Report for physical reservoir

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Introduction

Cu_2OSeO_3 is a chiral magnet with rich magnetic phases like skyrmion, conical, and helical, due to the Dzyaloshinskii–Moriya interaction. It exhibits gigahertz spin dynamics that vary with magnetic field and temperature. Each phase has distinct properties:

- Skyrmion phase: Strong memory capacity.
- Helical phase: Low nonlinearity, suitable for signal transmission.

These dynamics map input signals into a high-dimensional space, with phase tunability allowing task-specific adaptability in physical reservoir computing.

Setup (Input/Output)

- **Input:** Magnetic field values generated from field-cycling schemes tailored to specific tasks, such as chaotic Mackey–Glass signals for forecasting or sine waves for signal transformation.
- **Processing:** The spin-wave spectra of Cu_2OSeO_3 are recorded and analyzed as the reservoir's output matrix.
- **Output:** The computed results are obtained using ridge regression to transform the input signals or predict future behaviors.

Application Scenario

The material Cu_2OSeO_3 can be utilized in various neuromorphic computing tasks, such as:

- Forecasting chaotic time series, like Mackey–Glass signals.
- Performing signal transformations, for instance, converting sine waves to square waves.

Another potential application is in the field of digital graphics process, where the material can be used as special filters to process images or videos. Especially, the material can be used to generate special effects in movies or games. It can also be used in the field of artificial intelligence to process data and make predictions.

Advantages Over Software Solutions

- **Energy Efficiency:** Avoids the von Neumann bottleneck by integrating processing and memory within the physical system.
- **Task Adaptability:** Utilizes phase-tunable magnetic modes (e.g., skyrmion, conical phases) for diverse tasks without the need for fabricating new systems.
- **Performance:** Achieves high performance with reduced computational complexity, demonstrated by lower mean squared error (MSE) compared to software-only models.
- **Scalability:** Demonstrates feasibility across different magnetic systems, including room-temperature materials like $Co_8.5Zn_8.5Mn_3$.