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Formation of a Long-Lived Hot Field Reversed Configuration by Merging Two Colliding High-β Compact Toroids

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A new compact toroid (CT) device, C-2, has been built to form and sustain fusion-relevant field reversed configurations (FRC), one of the simplest magnetic confinement entities with average β (ratio of average plasma to magnetic pressure inside the separatrix) ~10. High temperature FRCs are produced in C-2 by dynamically merging two oppositely directed, highly supersonic high-β deuterium plasmoids preformed by the conventional θ-pinch technology, achieving record lifetimes of over 2 ms based on external diamagnetic measurements, with plasma diameter $\sim$ 1 m, poloidal flux $\phi_p \sim 15$ mWb, electron density $n_e \sim 10^{20}$ m^{-3}, and $T_i + T_e > 0.5$ keV. Most of the kinetic energy is converted into thermal energy upon collision, predominantly going into the ion channel: $T_i \sim T_e \sim 30$ eV before merging, while $T_i \sim 4.5T_e$ with $T_e \sim 100$ eV after merging, as derived from radial pressure balance and multi-chord, muli-pulse Thomson scattering measurements. Such high ion temperatures are also consistent with Doppler spectroscopy and neutron measurements. Strong poloidal flux amplification occurs during the merging process with a flux amplification factor exceeding 10, the highest ever obtained in a magnetic confinement system. Both temperatures and poloidal fluxes of the merged FRCs depend strongly on the speed of the initial individual plasmoids, favoring fast translation. The dynamics of the merging/reconnection process of the translated CTs are reproduced, for the first time, by a newly developed 2-D resistive magnetohydrodynamic code, LamyRidge. What is even more remarkable is that the final merged FRC state exhibits a dramatic improvement in transport with flux confinement times approaching classical values. The formation of such a well-confined, long-lived, high-β plasma state via collisional merging and magnetic reconnection should be of wide interest to fusion energy sciences and basic plasma physics research.