Topotronic multi-dimensional spin Hall nano-oscillator networks

Rendicontazione

Informazioni relative al progetto

TOPSPIN

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Periodic Reporting for period 3 - TOPSPIN (Topotronic multi-dimensional spin Hall nano-oscillator networks)

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Sintesi del contesto e degli obiettivi generali del progetto

TOPSPIN's overall aim is to i) fabricate, ii) optimize, iii) functionalize, iv) utilize, and v) explore very large-scale one-, two-, and three-dimensional spin Hall nano-oscillator (SHNO) networks. These nano-oscillators operate at microwave frequencies and can be utilized both for wireless communication and novel types of computing.

The project is divided into three work packages with separate goals as outlined below:

WP1 – Multidimensional arrays, ultra-low currents, and efficient (non-volatile) tuning.

Fabricate.

• Push the capability and quality of e-beam nano-lithography fabrication of SHNOs to demonstrate breakthroughs in multidimensional mutual synchronization: SHNO chains, very large two-dimensional (2D) SHNO arrays, and eventually 3D SHNO arrays.
• Develop nano-lithography processes to fabricate mutually synchronized magnetic tunnel junction based SHNO arrays to combine the best possible SHNO signal coherence with the highest microwave output power.

Optimize.

• Demonstrate SHNOs operating at orders of magnitude lower power consumption through the use of ultra-high spin Hall angle materials.
• Demonstrate low-power SHNOs operating at an order of magnitude higher microwave frequency.
• Demonstrate ultra-high Γp values, using perpendicular and mixed anisotropy bilayers, to increase SHNO synchronization speeds by orders of magnitude.

Functionalize.

• Demonstrate ultra-fast SHNO frequency tuning and tuning of the SHNO interconnection strengths and phases through the use of voltage-controlled magnetic anisotropy.
• Demonstrate non-volatile SHNO and interconnection tuning using ion oxide materials and phase change materials.

WP2 – Microwave signal generators, pattern matching, and neuromorphic computing.

Utilize.

• Deliver the first viable 10 – 300 GHz spintronic microwave signal generators.
• Demonstrate ultra-fast and ultra-efficient pattern matching using SHNO chains.
• Demonstrate highly scalable neuromorphic computing using synchronized SHNO chains and arrays.

WP3 – Novel characterization techniques for unrivaled time-, phase-, and spatial resolution.

Explore.

• Time- and phase-resolved Brillouin Light Scattering microscopy of mutually synchronized large-scale SHNO chains and arrays.
• Laser tuning and excitation of individual SHNOs in large arrays while observing both the non-local and global network response.

• Scanning transmission x-ray microscopy of SHNOs for extreme spatial resolution.
• Ultra-fast Lorentz microscopy of SHNOs for extreme time- and spatial resolution.

Lavoro eseguito dall’inizio del progetto fino alla fine del periodo coperto dalla relazione e principali risultati finora ottenuti

The project has been very successful, resulting in 13 publications, many in so-called high-impact journals. All three work packages have seen excellent progress.

We have demonstrated two-dimensional networks of mutually synchronized spin Hall nano-oscillators, which has allowed us to fully synchronize as many as 64 oscillators, which is about an order of magnitude more than any literature reports.

We have managed to combine memristor functionality with spin Hall nano-oscillator functionality in the same device and shown how we can program and store individual nano-oscillator properties in a chain of such oscillators. We have shown how this can be used for ultrafast pattern recognition.

We have demonstrated how two-dimensional arrays of spin Hall nano-oscillators can operate as oscillator-based Ising Machines.

We have developed a novel type of spin wave and phonon microscope where we combine femtosecond laser pulses with high repetition rates with so-called Brillouin light scattering microscopy. This new tool allows us to excite and study optically generated spin waves and phonons with unprecedented spectral and spatial detail.

Progressi oltre lo stato dell’arte e potenziale impatto previsto (incluso l’impatto socioeconomico e le implicazioni sociali più ampie del progetto fino ad ora)

We are the first to demonstrate two-dimensional networks of mutually synchronized spin Hall nano-oscillators, which has allowed us to fully synchronize as many as 64 oscillators, which is about an order of magnitude more than any literature reports. We are also the first to combine memristor functionality with spin Hall nano-oscillator functionality. Finally, we are the first to show that two-dimensional arrays of spin Hall nano-oscillators can operate as oscillator-based Ising Machines.

We have demonstrated a novel type of spin wave and phonon microscope combining femtosecond laser generated spin waves and phonons with detection using Brillouin light scattering microscopy.

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