Reservoir computing to recover optical communication signals

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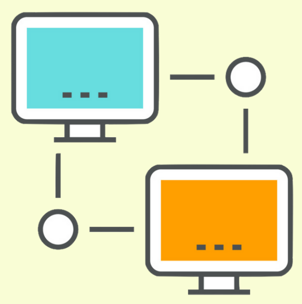
Optical communications

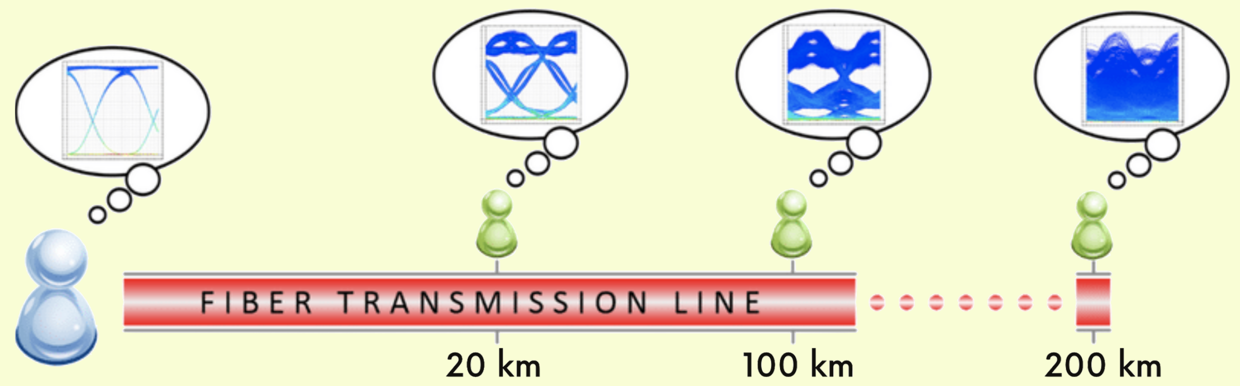


Fibre-optic communication is used by telecommunications companies to transmit telephone signals, Internet communication, and cable television signals. The contemporary fibre-optic communication networks operate even beyond the Tb/s scale in long-distances.

But... transmission impairments (chromatic dispersion, Kerr effect or four-wave mixing) limit communication speed and distance.

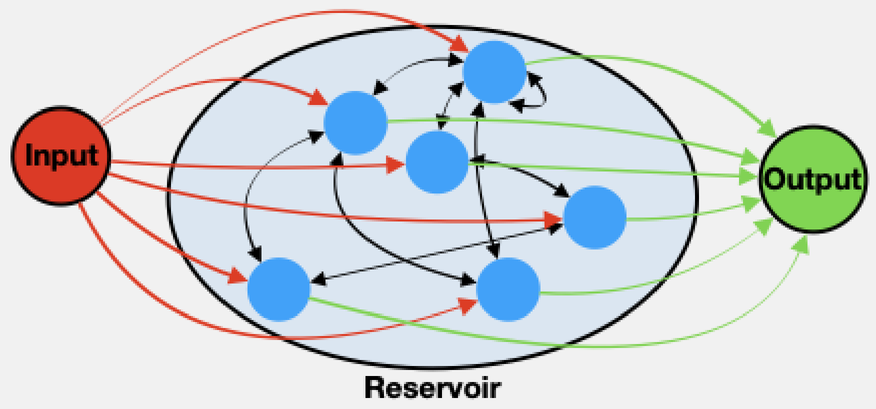
After 200 km transmission, the nonlinear distortion results in patterns from which is not easy to identify the initially encoded bits.

Is this a problem for reservoir computing?



Reservoir computing

Reservoir computing (RC) is a neuro-inspired concept that has proven to be a powerful platform to simplify the hardware implementation of recurrent neural networks for processing time dependent information.



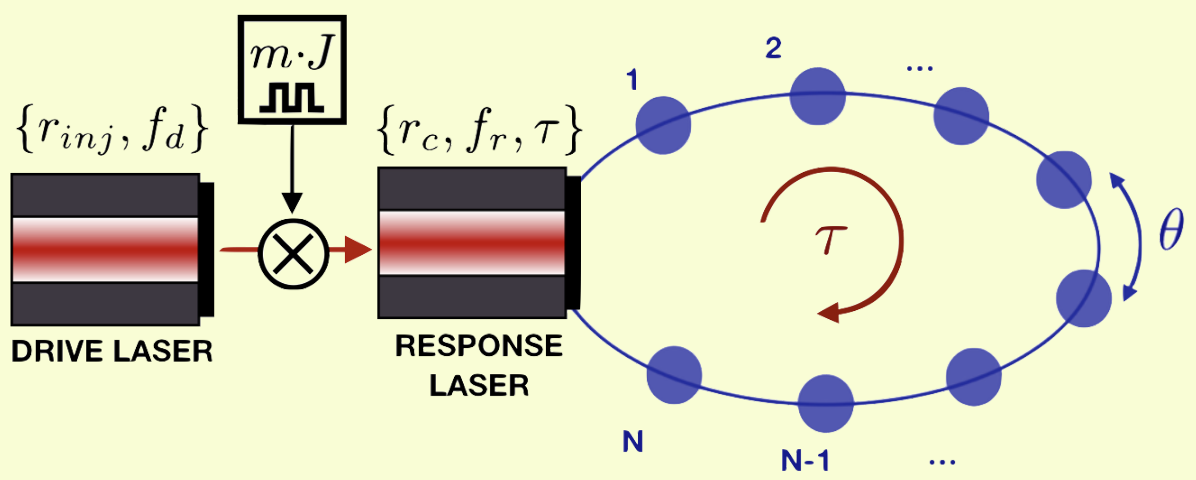
2 Conditions need to be fullfilled:

- ✓ Nonlinear transformation of the input
- ✓ Fading memory
- ⊕ All connections are fixed but the reservoir-output ones that are constructed using a linear classifier.

Can we recover optical communications signals with this technique?

Photonic RC for signal recovery in optical communications

An all-optical hardware implementation of RC would allow us to go to faster optical computing schemes.

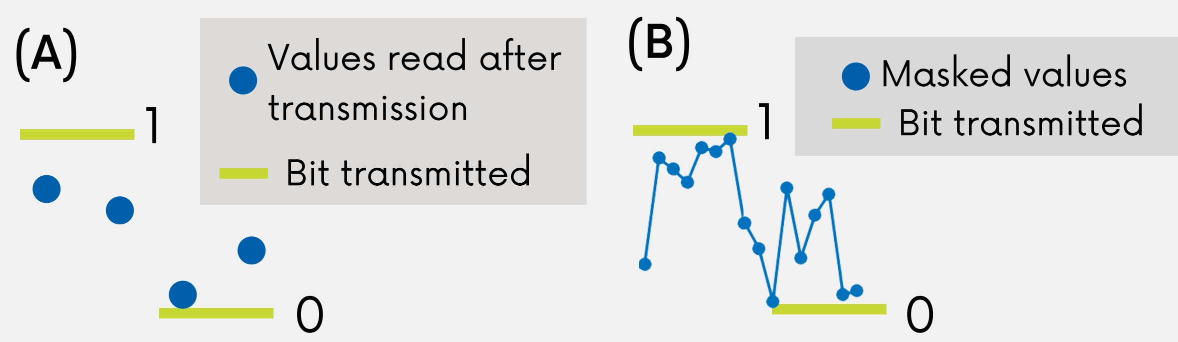


- ✓ Nonlinear transformation performed by a semiconductor laser acting as a response laser
- ✓ Fading memory introduced by the delayed feedback (implemented with a simple single-mode fibre)
- ⊕ The output layer is constructed offline from the response read at the oscilloscope

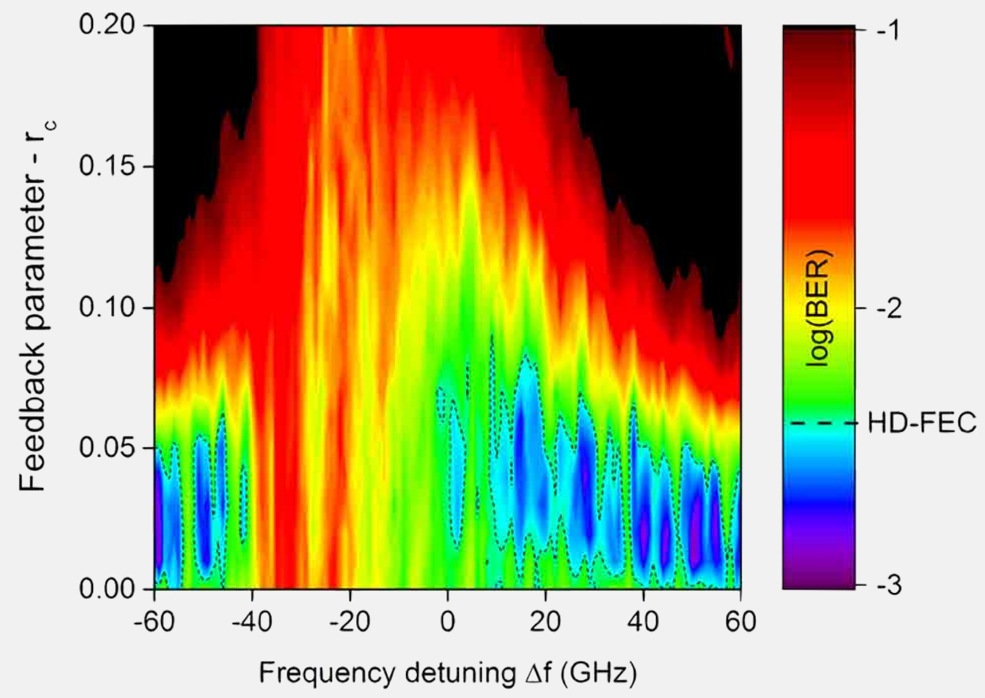
Performing signal recovery of optical communication signals:

The recipe

1. Consider the bitstream you want to process (A)
2. Mask it to obtain your virtual nodes (B)
3. Inject the information into the system by modulating the drive laser
4. Let the information go under the nonlinear transformation
5. Read the output of the photonic RC
6. Calculate (apply) output weights
7. Train (test) performance



The results: Bit Error Rate (BER)



I. estébanez, J. Schwind, I. Fischer & A. Argyris, *Nanophotonics 9 (13): 4163-4171*, 2020

- For certain values of the frequency detuning ($\Delta f = f_{drive} - f_{response}$) and feedback strength (r_c), we obtain better performance than the error-free data recovery (blue/purple region)
- For higher injection values (r_{inj}) we are able to increase the bandwidth response of the system to tens of GHz, so we can process information faster.

Photonic RC offers an exciting alternative to post-process signals that have undergone a complex nonlinear transformation.
Moreover, as it is an optical hardware implementation, in the future, we may avoid the optical to electrical bottleneck