Robustly Chaotic Dynamics in a 3-Level Laser Model with Opticl Pumping

Vladislav Koryakin

HSE University, Nizhny Novgorod, Russia

We present our recent results of a numerical study of a six-dimensional system describing the dynamics of the optically pumped three-level laser model. For the first time, we demonstrate that this system exhibits robustly chaotic attractors in an open region of the parameter space. Our results are based on the successive verification of all required pseudohyperbolicity conditions, as well as on checking the conditions of the Shilnikov criteria [1, 2]. In particular, we found two Shilnikov points (denoted as p_1 and p_2 in the figure below), where an additional degeneracy occurs for the pair of homoclinic loops. The region with a robustly chaotic attractor (colored in yellow in the figure below) originates from points the p_1 and p_2 and spreads quite far from these points. The boundary of these regions is associated with the curve $l_A = 0$, where the first foliation tangency occurs along the homoclinic
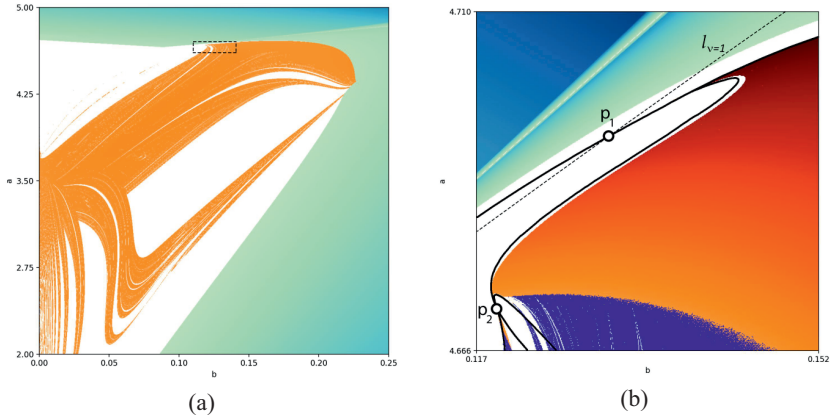

Figure 1. Two-parameter chart of dynamical regimes: a) chart of the top Lyapunov exponent; b) Enlarged fragment from Fig.1 a. Diagram of the minimum angle between subspaces. Robustly chaotic attractors exist in orange region where pseudohyperbolicity conditions for the corresponding 6D laser model are met. This regions originate from the Shilnikov points p_1 and p_2. In blue region a chaotic attractor exists but is not robust. The curve $l_{\nu=1}$ is a neutral saddle curve.

loops. The regions where the attractor is not robustly chaotic are colored in blue.

This is a joint work with K. Zaichikov.

This paper was supported by the RSF (Grant No. 25 11-20069).

References

[1] Shilnikov L. P., The bifurcation theory and quasi-hyperbolic attractors, *Uspehi Mat. Nauk*, 1981, vol. 36, pp. 240–241.

[2] Kazakov A., Koryakin V., Safonov K., Shilnikov, L., Cascades of Lorenz attractors in the Shimizu-Morioka, 2025 (in preparation).