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Plasma Dynamics in RF Plasma Sources with Time-Varying Magnetic Nozzles

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Plasma dynamics in diverging magnetic fields, known as magnetic nozzles, are fundamental processes in both astrophysical and laboratory plasmas. Since inductively coupled or wave-coupled plasma sources accelerate the plasmas without electrodes, these devices offer a prolonged lifetime compared to the system with metal walls or grids, making them especially attractive for applications such as space propulsion.

In typical laboratory configurations of partially magnetized plasmas, the electric field emerges primarily from the interaction between the electrons and the magnetic field. Consequently, the ions undergo acceleration by the electric field, facilitating the conversion of the enthalpy of electrons into the kinetic energy of ions.

Recently, unique plasma dynamics in time-varying magnetic nozzles have attracted attention.[1] Experimental investigations have revealed that when a time-varying diverging magnetic field, typically in the range of a few tens of kilohertz, is superimposed onto the magnetic nozzle, it generates supersonic ion flow. Additionally, large azimuthal plasma currents have been confirmed,[2] with the electron E x B drift current being identified as dominant, contrary to conventional static magnetic nozzles where the diamagnetic current prevails. Recent experiments have further validated significant spatiotemporal variations in potential, which serve as the driving force behind the observed ion acceleration.[3]

This presentation will review the results and findings from research on plasma dynamics in time-varying magnetic nozzles and will also discuss challenges and prospects for future plasma control techniques.

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References

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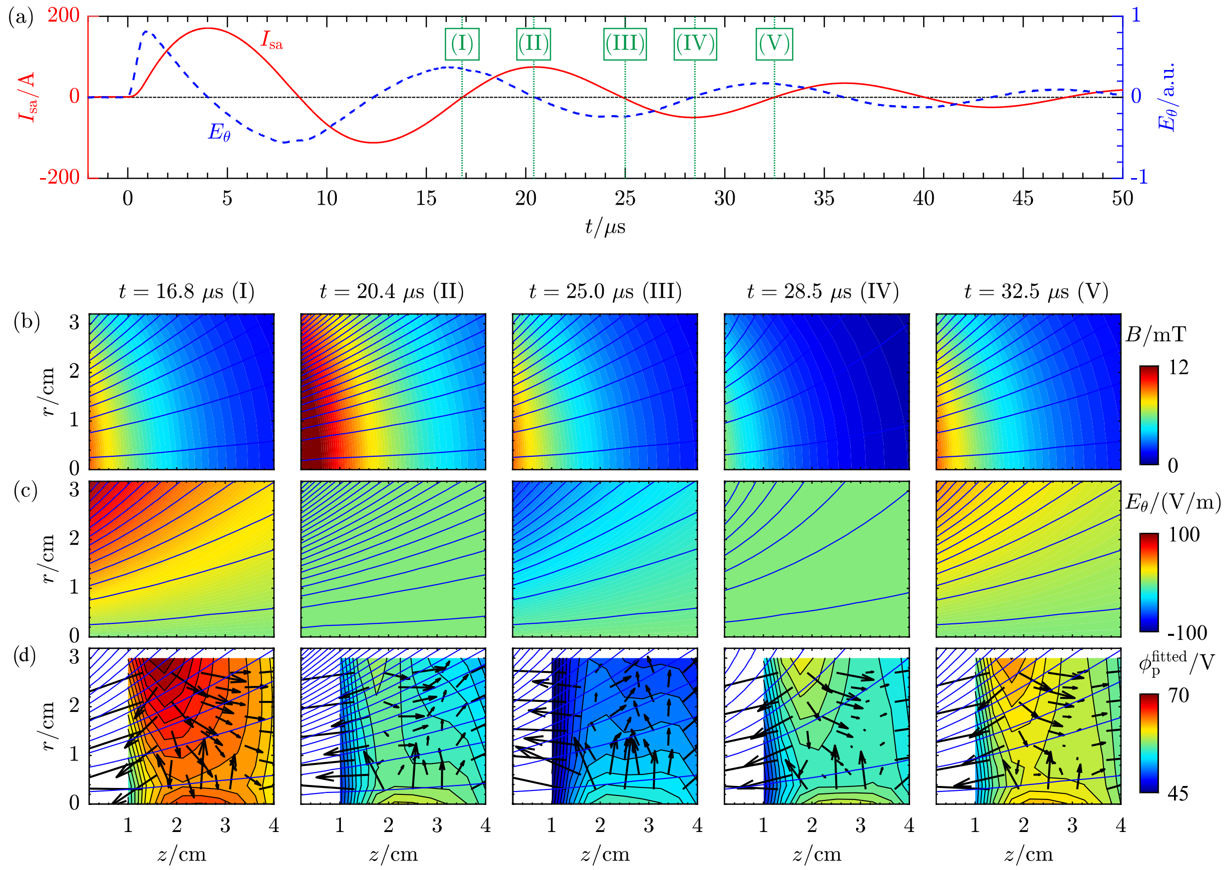

Figure 1. (a) Temporal evolution of spiral antenna current I_{sa} (solid red line) and the azimuthal electric field E_θ in an arbitrary unit (dashed blue line). The five dotted green lines indicate the selected times to draw (b), (c), and (d). Spatiotemporal evolution of the (b) calculated magnetic flux density $\boldsymbol{B}$, (c) calculated azimuthal electric field E_θ, (d) measured plasma potential ϕ_p and the corresponding electric field vectors. The solid blue lines indicate the magnetic field lines.