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Ultra-High Brightness Electron Beams From Very-High Field Cryogenic Radiofrequency Photocathode Sources

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Recent investigations of RF copper structures operated at cryogenic temperatures performed by a SLAC-UCLA collaboration have shown a dramatic increase in the maximum surface electric field, to 500 MV/m. We examine use of these fields to enable very high field cryogenic photoinjectors that can attain over an order of magnitude increase in peak electron beam brightness. We present beam dynamics studies relevant to X-ray FEL injectors, using start-to-end simulations that show the high brightness and low emittance of this source enables operation of a compact FEL reaching a photon energy of 80 keV. The preservation of beam brightness in compression is discussed. Also, extreme low emittance scenarios obtained at low charge, appropriate for pushing performance limits of ultrafast electron microscopy experiments, are reviewed. While the gain in brightness at high field is due to increase of the emission current density, further increases in brightness due to lowering of the intrinsic cathode emittance in cryogenic operation are also enabled. The potential to probe fundamental brightness limits in these cold, dense beam systems is examined. Issues in experimental implementation, including: dark current suppression, cavity optimization for cryogenic thermal dissipation, external coupling, and cryo-cooler systems are discussed.

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