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RESEARCH HIGHLIGHT

Valley light-emitting transistor

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In crystalline solids, it is often the case that the Fermi surface consists of multiple pockets at well-separated degenerate band extrema (that is, valleys) in momentum space. The valley index constitutes a discrete degree of freedom of carrier, just like spin. Exploiting valley in addition to spin will make future electronics more versatile. Two-dimensional (2D) transition metal dichalcogenides, a new class of direct-gap semiconductors,[1,2] have provided an appealing laboratory to explore valley-electronics, because of the discovery of a valley optical selection rule that allows optical control and detection of valley polarization.[3] Iwasa from University of Tokyo, and Riken and his team have now demonstrated in 2D WSe_2 the first electric control of valley-dependent optical emission.[4]

Their device is a forward-biased p–i–n junction (Figure 1a), where electrons and holes flow to the intrinsic region to recombine and emit photons. This electroluminescence is found to have a circular polarization, which changes sign when the p–i–n junction is flipped.[4] By the valley optical selection rule (Figure 1b), the observation implies that the light emission from the two valleys is unbalanced and determined by the electric control, realizing a prototype valley light-emitting transistor.

The valence band edge in 2D WSe_2 has strong trigonal warping that makes the dispersion asymmetric and valley-dependent: in valley K left-moving holes can have larger velocity than right-moving ones, while valley –K has the opposite situation. A large electric field can cause a valley-dependent separation of the electron and hole pockets and hence different light emission rates from the two valleys even in the absence of carrier valley polarization (Figure 1c).[4] The luminescence polarization therefore may be locally induced by the electric field from the built-in potential in the intrinsic region. Alternatively, a valley transport effect can lead to the same observation. Also due to the valley-dependent dispersion, the current driven by the forward bias can have different magnitude in the two valleys,[5] so that carriers injected into the intrinsic region are valley polarized, leading to circularly polarized luminescence. The unique signature of this valley transport effect is a spatial pattern of the polarization, depending on the orientation of the junction with respect to crystalline axis.[5] Spatial-resolved and polarization-resolved luminescence detection will potentially identify the dominating mechanism in the device.

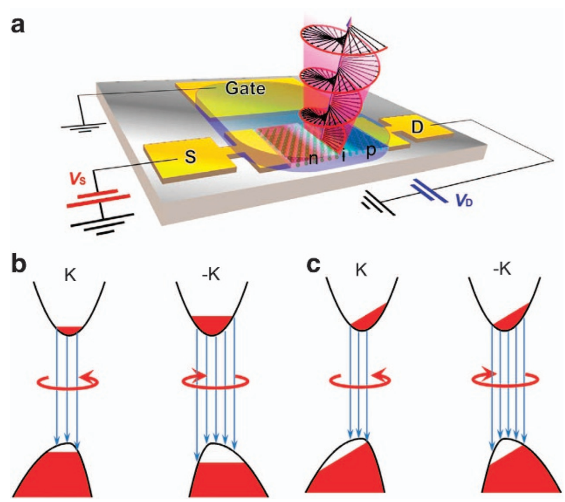

Figure 1 (**a**) Circularly polarized electroluminescence from a p–i–n junction electrostatically formed in two-dimensional WSe_2 (provided by Iwasa and coworkers[4]). (**b**) The momentum-conserving interband transitions in valley K (−K) couple to right- (left-) handed circularly polarized light only. Valley polarization of carriers can lead to circularly polarized luminescence. (**c**) In the absence of valley polarization, circularly polarized luminescence is possible in a large electric field, where the overlap between the electron and hole pockets becomes different in the two valleys due to the valley-dependent dispersions.

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