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Electrothermal instability growth in Magnetised Liner Inertial Fusion (MagLIF) liners

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The MagLIF concept involves the magnetic compression of a beryllium liner containing fusion fuel using the 26 MA Z machine, with an externally applied axial magnetic field to reduce thermal losses and laser preheat to adjust the fuel's adiabat [1]. The outer surface of an imploding liner subjected to a strong current pulse is susceptible to Magneto-Rayleigh Taylor instabilities (MRTIs). During the course of the implosion, the MRTI can penetrate through the inner surface of a MagLIF liner, disrupting the assembly of a uniform fuel column and reducing fusion yield [2]. Additionally, it has been observed in x-ray radiographs of the imploding liner that applying even a modest (10 T) axial field relative to the azimuthal field results in a significantly helical MRTI profile [3]. The source of this helicity is a source of debate within the community, as is the nature of the MRTI seed.

Out of multiple hypothesis, this work focuses on the electrothermal instabilty (ETI) as a potential seed. Here, the ETI occurs when an axial current encounters a resistive defect and is deflected around it, leading to enhanced current density and Ohmic heating around the defect, increasing the azimuthal extent of the resistive region, forcing further deflection, etc [4]. The Gorgon code was used to run 3D resisitve-MHD simulations to perform a systematic study of the behaviour of individual embedded defects in a MagLIF-relevant liner. A range of parameters were varied, including the defect's size, resistivity, position within the liner, etc. Additionally, the behaviour when adding an axial magnetic field was investigated. An artificially high field strength was used ($B_z = 100$ T), which showed angled ETI growth. Finally, full-circumference simulations with 1000s of (interacting) defects were performed that show the emergence of long wavelength perturbations in integrated density maps that also have an observable helicity in the presence of a 100 T field.

References

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