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Physics progress of Reversed Field Pinch magnetic confinement

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Over the last decade, the international RFP community has made large strides understanding key physics challenges for plasma confinement with weak external magnetization. This progress fundamentally changes the fusion outlook for the RFP. In several areas, resolving the RFP's fusion challenges is simultaneously advancing basic plasma physics, with potentially large impact in astrophysics. For example, the magnetic dynamo in the RFP reveals how large-scale instabilities can efficiently transport magnetic energy. An understanding of MHD tearing that supports dynamo action inspired current profile control. This produces a ten-fold improvement in confinement, comparable to a same-size, same-current tokamak. A recent push to higher plasma current reveals remarkable self-organization to a helical equilibrium, or quasi-single-helicity dynamo state, that also exhibits improved confinement. These controlled and spontaneous transitions from high to low levels of magnetic chaos probe transport in a stochastic magnetic field, the natural state of the field in astrophysical settings. High temperature ions >1 keV are observed, heated during magnetic reconnection events. This is reminiscent of non-collisonal heating in the solar atmosphere. Coupled with current profile control, improved confinement with multi-kilovolt temperature electrons and ions is demonstrated. Active control of the magnetic boundary is now routine to stabilize many resistive wall modes in pulse lengths >10 times their growth rate, an essential need for the RFP and likely other high beta configurations. Few options exist for steady-state current sustainment in fusion plasmas. One is Oscillating Field Current Drive, based on magnetic helicity conservation principles that underpin magnetic self-organization. Partial OFCD sustainment experiments so far agree with the self-organization physics basis. This work is supported by the US DOE and NSF.