Pulsed High Temperature Superconducting Central Solenoid For Revolutionizing Tokamaks

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Team members and roles

Commonwealth Fusion Systems

- Bob Mumgaard – Principle Investigator
  - CEO, Commonwealth Fusion Systems
  - MIT PhD, Applied Plasma Physics
- Brandon Sorbom – R&D Manager
  - CSO, Commonwealth Fusion Systems
  - MIT PhD, Nuclear Science & Engineering
- Justin Carmichael – Mechanical Engineer
  - 15 years ORNL, Fermilab, Argonne
- Joy Dunn – Manufacturing Engineer
  - 10 years SpaceX, Senior Manager of Dragon Manufacturing
- Charlie Sanabria –Test Engineer
  - LTS engineer at NHFML & LBNL
  - FSU PhD, Superconducting Materials

Partners

- Dennis Whyte – Advisory Committee Leader
  - Director, MIT Plasma Science and Fusion Center
- Nicolai Martovetsky – R&D Adviser
  - Chief Engineer and R&D Manager, Lawrence Livermore National Lab, US ITER Central Solenoid
- Rod Badcock – Optical Fiber Quench Detection Adviser
  - Deputy Director, Robinson Research Institute
- Maxim Marchevsky – Acoustic Quench Detection Adviser
  - Research Scientist, Lawrence Berkeley National Laboratory
- Kathleen Amm – Test Facilitator
  - Division Head, Brookhaven National Laboratory Superconducting Magnet Division

Goals and Motivation for Pulsed HTS Central Solenoid

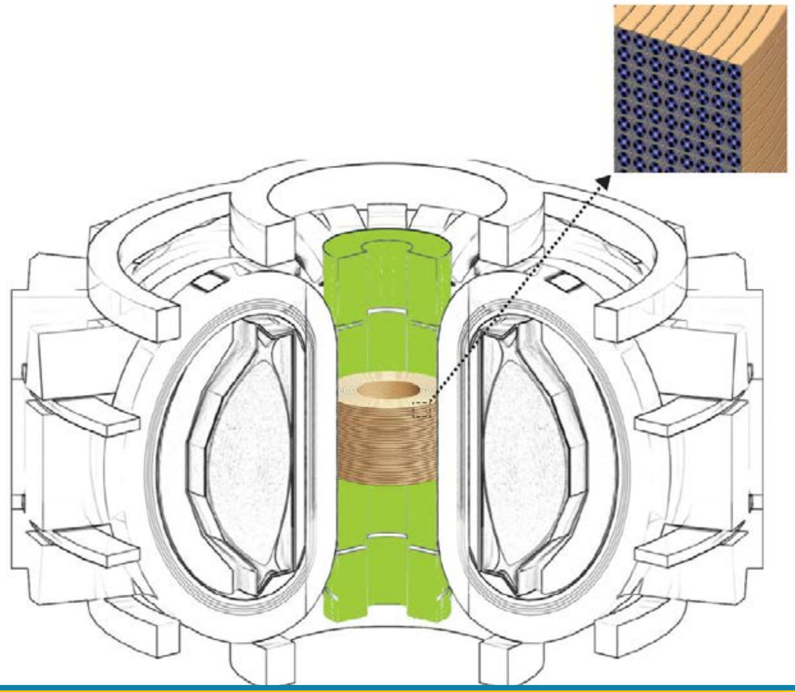
Goal

- Build a fast-ramping, high-field, high-temperature superconducting central solenoid model coil.
- Prove that a full-scale HTS CS can drive all of a power plant's plasma current.

Motivation

- LTS CS current density & B-field are too low to drive plasma current in an economically viable device.
- This forces power plant tokamaks to be steady state, have expensive external current drives, and use risky physics.

Metric	State of the Art	Proposed
Coil Peak Field	10 T	20 T
Coil Ramp Rate	0.4 T/s	4 T/s
Coil Current Density	20 A/mm^2	85 A/mm^2



For example ITER is currently:
Qualified to 30,000 cycles
Ramp-up consumption: 240Vs
Flatop consumption: 0.075V
Solenoid: 13T CS giving 277Vs
= *400s inductive burn*
Now replace with an HTS CS:
= *4000s inductive burn*
If back-to-back giving ~5 years of continuous operation!
ITER is now a reactor! No non-inductive current drive needed

CHANGING WHAT'S POSSIBLE

Tasks, risks, milestones, and outcomes

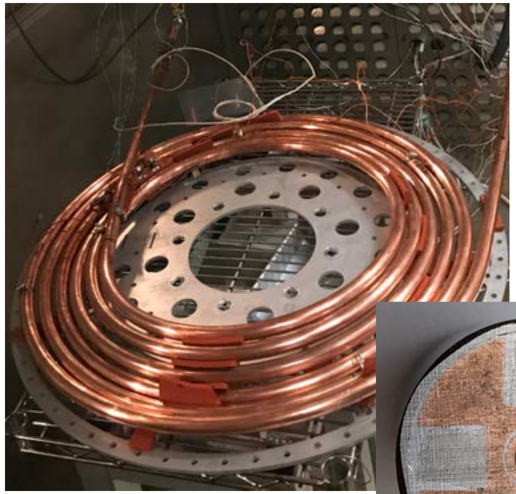
Low-loss Superconducting Cable and Joints
- CFS has developed VIPER HTS cable and joints and fully qualified them at SULTAN.
- VIPER cable shows minimal Ic degradation w/ hundreds of IxB cycles at 11 T, 50 kA.
- PIT VIPER is an evolution of VIPER that will achieve low AC losses suitable for CSMC.

Quench Detection
- Integrated fiber-optic quench detection has been qualified on VIPER with 100 ms detection times.
- Will be scaled to longer PIT VIPER cable lengths.

Manufacturing
- Automated former extrusion, tape insertion, jacketing and winding processes will be developed.
- Quench detection, pulsed power, cryogenics, insulation, and low loss joints benefit from other coil projects.

Integration
- Full scale coil build and integrated into SPARC.

PIT VIPER will reduce AC losses of VIPER cable by > 10x, enabling robust HTS cable in high dB/dt environment.



Short VIPER cable fabrication. This will be scaled and automated for CSMC PIT VIPER.

First tests of optical fibers on 3m VIPER cable. CSMC will develop reliable, rapid (< 0.75s) quench detection in high noise (voltage, temperature, strain) environment.

Techno-economic metrics and impact: Simple tokamaks

- Creates new fusion design space.
- Complex, expensive external current drive systems can be avoided.
- Avoid the necessary enhanced confinement and active control needed due to non-inductive current drive
- Enables HTS PF magnet. All-HTS tokamak design unifies, simplifies engineering systems.
- Enables simpler, more compact and less expensive RFP, FRC, and spheromak concepts.