(1) Electric-field control of magnetic spin waves
Collective spin wave excitations in ferromagnetic materials provide a promising platform for wave-like computing in nanoscale devices at GHz frequencies. Low-power excitation and manipulation of spin waves are key requirements for this future technology. As a summer student, you will explore electric-field control of spin waves in hybrid samples combining ferromagnetic and ferroelectric materials. The proof-of-principle experiments are based on the notion that magnetic properties (and thus spin waves) are electrically tunable via efficient coupling to a ferroelectric layer. Experiments include the growth of ferromagnetic films onto single-crystal ferroelectric substrates using magnetron sputtering, magneto-optical Kerr microscopy of magnetic domains, and detailed analysis of spin-wave transmission through a ferromagnetic film using broadband spectroscopy. Micromagnetic simulations in GPU-based MuMax software and electromagnetic simulations in CST studio will also be performed.

(2) Skyrmion bubbles in magnetic thin films and nanostructures
Recently, magnetic bubbles with non-trivial topological properties, called skyrmions, have been observed in nanometer-thick magnetic multilayers. Interfacial interactions between a magnetic material and heavy metals, such as Pt, favor a continuously rotating magnetization as found in these bubbles and so act to stabilize them. They are both a complex and interesting state of matter and a possible route to new data storage devices. The project will focus on controlling the interactions at the magnetic interfaces in order to create materials suitable for applications. As a summer student you will learn how to make the required thin films by magnetron sputtering, how to pattern devices in the cleanroom and how to make magnetic and electrical transport measurements. You will also model the devices through micromagnetic techniques to allow interpretation of the experimental data.

(3) Brain-inspired computing using oxide tunnel junctions
“Brain inspired computing” is an emerging field that aims to build neuromorphic computers that are highly efficient in terms of energy and space, scalable to large networks of neurons and synapses, and flexible enough to run complex behavioral models. Recently, researchers have suggested that ferroelectric tunnel junctions (FTJs), displaying voltage-controlled quasi-continuous resistance variations of two orders of magnitude and fast 10-ns operation, could serve as the basic hardware element of neuromorphic computational architectures. As a summer student, you will study the potential of FTJs for brain-inspired computing. The FTJs will be fabricated by pulsed laser deposition and advanced photo- and e-beam lithography. Electronic transport measurements will be conducted to mimic brain-like operations. Various models for tunneling transport will be used to fit the data.

(4) In-situ transmission electron microscopy of functional oxide materials
In the last decade, advances in transmission electron microscopy (TEM), such as aberration correction (Cs) and the development of in-situ sample holders for heating, cooling, and the application of electric fields, have enabled active material manipulation and characterization at the atomic scale. As a summer student, you will learn how to prepare cross-sectional specimen from oxide materials and use various TEM measurement techniques on a state-of-the-art instrument in the Nanomicroscopy Center. You will focus on high-resolution in-situ TEM analysis of ionic migration processes. These processes are known to dramatically affect the magnetic, ferroelectric, and electronic properties of complex oxides and, if understood, could lead to the emergence of a new class of “ionotronic” devices. The TEM experiments will be complemented by electro-thermal simulations in COMSOL Multiphysics.

More information about the research activities of the NanoSpin Group can be found on our website:

http://physics.aalto.fi/en/groups/nanospin/