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QUANTUM ELECTRONICS

MASKING MESSAGES USING CHAOS

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Abstract. We numerically investigate encoding messages on the output of a chaotic transmitter laser and its subsequent decoding by a similar receiver laser and we extract a message masked by a chaotic signal. The chaos was generated by the two ODE describing the chaotic behaviour of four-level laser with periodic pump modulation. The mask removal can be accomplished for digital signals as well as for analogue ones.

Key words: chaotic signal, masking.

1. INTRODUCTION

There has been some recent interest in the idea of using chaotic variables as a way of transmitting information [1-4], even if this idea is about fifteen years old yet [5-8]. The principle is that if we have two identical nonlinear low-dimensional dynamical systems, where one of the variable from the first system enslaves the second, this chaotic variable can be used as a carrier for a message. We show how to extract messages that are masked by a chaotic signal of two ideal four level laser with periodic pump modulation oscillators. The transmitter parameter is such that the circuit is in chaotic regime. The transmitter signal $n_1(t)$ is fed into the receiver, with the result that the receiver quickly synchronizes to the transmitter, starting from any initial conditions. This synchronization can be visualized by plotting $n_1(t)$ *vs* the corresponding receiver variable $n_2(t)$.

2. MATHEMATICAL DETAILS

Results of numerical integrations of the two ODE are sown in Figs. 1 and 2 and are in good agreement with those obtained in litterature [9,10]. We see that erratic patterns (chaotic behavior) occur for $\omega < 0.0136$, and regular behavior is present for $\omega \geq 0.0136$. The phase portraits from figures present limit cycles for regular behavior, and nondefinite aspect for chaos.

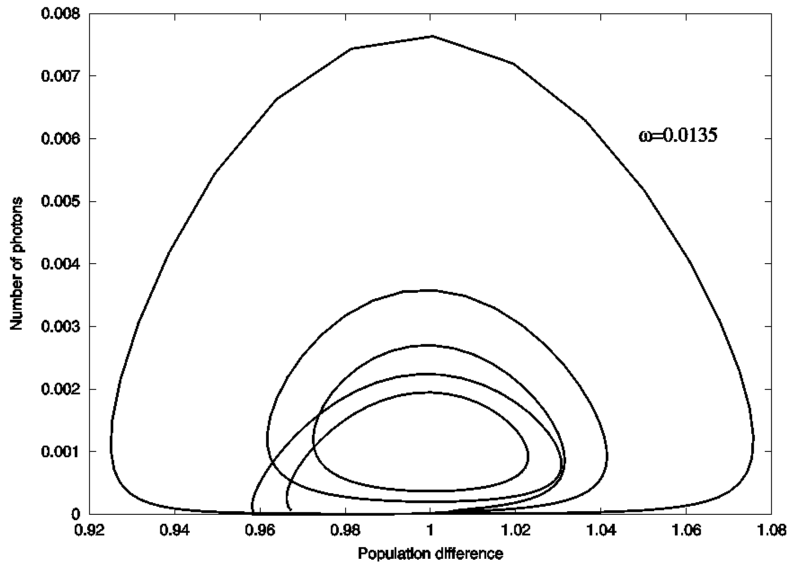

Fig.1 – Phase portrait for $\omega = 0.0135$.

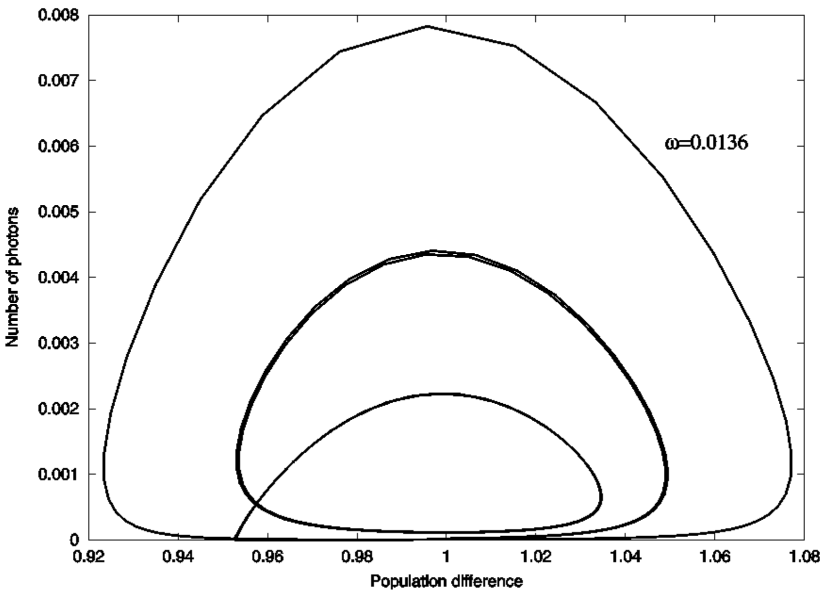

Fig. 2 – Phase portrait for $\omega = 0.0136$.

Likewise, the correlation dimension, which approximates the attractor dimension, is about two for regular patterns, and greater than two for irregular patterns (Fig. 3). Moreover, the error doubling time decrease suddenly from approximatively 35 for $\omega \geq 0.0136$ to above 5 for $\omega < 0.0136$ (Fig. 4).

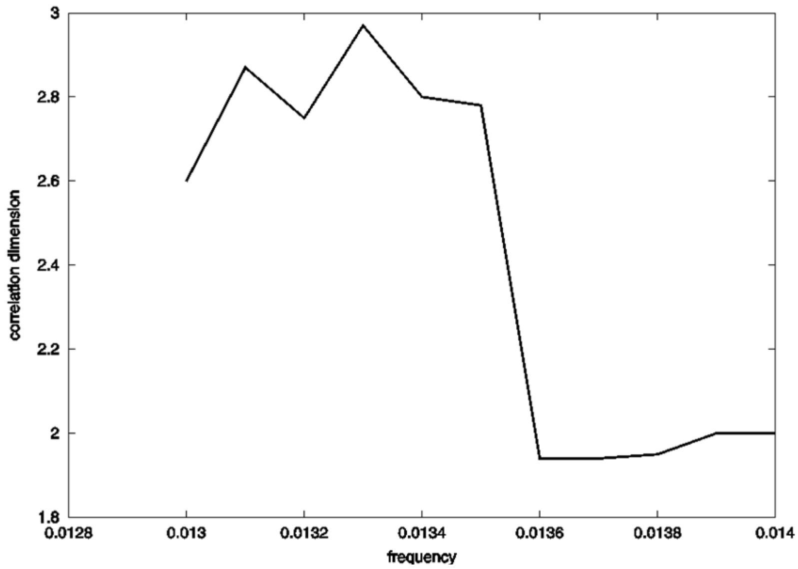

Fig. 3 – Correlation dimension *vs.* pump frequency.

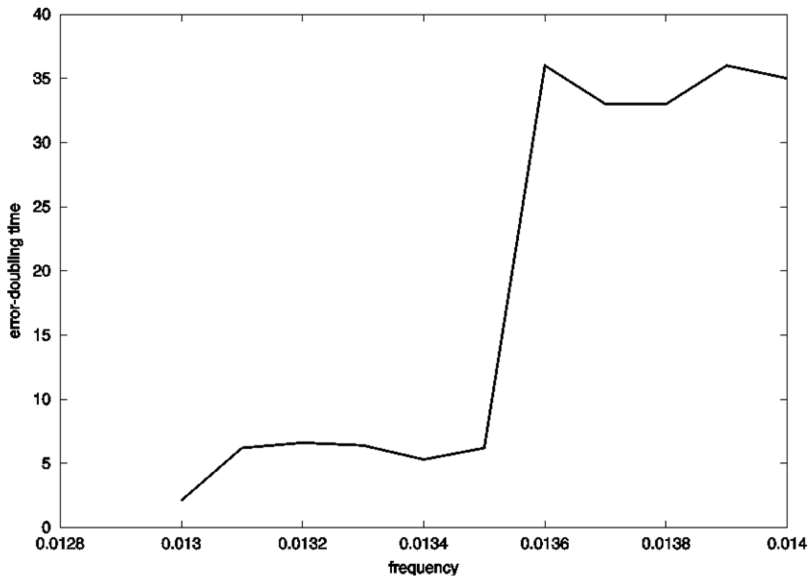

Fig 4 – Error-doubling time (arbitrary units) *vs.* pump frequency.

Chaotic behavior occurs for $\omega < 0.0136$, so for these values the maximum Lyapunov exponent should be positive, whereas for $\omega \geq 0.0136$ (regular pattern) it must be negative. Results shown that this method is able to detect the transition from regular to chaotic behavior, as can be seen from Fig. 5.

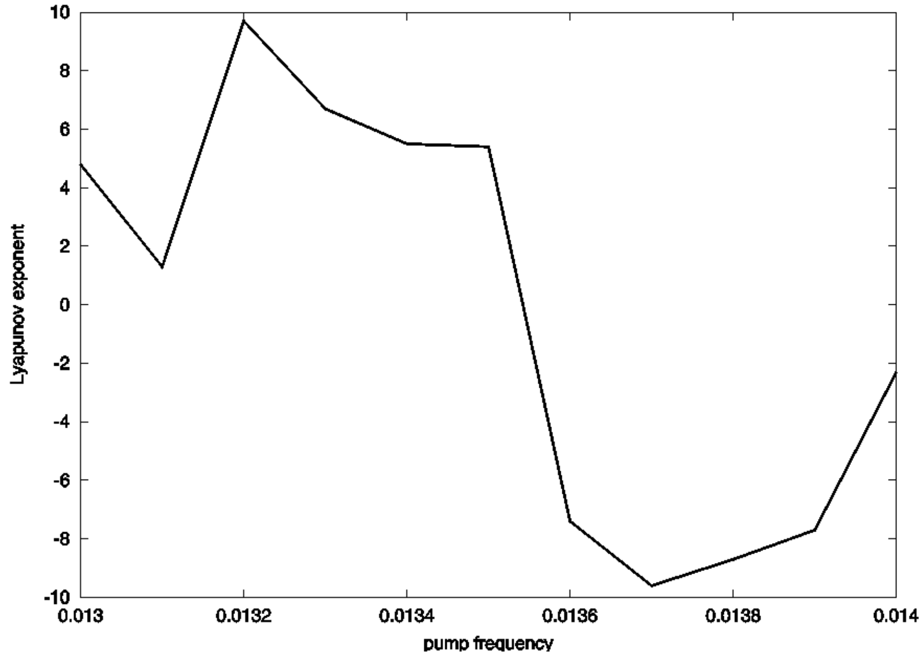

Fig. 5 – Maximum Lyapunov exponents *vs*. pump frequency.

The governing equations for the transmitter are:

$$\begin{aligned} \dot{q}_1 &= -q_1 + n_1 q_1 + s n_1 \\ \dot{n}_1 &= p_0 (1 + p_m \sin \omega t) - n_1 q_1 . \end{aligned} \tag{1}$$

While the receiver's state (n_2, q_2) evolves according to

$$\begin{aligned} \dot{q}_2 &= -q_2 + n_1 q_2 + s\ n_1 \\ \dot{n}_2 &= p_0 (1 + p_m \sin \omega t) - n_2 q_2 . \end{aligned} \tag{2}$$

In the second set of equations, the use of n_1 instead of n_2 has the effect of enslaving the second oscillator to the first. This means that if we start the two oscillators from different initial conditions, but using the same set of ω values, the variables in the receiver will soon synchronizes with the values of the sender.

3. RESULTS

For transmitting a message, we add a small amplitude message $m(t)$ to the variable $n_1(t)$ we get from the sender, $s(t) = n_1(t) + m(t)$. This new drive is fed to the receiver, and then we use the difference $s - n_2(t)$. Numerical integrations were performed for $m(t) = \sin(2.4t)$ (Fig. 6) and for $m(t) = \sin(3.6t)$ (Fig.7).

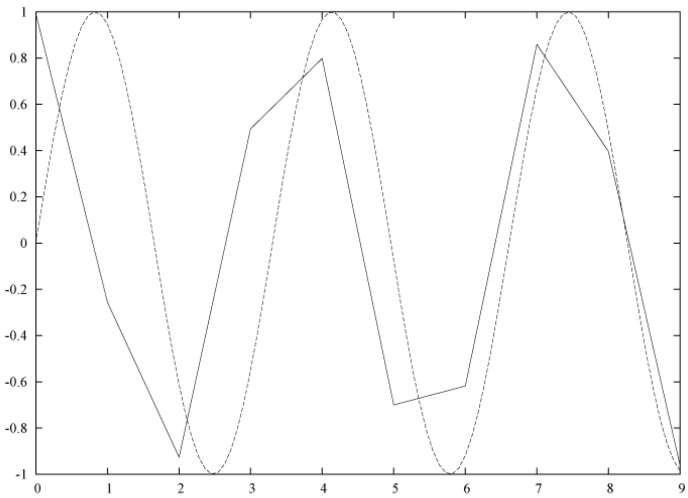

Fig. 6 – Recovering of the message m_1=sin(2.4*t*). Thin line = original signal, solid line = reconstructed signal.

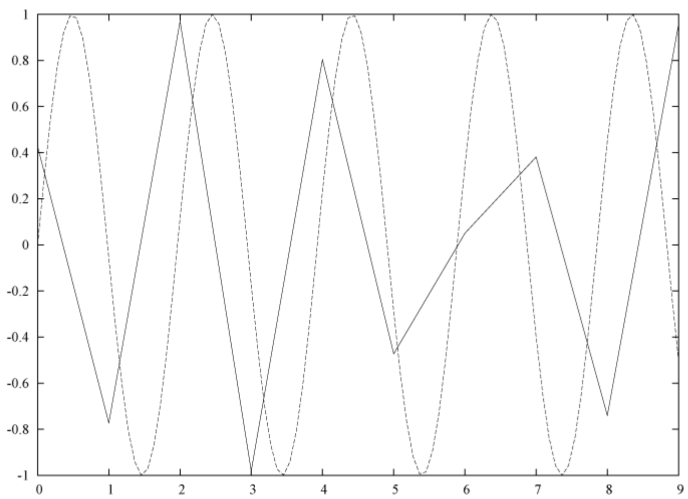

Fig. 7 – Recovering of the message m_2=sin(3.6*t*). Thin line = original signal, solid line = reconstructed signal.

We see from Figs. 6 and 7 the reconstruction is not very satisfactory, this being due to the dependence of the recovering process (numerical integrations) on the signal's frequency. The transmitter parameters that must be known in order to recover the message form a multidimensional space in which to hide the "key" for recovery.

4. SUMMARY

We numerically investigated encoding messages on the output of a chaotic transmitter laser and its subsequent decoding by a similar receiver laser. In order the reconstruction be optimal, the power spectrum must be analyzed for searching the synchronization peaks, but this work will be done in another paper.

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