Observation of Pulsed Field-Emission from a Carbon-Nanotube Cathode a HBESL (E-1023)*

[on-going work]


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High-Brightness Electron Source Lab (HBESL)

• **Mission:** R&D on e-sources and lasers

• **Facilities:**
  – ultra-fast laser system
  – 1.3-GHz RF gun+ beamline

• **Recent/on-going experiments:**
  – 2-photon e- emission from Cs$_2$Te,
  – field-emission from diamond arrays,
  – high-current field-emission from CNT
  – VUV light via inverse Compton scatt.
  – tailored e- bunch with laser spatio-temporal shaping.

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Field Emission (FE) & Carbon-nanotube (CNT) Cathodes

- Current density

\[ j(t) = A(\phi)\beta_e^2 E_z(t)^2 \exp\left( -\frac{B(\phi)}{\beta_e E_z(t)} \right) \]

- FE is appealing: no need for an ultra-stable auxiliary laser system

- Single emitter \(\rightarrow\) small transverse emittances

- Array of field emitters \(\rightarrow\) high current w. reduced beam quality, or patterned beams

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Pulsed field emission

- Pulsed field emission can be realized by locating the field emitter in a $t$-dependent field
- single-frequency RF gun not ideal: rms emission time is
  $$\sigma_t \sim \omega^{-1} \left[ \beta_e E_0 / B(\phi) \right]^{1/2}$$
- experiments at HBESL uses a 1.3-GHz gun…

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Experimental setup

[Image of experimental setup with annotations]

Mo cathode holder
Cathode substrate
rf gun
Cathode mount for DC tests
forward- and reflected-power diode signals
dipole magnet
e-bunch
solenoidal lenses
electromagnetic pick-up

[see also J. Hartzell et al., Proc. NAPAC’13 (2013)]
Fowler-Nordheim plot

radiabeam (DC test)
50 mA for 14 MV/m
(cathode #5)

about 22 MV/m
macroscopic field

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Beam current + beam density

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Observation of pulsed field emission

- electromagnetic pick-up located downstream of the electron source used to detect bunch e.m. fields
- observed 1.3 GHz and harmonic (up to 4th harm).
- inferred bunch length is ~ 50-70 ps
- no significant dependence on applied E field
Summary/Future

- Preliminary data on field emission from carbon-nanotube cathode are encouraging
- Current in excess of 300 mA have been observed
- Current stability was measured to be <5% over ~4 hours
- Smaller-area cathode being prepared at CNSI
- Next round of tests (June) will focus on beam emittance measurements
Credits

• At Fermilab the following people crucially contributed to the success of this experiment:
  – P. Prieto and H. Pfeffer (fixed our pulse transformer),
  – J. Reid, and T. Kubicki (RF support)
  – N. Eddy (fast scope)

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• NIU Grad. students: F. Lemery, B. Blomberg (cathode installation, RF measurements)