# Open vs closed loop receivers in all-optical chaos-based communication systems: the final round

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One of the main questions that remains open in chaos-based communications [1] is how much security can this technique offer?

Security aspects are often associated, by many researchers, directly to the receiver architecture although the security is related only indirectly with the receiver characteristics. Security is related to the difficulty of extracting the message from the chaotic carrier without using the authorized receiver.

It is our aim to show that privacy and security in all-optical chaos-based communication systems can only be achieved when small amplitude messages are used, which can be only recovered with a closed loop receiver. To that end, we have performed numerical simulations using the standard rate equations model for two emitter and receiver lasers unidirectionally coupled [2].

To quantify the degree of correlation between the master laser (ML) and the slave laser (SL) we use the average mutual information (MI). MI is a non-linear measure of the similarities between two quantities $x$, $y$ and is defined as $J_{xy} = \sum_{i,j} p_{ij} \log_2[p_{ij}/(p_i p_j)]$, where $p_{ij}$ is the joint probability of $x = x_i$ and $y = y_j$, $p_i$ ($p_j$) is the probability of $x = x_i$ ($y = y_j$). This quantity essentially measures the extra information one gets from a signal when the outcome of the other signal is known. For two independent signals $p_{ij} = p_i p_j$, and $J_{xy}$ is zero. Otherwise, $J_{xy}$ will be positive, taking its maximum value for identical signals.

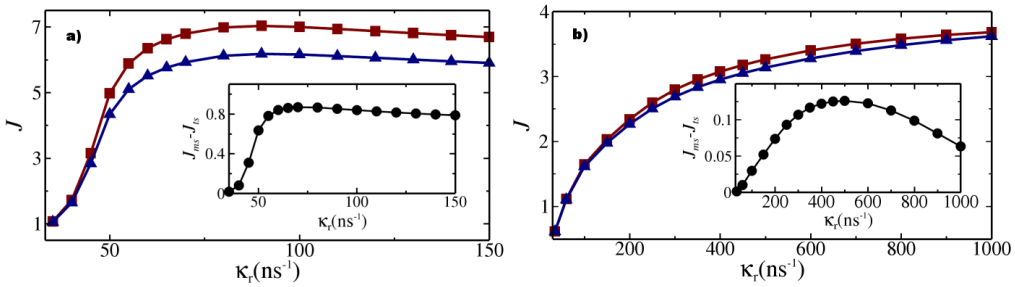


**Fig. 1** Average mutual information between the ML and SL in the a) closed loop and b) open loop scheme vs. coupling strength (triangles for $J_{ts}$ and squares for $J_{ms}$). The insets show the difference between $J_{ms}$ and $J_{ts}$ in both schemes.

Figure 1 shows the MI between the optical intensity of the ML ($P_M(t)$) and SL ($P_S(t)$), denoted as $J_{ms}$ and the MI between the transmitted signal, $P_T(t)$, and the slave signal $P_S(t)$ ($J_{ts}$), for the closed and open loop schemes. Both quantities, $J_{ms}$ and $J_{ts}$, are evaluated when a binary message of 1Gbit/s is codified in the output of the ML. The scheme we choose to encode the information is the chaos modulation (CM) scheme. In the synchronization regime $J_{ms} > J_{ts}$ and the receiver is able to filter out the message. It can be seen that the discrimination between the master output and the transmitted signal, i.e., $J_{ms} - J_{ts}$ (shown in the insets of the figures), is larger for the closed loop scheme than for the open one. The better chaos-pass filtering properties of the closed loop allows for the use of small amplitude encoded messages.

Our numerical results show that the best and most efficient way to transmit and recover small amplitude messages, which guarantees a certain degree of security in all-optical chaos-based communication systems, is to operate with the closed loop scheme in the receiver. On the contrary, the open loop scheme requires large amplitude messages that compromise the security.

## References

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