

Optical chaos based on a laser diode with positive feedback

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Goals

Globally we would like to transmit a high-frequency signal in encrypted form.

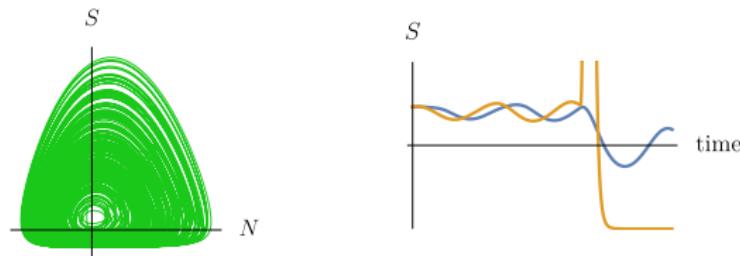
Here, we will consider the following steps towards this goal:

- dynamical chaos and synchronization
(to encrypt and decrypt signal);
- theory of the laser evolution and its adaptation under our needs;
- realization of the positive feedback in laser:
theory, modeling and practice.

Definition of dynamic chaos and applications

Map¹ f is **chaotic**, if

- periodic orbits are dense everywhere;
- orbits are mixed;
- f sensitive to the initial conditions.



Possible applications:

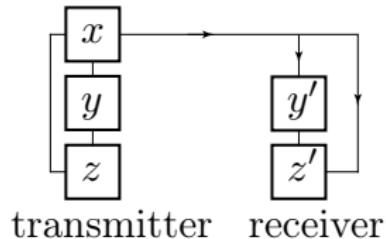
- random numbers generation;
- signal encryption.

¹W. Hirsch, S. Smale, Introduction to Chaos.

Synchronization

Possible² synchronization of chaotic systems:

enough to transmit
part of the signal;
configure system parameters.

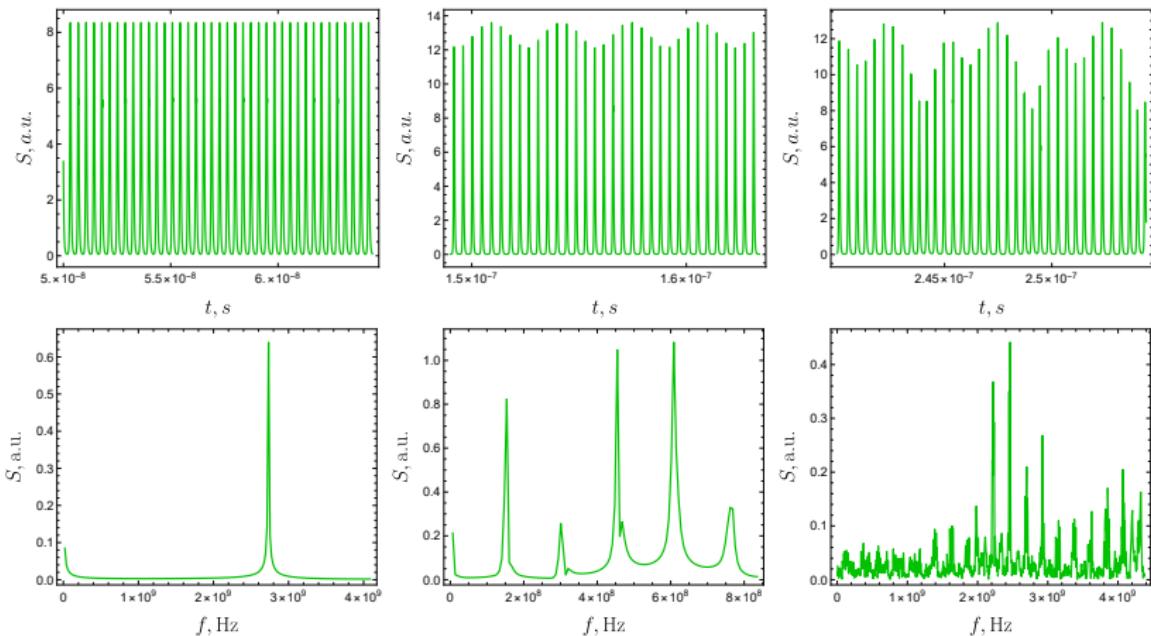


The use of optics to transmit the signal allows to achieve a greater bandwidth of the channel.

UHFO (ultrahight frequency oscillations) is a characteristic to optic systems.

²M. Pecora, L. Carroll, Synchronization in Chaotic Systems, 1990.

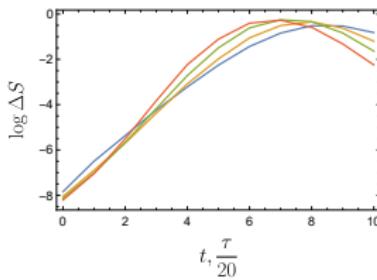
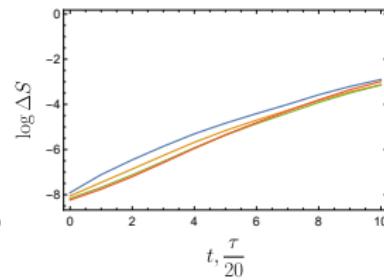
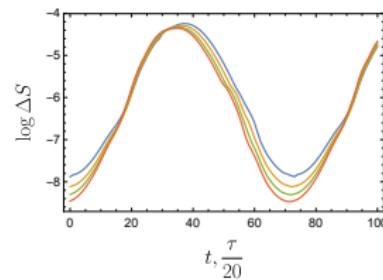
Chaos modelling. Different regimes.



Delay time τ : $2 T_r \mid 7.5 T_r \mid 12 T_r$

Chaos modelling.

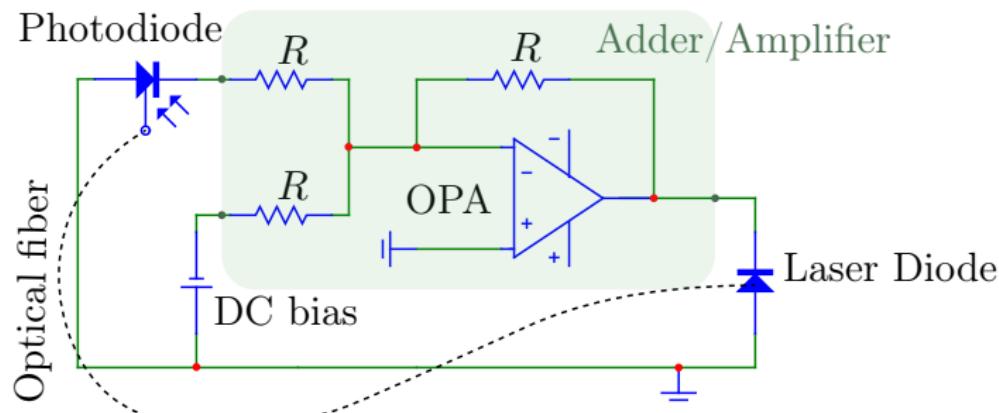
Lyapunov exponents calculation :



$$\frac{\tau}{\lambda} \left| \begin{array}{c|c|c|c} 2 T_r & 7.5 T_r & 12 T_r \\ \hline 0.0 & 1.62 f_r & 1.84 f_r \end{array} \right. \Delta S \sim \exp(\lambda t) \Rightarrow \log \Delta S = \lambda t + \text{const}$$

Scheme

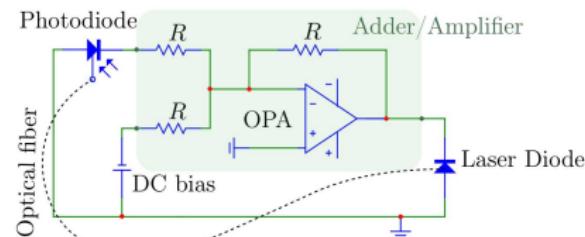
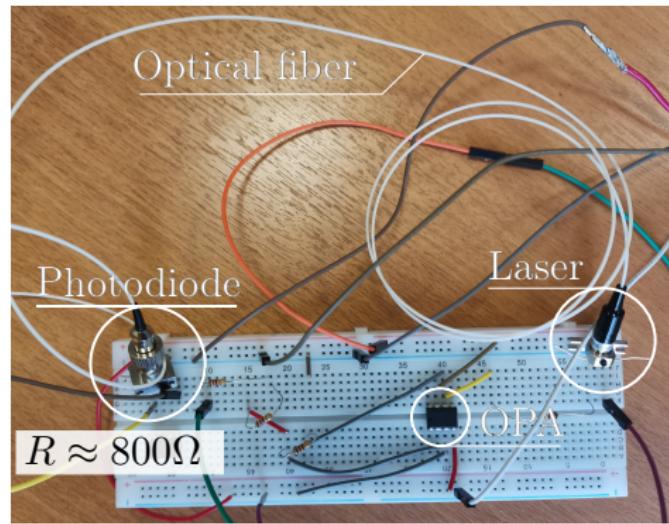
After several experiments came to this scheme with the summing amplifier:



Photodiode power is enough to not use an additional amplifier.

Realization

For testing, the assembly was carried out on the dumping board.

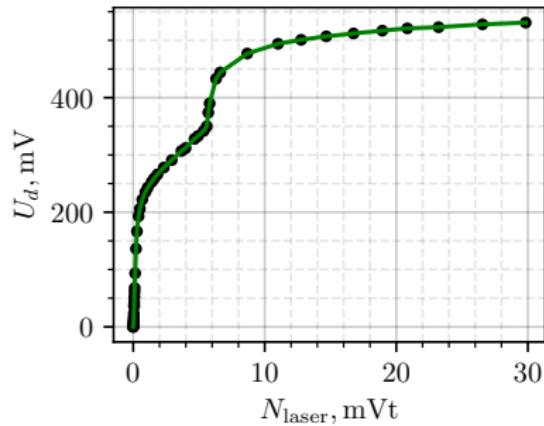
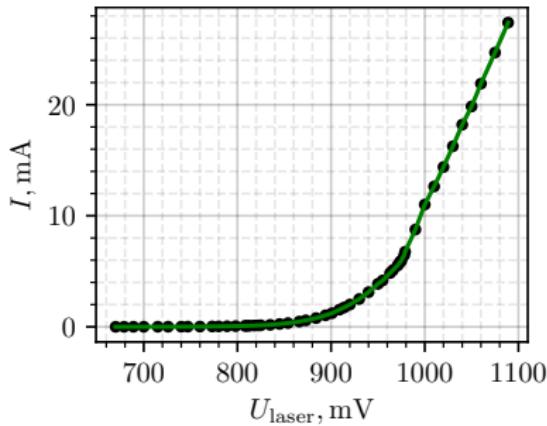


Thus, a scheme with positive feedback was implemented.
However, no desired oscillations were observed.

I-V curve

Makes sense to be in the most sensitive range, it was measured:

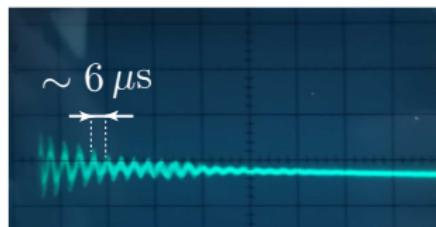
- I - V curve for a laser
- the dependence of the ph. diode voltage on the laser power.



So, laser voltage range of $0.95 - 1.00$ mV selected.

Problems

With used amplifiers, the following oscillations at the amplifier output with DC power can be observed:



This is due to the instability of the amplifier.

The main problem is that desired oscillations ~ 10 ns.

We proceeded to experiments with faster amplifiers, but it is useful to understand results of such delays.

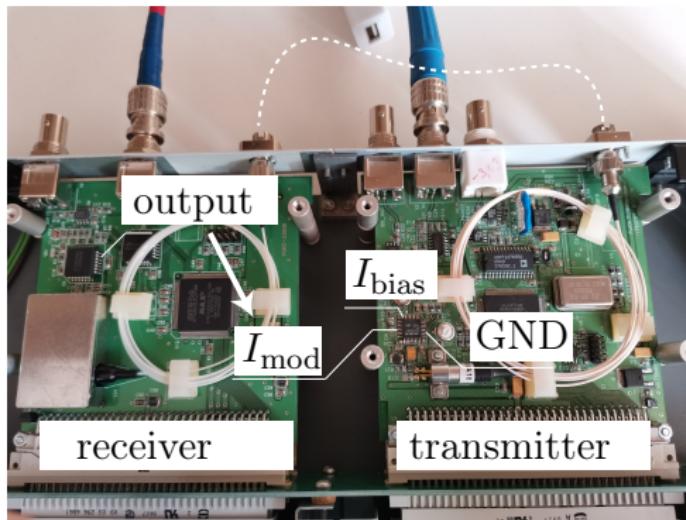
Real system

In real system³ $S_0^{-1} \int_0^\infty f(\eta)S(t - \eta)d\eta$ instead of $S(t - \tau)$.
It reduces oscillations.

³S. Tang, J. M. Liu, «Chaotic pulsing and quasi-periodic route to chaos in a semiconductor laser with delayed opto-electronic feedback», 2001.

Alternative implementations

It is possible to easily use partially finished decision:



In theory, it is enough to turn around (or navigate through the amplifier) several clems, what is planned to be implemented after more thorough preparation.

Chaos
○○○

Modeling
○○

Feedback impl.
○○○○

Slow adder
○

Results
○●

Conclusion