Control of Fermi level and valley population in PbSnSe quantum wells by light and magnetic field

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The utilization of the valley degree of freedom in semiconductors is expected to open new avenues for information processing. In this approach, i.e. valleytronics, a valley population is described by a pseudospin that can be used to store and manipulate information. Multivalley semiconductors provide a natural platform for the realization of this concept, and various experimental knobs have been explored to control the valley pseudospin. PbSnSe/PbEuSe quantum wells grown along (111) direction are one of such system. Here, two distinct types of valleys at the Γ and M points of the hexagonal 2D Brillouin zone emerge due to epitaxial strain induced by the PbEuSe barriers. Thus, strain has proven to be an effective control parameter for the valley pseudospin [1,2]. In this presentation, I will discuss two other approaches for controlling the valley population within this framework in (111) PbSnSe/PbEuSe quantum wells. The first approach is based on SU(3) quantum Hall ferromagnetism [3]. Our recent measurements show that, in a tilted high magnetic field, the filling factor of a two-dimensional hole gas occupying three equivalent M valleys can reach a value of two. This observation is consistent with the predicted breaking of rotational symmetry and the resulting valley polarization induced by a strong magnetic field. In the second approach, we control the valley occupation using visible and near-infrared light via the persistent photoconductivity effect [4]. The resulting shift of the Fermi level leads to a transition from a two-dimensional hole gas occupying threefold-degenerate M valleys to a two-dimensional electron gas confined to a single Γ valley. Spectral studies reveal that the persistent photoconductivity effect is reversible.

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[2] A. Kazakov, et al., PRB **111**, 245419 (2025)
[3] G. Krizman, et al., arXiv:2510.13874
[4] A. Kazakov, et al., arXiv:2605.19025