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Microcavity Implosions for Generation of Ultrahigh Electric Fields and Megatesla Magnetic Fields

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Microcavity implosions driven by multiple ultraintense laser pulses enable new regimes of strong electric and magnetic field generation. Laser irradiation of a target with an embedded micron-scale void generates a population of hot electrons which fill the void, driving implosion of the cavity. When the implosion is symmetric, the collapse of ions to the target center is accompanied by the generation of a strong electric field. In the case of spherical microbubbles, the resulting electric field is predicted to reach the extreme values needed to observe high-field phenomena such as vacuum polarization. Cylindrical microtube implosions, while less favorable for electric field production, generate strong axially-oriented magnetic fields, and can additionally amplifying applied fields, offering a path towards megatesla magnetic fields. The development microcavity implosion platforms would introduce new capabilities in extreme electric field and ultrahigh magnetic field generation for both high-field physics and magnetized high energy density plasma experiments. The scientific goal of this work is to verify the aforementioned promising theoretical predictions and develop microcavity implosions as an experimental platform for accessing high-field, QED, and Astrophysically relevant electric and magnetic fields.

The interaction of an ultraintense laser pulse with an opaque target produces a large population of hot electrons which can be leveraged to drive implosions in targets containing voids, as shown schematically in Figure 1. Implosion of the void is driven by charge separation between the hot electrons entering the void and the iniatially cold ions at the inner surface. When the void has a radially converging configuration such as a spherical bubble or a hollow cylinder, the imploding ion population can overshoot the electron density at the void center, generating a large, transient outward-directed electric field [1, 2].

In addition to strong electric fields, strong magnetic fields can also be generated by micron-scale implosions [3-5]. Axial magnetic field production in an originally non-magnetized microtube target is seeded by laser-induced spatial non-uniformities in the hot electron population. Magnetic field generation in this configuration may complement field generation by planar targets as an experimental platform for magnetic reconne- ction. In addition, microtube implosions are capable of significant magnetic field amplification.

A fundamental requirement of the described implosion process is substantial hot electron generation. The predicted laser intensities required to approach the Schwinger limit or to produce megatesla magnetic fields are on the order of 10^{22} - 10^{23} W/cm^2 [2, 3]. These predictions will require further verification by fully self-consistent simulations accounting for the details of the laser-driven hot electron production. The presence of strong electric fields may be diagnosable via the generation of energetic ions from the implosion [1, 2]. Megatesla magnetic field generation may require applied magnetic fields above 1 kilotesla – a higher amplitude than is currently available.

References

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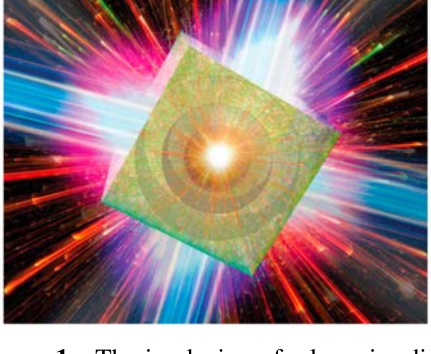

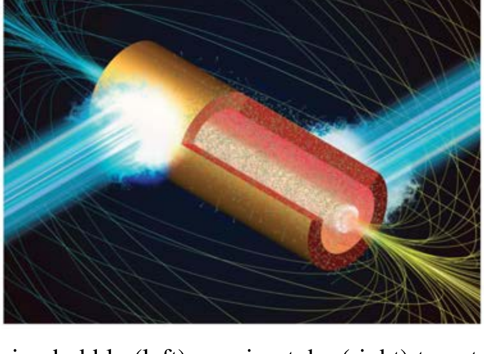

Figure 1 The implosion of a laser-irradiated microbubble (left) or microtube (right) target is accompanied by the production of extreme electric fields and can also deliver ultrahigh magnetic fields.