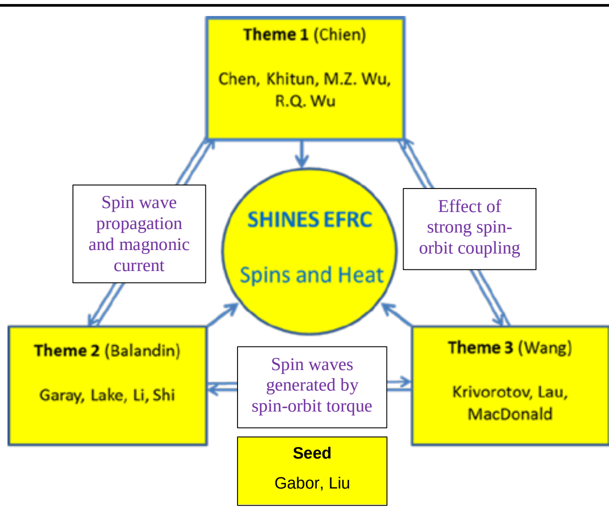
Spins and Heat in Nanoscale Electronic Systems (SHINES)
EFRC Director: Jing Shi
Lead Institution: University of California, Riverside
Start Date: August 2014

Mission Statement: *To explore the interplay of spin, charge, and heat and to control the transport of spin and energy for achieving significantly higher energy efficiencies in nanoscale electronic devices.*

The four-year objectives for the SHINES center include (1) better understanding of and significant improvement in pure spin current effects in nanoscale electronic devices, including magnonic switching, spin-torque oscillations, spin-orbit torques, and spin Seebeck effect through novel materials and heterostructures; (2) engineering of acoustic phonon and magnon transport in nano-structured materials via controlling their dispersions and interactions; and (3) exploration of spin-orbit coupling for low energy effects and spin superconducting condensate for dissipationless spin and energy transport.

The SHINES center is organized in the following three interactive themes:

Theme 1 (T1): Pure spin currents in metals and insulators
This theme involves five members: Chien, Chen, Khitun, M.Z. Wu and R.Q. Wu and 5 cross-team members: Lake (T2), Li (T2), Shi (T2), Wang (T3), and Krivorotov (T3). The theme is led by Chien. The main focus is on more efficient generation and detection of pure spin currents in metals and insulators and more efficient spin current-driven magnetization dynamics in both magnetic metal and insulator devices. The specific tasks include: high-precision determination of the spin Hall angle and spin diffusion length in strong spin-orbit coupling metals, especially ferromagnetic metals; search for large spin Hall angle and long spin diffusion length for high-efficiency energy conversion from heat; improved understanding of the spin Hall



T1: Pure Spin Currents in Metals and Insulators

T2: Phonon/Magnon Transport and Phonon/Magnon Engineering in Nanostructured Materials

T3: SOC Heterostructures and Highly Correlated Spin Materials

angle and anomalous Hall effect in ferromagnetic metals and alloys; demonstration of spin torque oscillators (STO) in magnetic insulator devices based on the spin Seebeck effect; investigation of the Gilbert damping mechanism in doped and undoped magnetic insulator films; demonstration of magnonic switching in magnetic insulator-based thin film devices with point contact geometry; experimental investigation and micromagnetic simulations of magnonic switching dynamics; and measurements of propagating spin wave dynamics in magnetic insulator films and two-dimensional magnonic crystals.

Theme 2 (T2): Phonon/magnon transport and phonon/magnon engineering in nanostructured materials

This theme involves 5 members: Balandin, Garay, Lake, Li, and Shi, and 4 cross-theme members: M.Z. Wu (T1), Khitun (T1), Wang (T3), and MacDonald (T3). The theme is led by Balandin. The main focus of this theme is on the control of phonon/magnon properties to manipulate heat transport in nanostructured materials. The specific tasks include: demonstration of the acoustic phonon engineering effects on phonon dispersion and thermal transport (e.g. thermal conductivity) in nanostructured materials through material and structural property optimizations; demonstration of acoustic phonon spectrum modifications in spatially confined hetero- and nano-structures; fabrication and demonstration of two-dimensional magnonic crystals with band gaps via material and structural tuning; spectroscopic measurements of propagating chiral spin wave edge modes; determination of phonon/magnon temperature distributions in doped and undoped magnetic insulator films subjected to temperature gradient via Brillouin light scattering; investigation of physical mechanism of the spin Seebeck effect in magnetic insulators; demonstration of magnon/phonon Hall effect (i.e. anomalous Righi-Leduc effect) in magnetic insulator crystals; and experimental and theoretical investigations of the physical origin of the effect.

Theme 3 (T3): Spin-orbit coupling heterostructures and highly correlated spin materials

This theme involves 4 members: Wang, Krivorotov, Lau, and MacDonald, and 3 cross-theme members: Chien (T1), Lake (T2), and Balandin (T2). The theme is led by Wang. The specific tasks include: demonstration and investigation of efficient spin-orbit torques in topological insulator/magnetic insulator heterostructures; theoretical and simulation studies of the effects of the spin-orbit torque on magnetization switching; demonstration and optimization of frequency-doubling high-efficiency spin torque oscillator nanodevices; better understanding of magnetization dynamics with micromagnetic simulations; measurements of spin-orbit coupling effects on electrical transport properties (e.g. weak localization and anti-localization) in transition metal dichalcogenide (TMD) nano-devices; measurements of temperature dependence of electron-phonon coupling in suspended TMD devices; theory and demonstration of spin superconductivity associated with the magnetic condensate in magnetic insulator nano-devices; and investigation of the stability and physical properties of the magnetic condensate.

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