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2D materials for infrared photonics

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In this talk, I will present our latest achievements related to the optical properties of topologically trivial 2D semiconductor molybdenum ditelluride (MoTe2) – a promising candidate for the near-infrared photon source belonging to the family of transition metal dichalcogenides (TMDs), and the atomically-thin topological insulator bismuthine – perspective for optically addressed quantum spin Hall systems. [1-3]

In the first part of my talk, I will address the MoTe2. The MoTe2, crystallized in the hexagonal form, is a semiconductor with an optical bandgap in the near-infrared spectral range. The expected excitonic emission is around 1060 nm at cryogenic temperature, translated to nearly 1240 nm at room temperature. Therefore, this is the only known TMD material with potential for application in near-infrared optoelectronic devices. One of the fundamental questions related to MoTe2 is its optical gap tunability. We address this question using the Coulomb engineering approach, a method where the Coulomb interaction between electrons and holes can be tailored through the interaction potential screening. First, we tested this approach by placing the mono- and bilayer MoTe2 crystal into various physical environments, providing the tunability of dielectric screening.[1] Second, we build the metal-oxide-semiconductor device, allowing electrostatic doping of the monolayer MoTe2 in a broad carrier density range with control over the charge sign.[2]

In the second part of my talk, I will share our findings on the near-infrared optical response of the quantum spin Hall topological insulator bismuthine at room temperature.[3] Our research has shown that the photo-modulated reflectivity experiment can effectively address the excitonic state in the isolation gap of the bismuthine. This finding potentially paves the way for setting up the light-matter interface for optical initialization of the topological states in this material system, opening up a world of possibilities for future research and applications related to optically controlled topological matter..

[1] J. Kutrowska-Girzycka, et al., Applied Physics Reviews 9, 041410 (2022)
[2] E. Zięba-Ostój et al., in preparation (2024);
[3] M.Syperek et al., Nature Communications 13, 6313 (2022).