Predicting the Future with Magnons: Forecasting Chaotic Time Series Data with reservoir computing

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The Mackey-Glass time series data describes how the density of mature circulating cells change over time using time delayed differential equations [1]. This is a standard problem to test the performance of physical reservoirs. Here, we used different magnon-scattering reservoirs (MSR) to carry out such a chaotic time series prediction task [2]. The memory and nonlinearity of magnons make our MSR a perfect candidate for such tasks.
The original data at discrete time steps was converted to frequencies in a range suitable to address magnons in NiFe microstructures. The magnon response is measured using time-resolved Brillouin light scattering spectroscopy (BLS). For the analysis, a time-integrated spectrum is extracted for each time step of the Mackey-Glass series. Then a simple linear regression $\mathrm{Y(t + t') = w(Y) + c}$ was used to complete the prediction of t' steps into the future. The general architecture is as shown in Fig. 1. We tested the system's performance by predicting up to 200 future time steps instead of only a few specific values commonly done in literature. The prediction using our MSR is highly accurate and even follows small changes in the actual data.
The task was carried out using five MSR with different geometries. Results from different MSR can be combined to increase the reservoir depth. In general, deeper reservoirs lead to more accurate prediction.
Based on recent work on the electrical detection of spin waves[3], the system can be fully integrated with an all-electrical readout. Such an implementation would enable a compact and scalable architecture, making it readily compatible with CMOS technology.

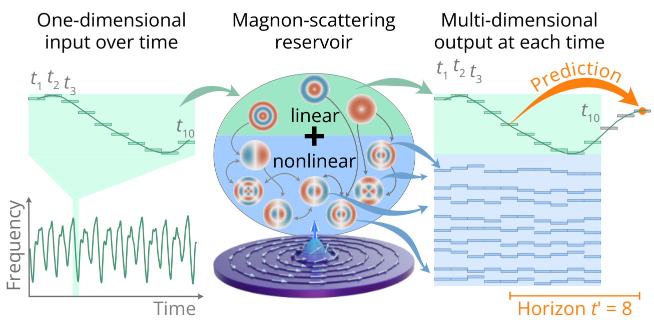

Figure 1. The 1D temporal input is encoded in a microwave current and applied to a NiFe microdisk in the vortex state (magnon-scattering reservoir). Nonlinear interactions between various magnon modes transform the 1D input into a multi-dimensional spectral output trained to forecast the future trajectory of the chaotic signal.

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