P 5: Magnetic Confinement II/HEPP II

Time: Monday 16:30–18:15 Location: ELP 6: HS 3

P 5.1 Mon 16:30 ELP 6: HS 3

Searching for SQuIDs:*Stable Quasi-Isodynamic Designs for Stellarators — •Alan Goodman, Pavlos Xanthopoulos, Gabriel Plunk, Sophia Henneberg, Carolin Nuhremburg, Hakan Smith, Craig Beidler, Gareth Roberg-Clark, and Per Helander — Max-Planck-Institut fur Plasmaphysik, D-17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are a uniquely attractive fusion reactor candidate due to their low neoclassical transport, excellent confinement of fusion-borne alpha particles, and vanishingly small bootstrap currents [1]. Due to the complexity of their geometries, QI stellarators must generally be designed through numerical optimization, which requires an objective metric that quantifies the degree to which a given design is QI. While once thought impossible, we recently showed that nearly-perfectly QI geometries can be found using an appropriately-designed objective function [2]. We have since built upon this approach, now finding QI geometries with reduced turbulence, improved MHD stability, and lower surface area-to-volume ratios, which are potential candidates for future stellarator experiments and reactors.

References:

[1] P Helander and J Nührenberg. Bootstrap current and neoclassical transport in quasi-isodynamic stellarators. PPCF (2009).

[2] A Goodman et al. Constructing precisely quasi-isodynamic magnetic fields, JPP (2023).

P 5.2 Mon 16:55 ELP 6: HS 3

Equilibrium and stability of plasma with arbitrary non-neutrality in a levitated dipole trap — •Patrick Steinbrunner[1], Thomas O'Neil[2], and Matthew Stoneking[3] — [1]Max Planck Institute for Plasma Physics, Greifswald, Germany — [2]University of California San Diego, La Jolla, United States — [3]Lawrence University, Appleton, United States

A purely nonneutral plasma can be confined in a global thermal equilibrium state as well as a local thermal equilibrium along magnetic field lines in a magnetic dipole trap. A plasma consisting of a mixture of electrons and positrons, as it is envisioned by the APEX collaboration (A Positron-Electron eXperiment), can only be confined in a local thermal equilibrium state. While global thermal equilibria are maximum entropy states and hence guaranteed to be stable, local thermal equilibria can be unstable.

One of the dominant instabilities, the diocotron mode, was studied to a great extend in the homogeneous magnetic field of a Penning-Malmberg trap. We will focus on the inhomogeneous magnetic field of a z-pinch, which serves as an approximation of the vicinity of a levitated coil. This implies two differences in comparison to a Penning-Malmberg trap. First, grad-B and curvature drifts influence the instability. Second, plasmas of arbitrary nonneutrality can be confined. We found that in the general case of arbitrary nonneutrality, the stability is governed by an interplay between the diocotron and the interchange instability.

P 5.3 Mon 17:20 ELP 6: HS 3

Direct Construction of Large Aspect Ratio Quasi-isodynamic Stellarators — •Katia Camacho Mata, Gabriel G. Plunk, and Alan G. Goodman — Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Quasi-isodynamic (QI) stellarators are attractive fusion reactor candidates due to their good confinement properties, inherent steady-state operation, low toroidal currents and favourable turbulence properties. However, optimisation methods traditionally used to find QI fields are highly dependent on the initial guess, often result in complicated geometries and do not offer physical insight into the solution space structure. The near-axis expansion (NAE) method, an expansion of the magnetohydrodynamic equations, can be used to construct exact QI equilibria in the vicinity of the magnetic axis, to first or second order. The NAE method is discussed, and it is shown that configurations with low neoclassical transport and simple boundary shapes can be constructed, even far from the axis, by carefully choosing the initial NAE parameters. The QI solution space structure is investigated using these parameters. The role the helicity of the magnetic axis plays in dividing the space into regions with different confinement properties is described and is used to construct NA QI solutions similar to existing optimised stellarators. The strengths of the NAE are discussed, namely its suitability to provide initial points for traditional optimization, and the ability to perform a systematic and exhaustive search of the QI solution space, aiding in the search of the next generation stellarator designs.

P 5.4 Mon 17:45 ELP 6: HS 3

Stochastic Single-Stage Stellarator Optimization for EPOS and Analysis of Coil Perturbations — •Pedro F. Gil, Jason Smoniewski, Paul Huslage, and Eve V. Stenson — Max-Planck-Institute for Plasma Physics, Garching, Germany

The EPOS (Electrons and Positrons in an Optimised Stellarator) project, as part of the APEX (A Positron Electron eXperiment) Collaboration, aims to build a small-scale stellarator for the confinement of pair plasmas. The magnetic field in EPOS will be quasi-axisymmetric, meaning that the magnetic field amplitude is invariant along a toroidal coordinate. This symmetry ensures the good confinement of trapped particle orbits. The device will receive a limited amount of positrons setting a constraint on its size, leading to unmanageable coil manufacturing and assembly tolerances. An analysis of the perturbations that affect the induced magnetic field is performed in order to guide the optimization towards robust configurations.

Stellarator optimization is usually a two-step process: find a target equilibrium, and design coils to match that desired equilibrium. Stochastic optimization of the coils randomly perturbs the shape of the coils N times and averages the magnetic field. This both broadens the width of the minima allowing to find more robust configurations and reduces the likelihood of getting trapped in local minima. Combined with a single-stage approach it smooths the objective function while searching for both coils and plasma. This method is expected to relax the coil construction constraints for EPOS into the $\pm$ 0.3 mm range, making it buildable.

P 5.5 Mon 18:00 ELP 6: HS 3

Optimized HTS Coils for the EPOS Stellarator — •Paul Huslage, Pedro Gil, Jason Smoniewski, and E. V. Stenson — Max-Planck Institue for Plasma Physics

The future EPOS (Electrons and Positrons in an Optimized Stellarator) aims to confine an electron positron pair plasma using non-planar high-temperature superconductor (HTS) coils. The non-planar shape combined with the requirement for compactness results in significant mechanical strain imposed on the HTS tapes, which can cause cracks in their functional ceramic layer and requires careful optimization of the coils. With its small size and moderate magnetic field (R=0.2m, B=2T), EPOS provides an attractive platform for advancing stellarator coil design.

En route to an engineering design for the experiment, we built several non-insulated, superconducting prototype coils, both planar and non-planar and operated them under cryogenic conditions. We use 3D-printed metal frames to wind the superconductor into the desired shape.

We present our prototype coils together with critical current measurements and quench tests both in liquid nitrogen and at 20 K inside a vacuum chamber.