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Title
Effects of magnetic nozzle configuration on ion beam generation for RF electrode-less plasma thrusters

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Abstract
RF electrode-less plasma thrusters are a type of electric propulsion (EP) system that employs radio-frequency excitation to generate the plasma and a magnetic nozzle (MN) to enhance plasma acceleration [1]. This new technology has been receiving a lot of interest in the EP community as its numerous benefits make them a competitive choice for future low-thrust space missions. When compared to gridded ion engines and Hall Effect thrusters, the lack of electrodes and neutralisers of the RF plasma thruster's design, together with the advantage of a magnetic nozzle in reducing plasma losses, could increase the lifetime of the propulsion system. Additionally, the concept of magnetic thrust vectoring (MTV) for radio-frequency plasma thrusters, which relies on a steerable magnetic nozzle to control the direction of an ion beam, has been proposed [2–6]. Such a system would allow for a contactless and electrode-less control of the plasma, decreasing the thruster erosion due to plasma-wall interactions. Additionally, the capability to tune the magnetic field configuration would enable full modulation of the in-flight thrust profile of the spacecraft. However, the highest efficiency reached so far during the testing campaigns has been 30% [7]. In order to make MN plasma thrusters a competitive choice with respect to current employed EP systems, the coupling of the expanding plasma with the magnetic nozzle has to be fully understood. The purpose of this research is to present measurements of an RF plasma expanding in a magnetic nozzle under different magnetic field configurations. As the focus is on future thruster applications, the study is aimed at the characterization of an accelerated ion beam. A controllable 3D magnetic nozzle, whose designed was based on the study carried out by [3], was incorporated and tested into Moa, a new plasma reactor apparatus dedicated to the study of magnetic nozzle RF plasma thrusters at the University of Auckland. Spatial mappings of the plasma characteristics during the expansion phase are presented for different magnetic field topologies, namely: a symmetric nozzle with increasing magnetic field strengths to study the effects of changing magnetic field on ion acceleration, and a deflected magnetic nozzle to study plasma steering. The research will not only provide knowledge of contactless steering systems for electric propulsion, but will also allow for further understanding of the mechanisms that guide plasma generation and expansion in a divergent magnetic field.

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