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RPPR Final Report
as of 25-Jul-2018

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Report Term: 0-Other

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Major Goals: The broadband ultrafast femtosecond laser system sponsored by this award will be incorporated into our existing magneto-optical microscopy system with a pump-probe configuration to support our ongoing research projects on magneto-optical investigation on ultrafast spin dynamics in diverse topological magnetic materials, magnetic nano-structures, and spintronic nanodevices. Our research projects particularly aim to provide fundamental knowledge on ultrafast dynamical behaviors of magnetization and new interfacial topological phases toward realizing innovative spintronic nanodevices and THz applications. Along the direction of this study, our group proposed several progressive research objectives as listed below:

- Develop a magneto-optical microscope that operates in either the Faraday or the Kerr mode with a pump-probe configuration based on a state-of-the-art femtosecond laser. This system will be able to provide: (i) Temporal resolution of < 40fs; (ii) Tunability of the pump and probe laser wavelengths in the range of 450?10,000 nm; (iii) Sub-micrometer spatial resolution; and (iv) Temperature control in the ~4K to 400K range.
- Experimentally and theoretically study the deterministic ultrafast laser-induced magnetization reversal with emphasis on the sub-picosecond interaction of the magnetic order with the electric and magnetic plasmons during the magnetization reversal process.
- Design and construct ferrimagnetic/plasmonic nanostructures with enhanced the performance and energy requirements of optically-controlled ultrafast spintronic devices.
- Induce the magnetic order into the TIs through proximity effect or interfacial exchange coupling by engineering the interface of TIs with other high Curie/Néel temperature magnetic materials (with trivial topology).
- Understand and manipulate the fundamental relativistic SOC, SOT, and related physics in TI by engineering the interfacial exchange interactions and proximity effects in new types of TI-based magnetic heterostructures, i.e. TI/X heterostructures, where X = magnetic TI, ferromagnetic insulator, ferrimagnetic insulator, and antiferromagnetic
- Utilize time-resolved magneto-optical measurements to study the THz dynamics of AFMs induced by the giant SOT of adjunct TIs or exchange coupling to TIs.

Accomplishments: - Finalized the detailed specification and design of the equipment with vendors, the finalized broadband tunable femtosecond laser system has the following capabilities: (i) Temporal resolution of < 40fs enabling temporal resolution for terahertz processes; (ii) Tunability of the pump and probe laser wavelengths in the range of 290?2,600 nm; (iii) Peak pulse energy of 7mJ; (iv) Sub-micrometer spatial resolution; (v) Temperature control in the ~4K to 400K range; and (vi) Synchronization to an external source. This system is currently being assembled and optimized for signal-to-noise ratio and will be fully operational shortly.
- Observed a helicity-dependent signal in a prototypical antiferromagnetic heterostructure Pt/NiO which suggests THz excitations of antiferromagnets and demonstrated that our pump-probe setup has the ability to investigate

antiferromagnetism and related phenomena.
- Explored SOT-assisted approaches to manipulate antiferromagnetic spin damping /precession frequencies and SOT in Pt/IrMn heterostructure.
- Successfully fabricated Co/Pt ferromagnetic stacks with embedded plasmonic nano-disk lattice and demonstrated the good perpendicular magnetization in this nano-structure as well as the helicity dependence of plasmon-enhanced ultrafast magnetization dynamics
- Experimentally studied spin dynamics of TI/CrSb using pump-probe techniques. A ferromagnetic order induced in TI is clearly detected at 85K, whereas the spin dynamics of TI/CrSb appears to be dominated by this FM order and thermal effects and has large damping.
- Experimentally quantified the efficiency of spin-orbit torque in magnetically-doped TI heterostructure using magneto-optical means, and results exhibited good consistency with theoretical prediction and previously-reported values using other approaches

Training Opportunities: Nothing to Report

Results Dissemination: Nothing to Report

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: Nothing to Report

PARTICIPANTS:

Participant Type: PD/PI
Participant: Kang Lung Wang
Person Months Worked: 1.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
National Academy Member: N
Other Collaborators:

Participant Type: Graduate Student (research assistant)
Participant: Quanjun Pan
Person Months Worked: 3.00 **Funding Support:**
Project Contribution:
International Collaboration:
International Travel:
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Other Collaborators:

RPPR Final Report
as of 25-Jul-2018

Major Goals are determined by agreement between the researcher and the sponsor. (limit to 8000 characters or less)

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A description of what was accomplished under the goals during the reporting period

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