

QUASi-Axisymmetric Research (QUASAR) Experiment

The ability of the facility to contribute to world-leading science in the next decade (2014-2024)

Grade: (b) - important

QUASAR is a new facility to (1) solve two crucial problems for fusion, namely, disruptions and steady state, and (2) understand the role of magnetic symmetries in plasma confinement. It will use the innovative principle of quasi-axisymmetry to produce and understand the properties of plasmas that simultaneously are disruption free, steady-state with low recirculating power, stable at high pressure, high confinement (similar to tokamaks), and smaller size than other stellarators. Quasi-axisymmetric configurations are theoretically predicted to have good confinement. The QUASAR design merges the high confinement property of the tokamak with the stability and steady-state properties of the stellarator.

QUASAR will study of the role of magnetic symmetry in plasma confinement. One important property is the ability to confine plasma at high plasma pressure as a result of a design optimization process that eliminated all known large-scale plasma instabilities. An important prediction of quasi-axisymmetry is the ability to support relatively large plasma flows, which in tokamaks, have been shown to suppress the small-scale instabilities that lead to turbulent energy loss. The underlying similarity in symmetry between the quasi-axisymmetric stellarator and the axisymmetric tokamak has enabled the knowledge gained in tokamak research to be applied directly to the design of the QUASAR device. The conceptual advance of designing an externally controlled plasma equilibrium to meet a set of physics criteria was made possible by high-performance computing, an important continuing task. The QUASAR experiments will validate the extensive numerical models and optimization methods used in its design.

The QUASAR facility fills a critical gap in world fusion research. No stellarator in the world is based on the principle of quasi-axisymmetry. Existing stellarators, particularly Wendelstein 7-X in Germany, exploit advanced optimization strategies, but without the strong physics overlap with tokamaks that allows the quasi-axisymmetric stellarator to build on tokamak advances, including those from ITER. The QUASAR symmetry principle also permits more compact confinement, similar to that of tokamaks. The uniqueness of the QUASAR design will place it, alongside the much larger stellarators in Germany and Japan, as a leadership-class fusion and plasma physics experiment worldwide.

The readiness of the facility for construction

Grade: (a) - ready to initiate construction

The QUASAR facility will employ the device components that were developed as part of the National Compact Stellarator Experiment (NCSX) project, which was terminated in 2008. Potential modifications to the NCSX design would be limited to minor changes to the shaping capability (the trim coils), required to achieve targeted nearby equilibria that are predicted to have substantially-reduced turbulent losses.

An extensive body of documentation has been developed that addresses the remaining construction activities, including a detailed assembly plan and risk assessment. An international engineering review in 2007 confirmed the feasibility of completing construction, based on the demonstration of certain critical assembly operations. The most challenging components have already been fabricated (modular coils, vacuum vessel sectors, toroidal field coils) and critical assembly operations demonstrated. Ideas for simplifying the assembly process have been identified.

Scientific community considerations

The need for a quasi-axisymmetric plasma confinement facility has long been recognized by the U.S. and international fusion communities. In 2001, a positive physics validation review of the NCSX project

affirmed the design principles of the compact quasi-axisymmetric design of NCSX. The NCSX project was positively reviewed by the Fusion Energy Sciences Advisory Committee both in 2001 and again in 2007. It was described in the FESAC report *Priorities, Gaps, and Opportunities: Towards A Long-Range Strategic Plan for Magnetic Fusion Energy* (October 2007). It was further described in the report *Research Needs for Magnetic Fusion Energy* (2010), which resulted from a community exercise that culminated in a research needs workshop (June 2009).