Photonic Information Processing at 20GS/s rates based on a Laser System with Delayed Feedback

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The demands of society on information processing rise every day. Novel information processing schemes based on machine learning approaches like reservoir computing (RC) [1] have attracted strong interest in the last years. Making use of complex dynamics, RC is capable of state-of-the-art performance at tasks traditional computers struggle with. Photonic implementations of RC are of great interest due to their high speed and easy implementation. A reservoir computer, conceptually as simple as a semiconductor laser with delayed optical feedback already proved excellent (tasks?) at 5GSamples/s rates thanks to its nonlinear responses in the GHz regime [2]. The study of the properties of the system and their impact on the RC performance is crucial to better understand the underlying physics, improve designs and tailor systems for specific tasks.

In this work we experimentally explore the potential of semiconductor lasers with optical feedback and optical injection for ultra-fast information processing. We study the fundamental properties and key parameter dependencies of this complex system, and connect them to the information processing performance. Identifying the best conditions we demonstrate excellent performance for information injection at modulation rates up to 20GS/s.

Our photonic RC setup is based on a discrete mode quantum well semiconductor laser. The laser is subject to delayed optical feedback, implementing the reservoir. The optical fiber delay loop includes components to control the conditions of the feedback light. The injection of information is realized using a single mode DFB laser emitting continuous wave and modulating its output with an amplitude modulator. We study information processing performance and properties of the photonic reservoir computer at different modulation rates up to 20GS/s. We evaluate fundamental optical and dynamical properties of the system, in particular injection locking, consistency of the responses of the system to modulated optical injection (Fig. 1a), and memory of the reservoir computer (Fig. 1b). We identify regions with different properties, and how tuning one parameter can allow access to different set of properties. Information processing performance is evaluated with a nonlinear time series prediction task (Fig. 1c), training the reservoir computer to perform three time steps prediction on a chaotic Mackey-Glass time series. Best prediction errors are obtained when memory and consistency show suitable properties. We can maintain non-degrading performance up to the highest modulation rates.

In conclusion, we show information processing with excellent performance up to modulation rates of 20GS/s. These results pave the way for novel hardware-implemented computing schemes based on complex systems properties.

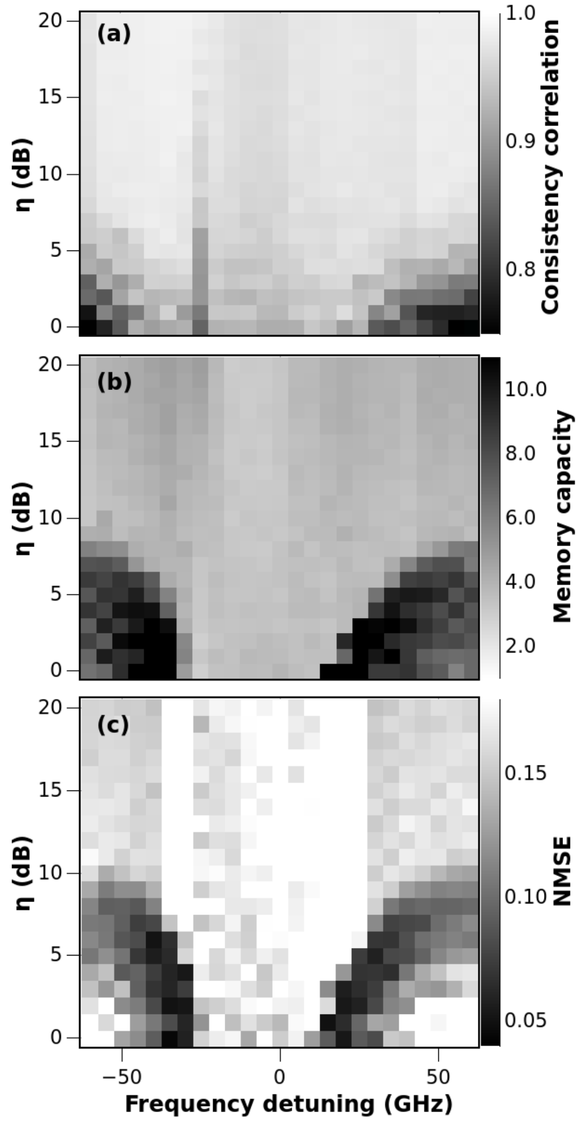

Figure 1: Results of (a) consistency, (b) memory, and (c) nonlinear time series prediction error dependence on frequency detuning and η (feedback attenuation) for a modulation injection at 10GS/s. All panels share the horizontal axis.

[1] H. Jaeger and H. Haas, Science **304**, 7880 (2004).

[2] D. Brunner, M. C. Soriano, C. R. Mirasso, and I. Fischer, "Nat. Comm. **4**, 1364 (2013).