Title of the doctoral dissertation:
Study on the chaotic behavior of Hall effect thruster plasmas
Author:
Agnieszka Jardin, Institute of Plasma Physics and Laser Microfusion
Supervisor:
dr hab. Piotr Lubiński, prof. UZ, Institute of Physics, University of Zielona Góra

Abstract

The Hall effect thruster is nowadays widely used as an engine for correcting the orbit and movement in outer space of various types of research, communication and spy equipment. Therefore, two projects named KLIMT and HIKHET were implemented at the IPPLM research institute in Warsaw, leading to the creation of prototypes robust against overheating and efficiently operated with krypton fuel. These engines were constructed and tested by the Plasma Accelerator Team, in which the author of this doctoral dissertation is an active member.

Since their conception in the 1960s, Hall effect thrusters have experienced numerous undesirable and harmful plasma instabilities despite stable operating conditions (constant mass flow rate of gas, discharge voltage, or coil currents), which significantly affect their performance. The resulting instabilities can be easily observed in the discharge current or ion current waveforms. Therefore, in order to collect relevant data for the purposes of this doctoral dissertation, an oscilloscope and self-designed electrical probes recommended for this type of research were used.

Since the occurrence of deterministic chaos in nonlinear systems, an example of which is the type of thruster tested here, may affect its performance, it was decided to analyze the recorded time series in this respect. In this dissertation, for the first time, the search for chaos in thruster experimental data has been explored thoroughly. Among other aspects, the studies included bifurcation diagrams and power spectra, phase space reconstruction as well as recurrence quantification analysis based on recurrence plots. During these investigations, fractal dimensions, largest Lyapunov exponents, entropy and several other indicators of chaotic behavior could also be determined. The possibility of correlating the occurrence of chaotic behavior with changes in thruster performance was studied using the discharge voltage as a control parameter.

In conclusion, the dissertation describes the research on plasma emitted by a Hall effect thruster and the interpretation of the results in the context of low-dimensional deterministic chaos. Chaotic behavior was detected with the help of several independent indicators, during thruster operation in the deep oscillation mode, so-called global mode. The author hopes that these results will make a significant contribution to optimization research on Hall effect thrusters.

Jardin