The Need for a Strong US Stellarator Program

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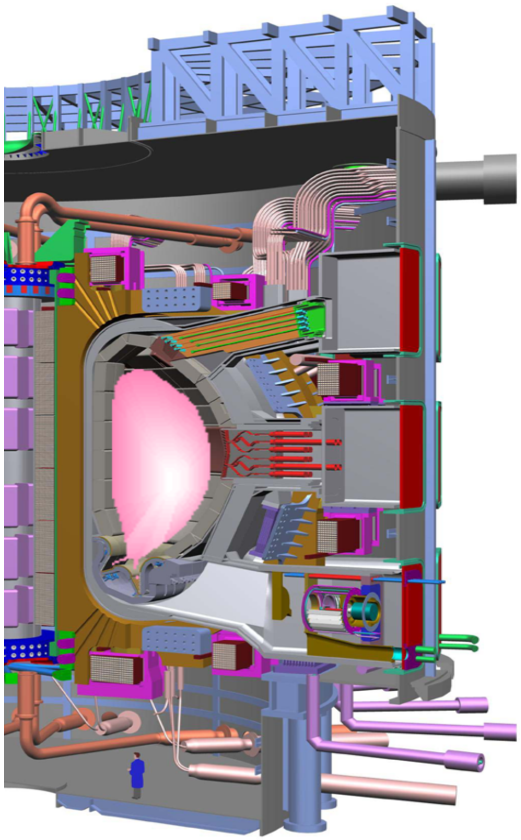
Confinement Innovations Needed Beyond ITER

Need

- Higher fusion performance at ~same size
  P_{fusion}, Q, $Q_{engineering}$
- Steady state with less CD, more bootstrap current
- Disruption free, reliable
- Robust divertor
- TBR > 1



But, must be simpler, more cost effective.

Must develop solutions to make energy application credible, in parallel with ITER at latest.

Stellarators Provide Solutions

Steady-state toroidal plasmas with

- ✓ No disruptions. Equilibrium maintained by external coils
- ✓ No current drive ⇒ intrinsically high Q, higher reliability
  easier to get TBR > 1
- ✓ Quiescent steady state at high-beta with confinement similar to tokamaks.
- ✓ Very high density limit ⇒ easier plasma solutions for divertor
  reduced fast-ion instability drive
- ✓ Not limited by macroscopic instabilities. No need to control profiles. No need for feedback or rotation to control instabilities. Greatly simplify plasma control and related diagnostics

Shaping flexibility to control and increase confinement and β

Greatly simplifies many aspects of burning plasma designs.

Eliminates many auxiliary systems.

US Leadership & Innovation

Past US Leadership in 3D physics and stellarators:

- Development of Quasi-symmetry: tokamak-like transport
- 3D equilibrium codes
- 3D shape optimization to increase β & control MHD stability
- Optimized 3D shaping at tokamak-like aspect ratio

Present:

- 3D shaping to control turbulent transport
- Methods to simplify 3D coils and configuration

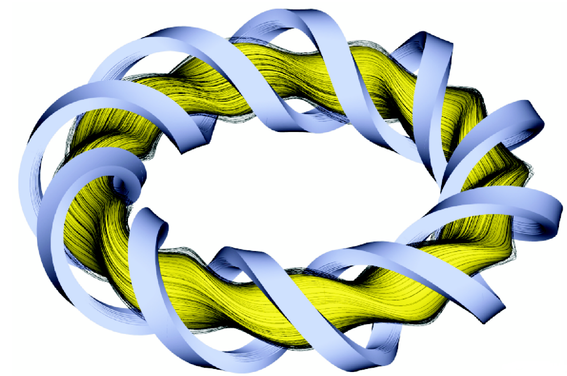
US is highly-sought collaborator on international stellarators, to apply our expertise and tools.

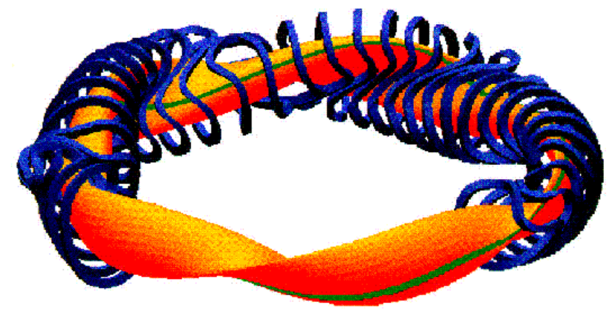
Is there a Niche for the US?

Japan and EU have large stellarator programs.

What opportunity is there for US leadership?

- LHD: Helical coil optimization; A~6;
  conflict between good
  confinement & MHD stability
- W7X: quasi-isodynamic; A~11
  good confinement & stability β~5%
  strong flow damping
- Both have strong helical divertor programs





US roles:

Quasi-symmetry (QA, QH, QP): tokamak like transport

Lower aspect ratios. Optimization for higher β & conf.

Strategies to simplify coils.

Needed Elements for US Program

Need to act on discoveries and innovations

- Use solutions to make fusion practical & timely
- Validate and test theoretical and numerical predictions

Recommendation: Evolve a substantial US program element on 3D shaping to accomplish US goals, in addition to AT/ST

- Will simplified coil strategies work for optimized 3D shaping?
- Can integrated high performance be achieved? How high?
- Predictive modeling capability for 3D configurations?
- Is there a practical 3D divertor design?

(FESAC-TAP & ReNeW)

Need medium-scale experiment, strong theory, & design programs.

Need to have results to inform decisions and designs for next steps.