Magnon-Plasmon Polaritons: New Solid-State Quasiparticles

Our modern everyday life relies on the use of computers, electronics, and wireless communications. These technologies became indispensable very fast and it appears that our lives will be even more intertwined with their use. However, there are two fundamental issues in this development. Firstly, **information technologies rely on a constant, exponential growth of computing possibilities of electronic devices.** For example, future artificial intelligence would require a lot more computing and storage capacity than is available now. The development of silicon-based technologies allowed to fulfill this need for growth but the current level of miniaturization of electronic technologies will finally approach their physical limits and then growth in computer possibilities will slow down. Secondly, traditional **silicon-based electronics rely on electron currents causing huge energy losses**.

Moving from transistors based on silicon to much faster devices based on antiferromagnetic materials might solve both issues at the same time. Spintronic devices can be more energy efficient because they rely on spin current, which does not cause Joule heating like a flow of electrical currents in traditional electronic devices. Devices based on antiferromagnets have smaller physical limits for their size than traditional transistors. Moreover, intensively researched in recent years, two-dimensional antiferromagnetic materials have spin dynamics faster than electrons in silicon by orders of magnitude. Thus, some of these materials might constitute a basis for a sustainable and efficient future of computers and wireless communications.

However, before we can start thinking about real-life spintronic devices based on two-dimensional antiferromagnets, a lot of **basic research must be conducted to better understand this group of materials and develop methods of using them**. The particular challenge is in reading and writing the state of an antiferromagnetic material because magnetic materials weakly interact with electromagnetic waves at terahertz frequencies. This band of frequencies is of interest because it is roughly a few hundred times faster than the gigahertz frequencies used in current electronics. **In this research proposal, we propose to use electromagnetic resonators to enhance the interaction of antiferromagnetic matter with electromagnetic radiation**. When this coupling is strong, so-called polariton modes are formed, which are hybrid modes of light and matter. Research on this phenomenon in other bands of frequencies and different matter excitations (for example exciton-polaritons in quantum dots) have led to polariton lasers, quantum information transducers, etc. Similar developments in the range of THz frequencies are only in their beginning because research there is much less advanced.

The main goal of this project is to couple excitations of two-dimensional spin lattice (magnons) with excitations of two-dimensional electron gas (plasmons). Such a coupling was not yet achieved as two-dimensional antiferromagnetic materials have only recently been actively investigated. **These recent developments in the research on magnetism offer an unprecedented possibility to couple plasmons and magnons**. An outcome could allow for electrical control and detection of magnetic states, which could serve for future spintronics devices. We consider different configurations in which such a magnon-plasmon coupling can be achieved. One of them relies on using optical resonators as mediators of this interaction, which will be possible based on the developments in the research mentioned in the previous section.