Is Laser Cooling for Heavy-Ion Fusion Feasible?

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Heavy-ion beams, each with current in the kiloampere range and particle energy in the gega-electronvolt range, must be focused onto a millimeter-size spot to provide the power required for ignition of high-gain targets for inertial confinement fusion. However, the focal spot size is always enlarged by chromatic aberration generated by the thermal spread of the beam ions in the direction of beam propagation. Enlarged focal spot degrades the target performance. For high-current beams, conventional remedy for chromatic aberration using sextupole magnets has shown to be ineffective.[1] If novel correction schemes can be found, then the spot size can be reduced to below that previously believed possible. Smaller spots can mean lower pulse energy targets and the heavy-ion fusion scenario can look more attractive. Success in laser cooling of ion beams in storage rings has led us to explore the feasibility of applying laser cooling for heavy-ion fusion, and the recirculator configuration proposed for heavy-ion fusion appears to be well suited for this purpose. However, using particle-in-cell simulations and theoretical arguments, we demonstrate in this paper that although laser cooling of heavy-ion beams is feasible in principle, the rapid velocity-space diffusion of ions in the bump-in-tail distribution, set up by the cooling lasers, limits the velocity-space compressibility of the thermal spread along the beam. Consequently, laser cooling is impractical for high-current, heavy-ion beams for the proposed recirculator configuration. Nevertheless, if the recirculator architecture or the target requirement can reduce the beam current, then the cooling scheme described here should work.

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[1]Ho, D. D.-M. and Crandall, K. R., *Bull. of the Am. Phys. Society* 37 (1992) 1531.