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Ricardo Alcorta Galvan, Marc Sansa Perna, Martial Defoort, Bernard Legrand,  
Guillaume Jourdan

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# On the use of optomechanical devices as chaos-generating systems for chaotic cryptography

Alcorta Galván, Ricardo<sup>1</sup>; Sansa, Marc<sup>1</sup>; Defoort, Martial<sup>2</sup>; Legrand, Bernard<sup>3</sup>; Jourdan, Guillaume<sup>1</sup>

1) CEA-Leti, Université Grenoble Alpes. 2) TIMA-CDSI - Circuits, Devices and System Integration. 3) LAAS-MEMS - Équipe Microsystèmes électromécaniques

In recent years, chaotic systems have received increasing attention for their potential applications in sensing and the possibility of implementing secure communication thanks to chaos-based cryptography. Chaotic cryptography is a type of material cryptography in which the information to be transferred is masked with a larger amplitude signal generated by a chaotic system. On the receiver side, the mixed signal is fed to a similar chaotic system which synchronizes to the first one resulting in a retrieval of the information. For effective synchronization, it is essential that the chaotic systems used at both ends exhibit closely matched dynamics, which in turn requires the selection of a specific physical system.

MEMS devices and chaotic lasers have been proposed as chaotic systems for implementing this material cryptography. While MEMS devices offer the advantages of efficiency, compactness, and seamless integration, lasers are well-suited for compatibility with existing optical communication infrastructures. Modern fiber links, characterized by their low loss and high bandwidth, facilitate the rapid transfer of signals over long distances. Experimental demonstrations have successfully employed modulated chaotic lasers for encrypted communications [1].

The use of optomechanical devices would bridge the gap between MEMS and chaotic lasers, combining the advantages of extensive bandwidth and telecom compatibility with the efficiency and compactness of MEMS. In this work, we explore the feasibility of employing optomechanical systems for chaos-based encryption. These fundamentally non-linear systems are known to enter chaotic regimes in low-frequencies (tens of MHz) due to thermo-optic slow dynamic effects [2] as well as due to the intrinsically non-linear optomechanical coupling for frequencies as high as that of the mechanical mode at GHz range. For certain excitation parameters, the system is also prone to dynamical onset of chaos by frequency and amplitude modulation of the driving signal [3].

The different chaotic regimes that may be achievable using a single optomechanical cavity, the direct transduction of the chaotic signal into laser frequency for optical fiber transmission, and the high degree of integration of fully silicon-based optomechanics makes them a compelling solution for chaos-based cryptography.

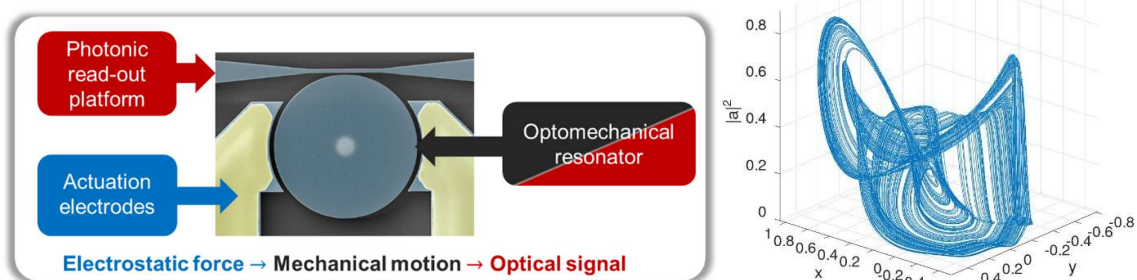


Figure 1.- Left, microscope image of a suspended Si disk optomechanical resonator with an optical waveguide for laser coupling and electrodes for electrostatic mechanical excitation. Right, simulated chaotic attractor from a Si disk optomechanical resonator driven by an amplitude-modulated laser ( $x$  : position,  $y$ : velocity,  $|a|^2 \propto$  optical mode amplitude; all in arbitrary units).

[1] Argyris, A., Syvridis, D., Larger, L. *et al.* Chaos-based communications at high bit rates using commercial fibre-optic links. *Nature* **438**, 343–346 (2005).

[2] Navarro-Urrios, D., Capuj, N., Colombano, M. *et al.* Nonlinear dynamics and chaos in an optomechanical beam. *Nat Commun* **8**, 14965 (2017).

[3] Defoort, M., Rufer, L., Fesquet, L. *et al.* A dynamical approach to generate chaos in a micromechanical resonator. *Microsyst Nanoeng* **7**, 17 (2021).