took via spectroscopy, and we were able to measure important properties of the material, such as a huge 23-fold light emission intensity increase, number of carriers in each valley, intraband lifetimes, and other parameters that will give us more insight into the behavior of this material on the atomic level.

This new computational work suggests that the unique shape of 1-atom thin semiconductor flakes makes them excellent habitats for electron-hole liquids, even above room temperature. Mixing the results of multiple computer models and experiments allowed us to verify that light emission from these flakes was indeed a signal of droplet formation.

The fact that this first-principles analysis successfully predicts the measurements we previously observed is a big victory both for the validity of these electron-hole liquid observations and for the use of fundamental physics models to analyze spectra and extract meaningful information about the system.

We still cannot fully explain the light emission coming from these droplets, but one thing is clear: atomically thin materials play by their own set of rules.

More information: R. L. Wilmington et al. Fermi liquid theory sheds light on hot electron-hole liquid in 1L−MoS2, *Physical Review B* (2021).
DOI: 10.1103/PhysRevB.103.075416

Provided by North Carolina State University