Institute of High Pressure Physics
Polish Academy of Sciences
Warsaw

PhD positions in theoretical tailoring of perovskite and quantum-well lasers

Two PhD positions are available from October 2019 in the Institute of High Pressure Physics Polish Academy of Sciences (www.unipress.waw.pl) in Warsaw. PhD students will learn in the Warsaw PhD School in Natural and BioMedical Sciences (www.warsaw4phd.eu), formed by nine institutes which create interdisciplinary environment. The projects will be supervised by Prof. Małgorzata Wierzbowska, in a collaboration with the specialists on synthesis, crystal growth, material characterization and developers of the Yambo code (www.yambo-code.org).

1. Excitonic design of lead halide perovskites for lasers

Perovskites ABX_3 (A=methylammonium,formamidinium,Cs,Rb and B=Pb,Sn and X=Cl,Br,I), their low-dimensional structures, such as 2D, nanowires, quantum dots, and the heterostructures with organic layers (inorganic also to be checked) continuously attract interest of researchers as photovoltaic and optoelectronic materials (LEDs and lasers). Since 2014, the optically pumped perovskite lasers, both short-pulse and continuous-wave type, were reported. However, a construction of the electrically pumped laser still remains a challenge, being one of our tasks. The excitonic binding energies in these materials range 25-400 meV, and probably this is not a record. Due to a high light-refractive index (of 2.2-2.5) at the perovskite-air interface, natural nanostructure cavities do not require mirrors. Moreover, an integrated system with the perovskite optically-active layer and topological edge-state mirrors could be achieved, with application to polariton lasers.

2. Excitonic mechanisms in III-V and II-VI semiconductor quantum wells

Semiconductor single and multiple quantum wells are used for the electrically pumped lasers/masers and strong LEDs. First topological insulator laser and polariton laser were built using III-V materials. These devices cover the energetic range from infrared to deep ultraviolet, and the shortest wavelengths are offered by II-VI rock-salt semiconductors. A quest for stable long-term and high-power devices operating at high temperatures does not stop, especially for continuous-wave lasers. Both direct-gap as well as indirect-gap systems become efficient emitters, setting new questions about microscopic mechanisms. Even more advanced problems concern Bose-Einstein condensates and charged excitons (trions). Optimization of the QW parameters on the *ab-initio* and many-body levels will support experimentalists not only with new data, but most importantly with a clarification of underlaying physical effects.

Methods to be used in the projects: *ab-initio* many-body techniques, which are beyond the density-functional theory (DFT), such as the GW approach and Bethe-Salpeter equation. They enable to obtain realistic optical spectra, oscillator strength, exciton binding energy and radius etc.

IHP PAS (Unipress) is a leading center for the research and growth of the GaN wafers and optoelectronic devices, which are put on the market by Ammono and TopGaN, but not only. The high pressure basic and applied research extends to superconductivity, topological insulators, terahertz generators, food conservation, bank of human milk, ceramics and glasses. Our activity is not limited to the above fields but covers many branches of material science.

Warsaw is a dynamic capital city of Poland (1.8 million residents), in a heart of Europe, well connected with other cities in Poland, Europe and beyond, as well as with Baltic Sea and Polish mountains. Modern and historical city (UNESCO world's heritage) offers many sport and cultural centers, social environment, and bars serving fantastic traditional Polish food.

Desired skills (criteria). M.S. degree in one of the fields: physics, chemistry, computer science or similar is obligatory. Strong motivation to conduct a research in physics and computation material science is essential. Knowledge of at least one: density functional theory, quantum chemistry methods, tight-binding approach is needed for a start. Being familiar with python and latex is beneficial. Ability to work with the linux environment and writing/reading in English is necessary.

All documents required by Warsaw-4-PhD School should be sent via http://www.warsaw4phd.eu
and to Prof. Małgorzata Wierzbowska (IHP PAS Warsaw, malwi45@gmail.com).