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Next Generation High Brightness Electron Beams From Ultra-High Field Cryogenic Radiofrequency Photocathode Sources (12' + 3')

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Recent studies of the performance of radio-frequency (RF) copper structures operated at cryogenic temperatures have shown a dramatic increase in the maximum surface electric field that may be reached. We propose to utilize this development to enable a new generation of photoinjectors operated at cryogenic temperatures that may attain, through enhancement of the launch field at the photocathode by a factor of four, well over an order of magnitude increase in peak electron beam brightness. We present detailed studies of the beam dynamics associated with such a system, concentrating on an emittance-compensated S-band photoinjector that may directly substitute that of the LCLS X-ray free-electron laser. We show in this case that the increase in brightness leads directly to a factor of two reduction in gain length, with attendant increase in X-ray radiative efficiency. Extreme low emittance scenarios obtained at low operating charge, appropriate for dramatically pushing performance limits of ultrafast electron diffraction and microscopy experiments, are reviewed. Further, a scheme for achieving very low, asymmetric emittances for eliminating the electron damping ring in an linear collider is discussed. While much of the gain in brightness is due to increase of the emission current density via field enhancement, further increases in brightness due to lowering of the intrinsic cathode temperature in cryogenic operation is also enabled. The potential to probe fundamental brightness limits in these cold, dense beam systems is examined. Issues in experimental implementation, including cavity optimization for lowering cryogenic thermal dissipation, external coupling, and cryo-cooler system are discussed.

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