UCLA Pegasus advanced photoinjector laboratory

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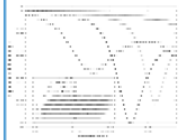
Femtosecond relativistic electron diffraction

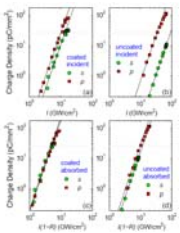
This is a novel technique capable of study matter at the atomic scale with ultrafast temporal to resolution: ultrafast relativistic electron diffraction. By using relativistic energies the Pegasus beams can be 1000 times more intense than the ones used in non relativistic electron sources enabling study of irreversible ultrafast processes by single-shot diffraction patterns.

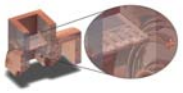
- Pegasus is the first photoinjector laboratory which has demonstrated the use of a relavistic electron beam to study an ultrafast process (laser-induced heating and melting of a thin gold sample) by single-shot diffraction patterns. APL **97**, 063502 (2010)
- Continuously time-resolved MeV diffraction. In this scheme, we use an X-band RF deflector to streak a long electron beam after it has been diffracted by a laser-pumped gold sample. The result is that we obtain in a *single image* the entire time-history of the process. The temporal resolution which in the first experiments was 400 fs, is only limited by the deflector configuration (and not by the beam bunch length). J. Appl. Phys. 108, 114513 (2010).

Source and cathode development

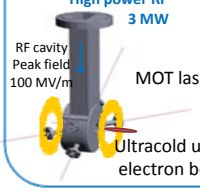
- ❑ Polarization effects in multiphoton photoemission. Oblique incidence.
- ❑ Plasmon assisted multiphoton photoemission. Collaboration with LBNL Padmore group.
- ❑ Solid free-form fabricated cathodes. Collaboration with Radiabeam Technologies.
- ❑ Modification to cathode assembly to allow compatibility with nanofabrication facilities and novel cathode testing
- ❑ Beyond conventional cathodes: Ultracold electron source development (with Prof. Hudson @ UCLA).







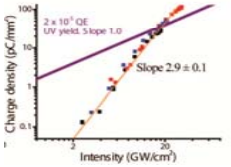
- SFF copper cathode cathode recently successfully tested at UCLA's Pegasus photoinjector under high RF power



Ultrashort laser pulses in RF photoinjectors

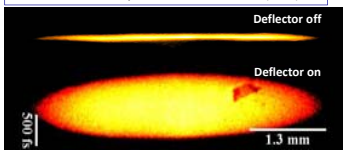
- ➢ High charge: Blow-out regime of operation of RF photogun.Strong space-charge expansion
  - Generation of uniformly filled ellipsoidal beam distributions
  - Linear phase spaces & High beam brightness !
  - Mlultiphoton photoemission.
- ➢ Low Charge: Ultrashort e-beam generation for FRED

P. Musumeci et al., Phys. Rev. Lett, 104, 084801 (2010)

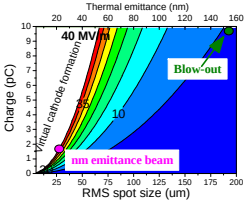


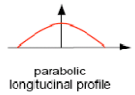
Parameter	Value
Laser pulse length	35 fs (rms)
Peak field on the cathode	80 MV/m
Beam energy	3.5 MeV
Beam charge	20 pC (blow-out) 1.6 pC (FRED)
Injection phase	25 degrees
Beam emittance	0.7 mm-mrad
Bunch length	100 fs rms (FRED)

P. Musumeci et al. , *Phys. Rev. Lett.* **100**, 244801 (2008)

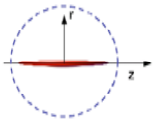


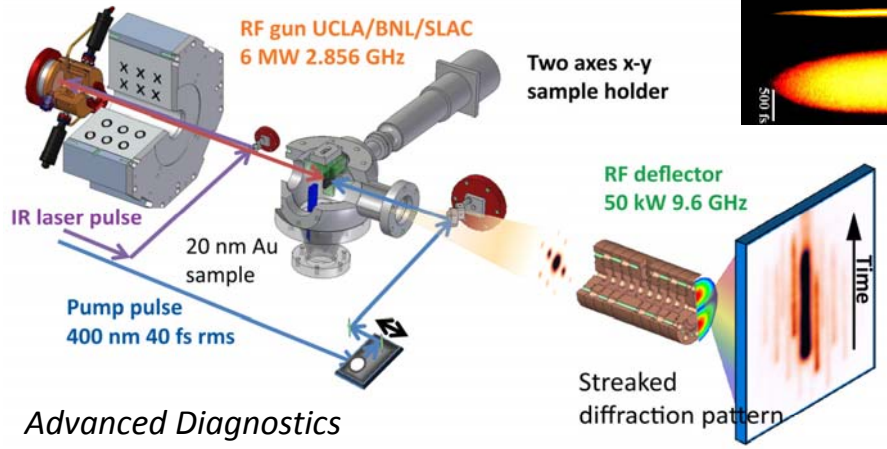
Cigar beams





Uniformly filled ellipsoidal distribution by space charge transverse expansion





Non linear longitudinal space charge oscillations in relativistic electron beams

Start with e-beam modulated at the cathode.

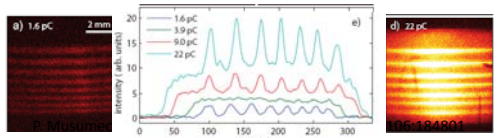
By increasing charge, modulation washes out.

After a ¼ plasma period, beam distribution is completely flat (shot noise suppression techniques).

After ½ plasma oscillation, linear theory predicts modulation to come back.

Non linear theory is even better.... Modulation comes back with increased harmonic content and enhanced peak current !!!

Musumeci et al., PRL 106:184801, 2011



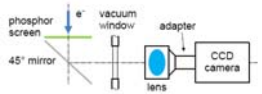
P. Musumeci et al., PRL 106:184801 (2011)

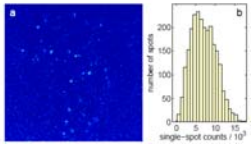
Advanced Diagnostics

Single electron detection

- 4 MeV e- deposits 40 keV in 100 um thick fluorescent screen.
- Calculate fluorescence efficiency + collection efficiency
- ~100 photons per MeV electrons arrive to CCD camera.

R. K. Li et al., submitted to JAP

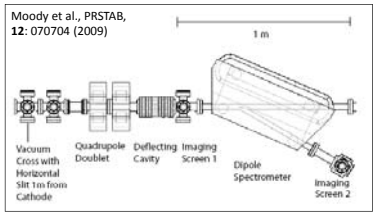




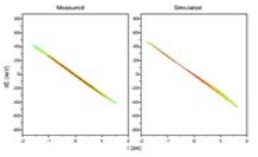
- Ultralow charge beam measurements.
- Ultrafast relativistic electron diffraction.

Longitudinal Phase Space Measurement

Moody et al., PRSTAB, **12**: 070704 (2009)



- Control the induced energy spread from the cavity as predicted by Panofsky-Wenzel theorem
- Record resolution in time (50 fs) and energy (1 keV).



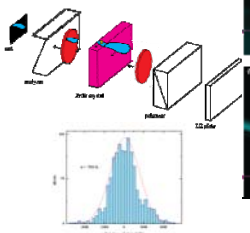
Very linear phase spaces

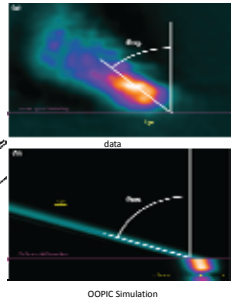
High 6D beam brightness

< 0.5 um longitudinal emittance

90 degrees Electro-Optic Sampling

Scoby et al., PRSTAB, 13, 022801 (2010)

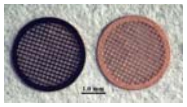


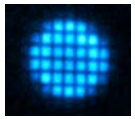


Sub 0.1 mm-mrad emittance measurements

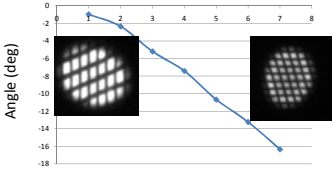
- Dark field pepper-pot technique.
- Same information as pepper-pot technique.
- Great diagnostics for 4D transverse phase space.

Use TEM grid as "pepper-pot





Correction of skew quadrupole at the gun exit



Pegasus upcoming upgrades

- Laser upgrade 2 TW 100 mJ/50 fs
  - 20 MW @ THz power
  - Pump irreversible phase transition.
  - Inverse Compton Scattering. Create LCLS photons
  - External injection. Create linear plasma wakes with 2 TW + inject RF photoinjector generated beam.
- RF hybrid gun
- Coupled-slot linac accelerating section
  - 15 MeV energy
  - RF compression