Novel optimized stellarator configurations

Integrated optimization for good flux surfaces [1]

- Flux surfaces are not guaranteed in 3D fields.
- But, for many stellarator optimization objective functions, it is convenient to assume good surfaces.
- So, at each iteration, compute two B representations: one assuming surfaces (VMEC) and one not assuming surfaces (SPEC).
- Penalizing Greene’s residues in the objective function [4] makes the two representations consistent by the end of the optimization.

Objective function:

\[
\text{Corresponding SIMSOPT [3] script:}
\]

\[
\text{Aspect ratio: } f = \left( A - 6 \right)^{\frac{1}{5}} + \left( l - 0.39 \right)^{\frac{2}{3}} + \left( h - 0.42 \right)^{\frac{2}{5}}
\]

Quasisymmetry error:

\[
+2 \sum_{m,n} \frac{\beta_m(s=0.5) - B_0}{B_0} + 2R^2 + 2R_{ch}^2
\]

Greene’s residues for X- and O-points, from SPEC

Stellarators with precise quasisymmetry and excellent confinement [2]

Previous quasisymmetric stellarators:

New QA

New QA + magnetic well

New QH

New QH + magnetic well

Optimization procedure for new configurations:

- Objective functions:

\[
f_{QM} = \left( A - A^* \right)^{\frac{1}{5}} + \left( l - l^* \right)^{\frac{2}{3}} + \left( h - h^* \right)^{\frac{2}{5}}
\]

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\]

- The usual parameter space: \( R_{ch}, a_{m,n} \), defining a toroidal boundary

- 6-stages: increasing \# of \( R_{ch}, a_{m,n} \) modes varied & code resolution

- SIMSOPT [3] with VMEC

- Vacuum fields, to ease confirmation of surface quality

- Algorithm: default for nonlinear least-squares in scipy

References


[7] 3D flux surfaces used: Boozer, Quasisymmetry

\[
\text{Before optimization}
\]

\[
\text{After optimization}
\]

Final configuration has excellent quasisymmetry

Poincare plots from SPEC confirm good surfaces:

Quasisymmetry is achieved to high precision

The rotational transform turns out strikingly flat

Alpha particle confinement is excellent

Neoclassical transport is extremely small

\[
\text{Previous configurations}
\]

\[
\text{New QA}
\]

\[
\text{New QA + magnetic well}
\]

\[
\text{New QH}
\]

\[
\text{New QH + magnetic well}
\]
Coils for the new QA configurations

With Florian Wechsung, NYU. Coils optimized using SIMSOPT [3].

New QA:

New QA+well:

<R>/10 between filament centers