# **E-886** (Piot) **Advanced Accelerator Physics Experiments at the Fermilab/NICADD Photoinjector Laboratory (FNPL)**

*Chicago, DESY, Fermilab, Georgia, INFN-Milano, LBNL, Northern Illinois, Rochester, UCLA*

**Status:** *Data-Taking*

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The Fermilab/Nicadd[1] Photoinjector Laboratory (FNPL) jointly operated by Northern Illinois University and Fermilab, is available for experiments by any interested group. Proposals for new experiments are evaluated by the FNPL Advisory Committee chaired by K.-J. Kim of the University of Chicago (see http://nicadd.niu.edu/fnpl for details).

**Existing equipments and capabilities:**

The FNPL consists of a 1+1/2 cell L-band rf-gun equipped with a high quantum efficiency Cesium-Telluride photocathode allowing the photoemission of electron bunches with charge up to approximately 15 nC). The thereby generated bunches are further accelerated, up to 16 MeV, by a downstream TESLA-type superconducting accelerating cavity operating with a nominal accelerating gradient of approximately 12 MV/m. Downstream of the TESLA cavity the beamline includes a set of quadrupoles and steering dipoles elements for beam focusing and orbit correction, a skew quadrupole channel that allows the generation of flat beam using an incoming angular-momentum-dominated beam. The beamline also incorporates a magnetic bunch compressor chicane which can enhance the bunch peak current up to approximately 2.5 kA. The diagnostics for measuring transverse beam properties consist of electromagnetic beam position monitors, optical transition radiation screens (for measuring beam transverse density) and three emittance measurements station based on the multi-slit mask technique. The bunch length measurement is performed by a streak camera that streaks optical transition radiation pulses emitted by the bunch. An alternative frequency-domain bunch length diagnostics based on Martin-Puplett interferometry of coherent transition radiation is also available. Downstream of the beamline, the beam can be bent in a dispersive section, to measure the beam energy distribution, or transported in a straight ahead user experimental area.

The FNPL facility can be operated remotely and to date teams from LBNL, and DESY have used this capability to remotely perform beam physics experiments.

**Research activities for FY2004:**

***Theory and simulations:***

Modeling and numerical studies have primary focused on the beam dynamics associated to the flat beam generation along with improved numerical tools for optimizing the flat beam production. Our best result indicates that FNPL, in its present configuration, should be able

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1 NICADD is an acronym for North Illinois Center for Accelerator and Detector Development

to generate flat beam with transverse emittance ratio above 300 (for a bunch charge of 0.5 nC).

An analytical model of the limiting effects in the round-to-flat beam transformation was developed and benchmarked against various numerical simulations (Astra, Elegant and Synergia/ImpactZ). The model includes chromatic effects and non axi-symmetric incoming magnetized beams, efforts are on-going to also incorporate linear transverse space charge.

Numerical simulations of the impact of non-uniform transverse photocathode drive-laser distribution were incorporated in the modeling. Simulations performed for the case of round beams, suggest a possible degradation of beam emittance by a factor ~3 compared to the nominal case (Uniform distribution) when considering non-uniformity similar to those measured on our laser transverse distribution.

***Experimental activities:***

Many improvements on the photocathode drive laser were performed: an on-line CW autocorrelator was rebuilt and commissioned making the characterization of the laser oscillator pulse length upstream and downstream of the fiber stretcher possible. A new frequency quadrupling test optical line has been installed and has been used to try to optimize the conversion efficiency from infrared ( =1024nm) to ultraviolet ( =262nm). The data on conversion efficiency are also being used to benchmark a semi-analytical model. A simple version of an interferometric pulse stacker was developed and used to produce a two-macroparticles bunch. Such a bunch allowed the investigation of the longitudinal focusing property of the rf-gun and the TESLA superconducting cavities. Finally the ~20 m long transport line that brings the laser from the laser room to the accelerator enclosure was modified to perform as an optical imaging system. Such an improvement should improve alignment tolerance on the interferometric pulse stacker and will also provide a tool to control and quantify the impact of transversely shaped laser spot on the electron beam parameters.

Significant progress on the flat beam experiment were reported: a systematic studies of an angular-momentum-dominated beam produced in a photoinjector was performed and the dependencies of angular momentum on initial conditions (photocathode drive laser transverse size, axial magnetic field on the photocathode) were all measured and checked against theory and numerical simulations. We developed and exercise procedures to remove the angular momentum of the incoming angular-momentum-dominated electron beam and generate a flat beam. These improvements resulted in more reproducible flat beam conditions and measurements. At the end of 2004 we were able to reproducibly obtain flat beams with transverse emittance ratios above 50; our record being set to an emittance ratio of 75±5 for a bunch charge of 0.5 nC. We believe this measured emittance ratio is still limited by spurious dispersion introduced by dipole correctors. Such a spurious dispersion results in an overestimate of the smallest of the flat beam emittance. We are currently improving the dispersion correction.

The optical transition radiation monitors were upgraded to incorporate digital cameras; such an upgrade resulted in an improvement by a factor of two for the resolution on the beam transverse size measurements. The limitations of the bunch length diagnostics based on Martin-Puplett interferometry of coherent transition radiation have been investigated: two types of infrared detectors were tested and a measurement of the pyro-electric detector frequency response was performed using the electron beam signal.

A team from UCLA installed a new plasma wake-field experiment aiming to produce 1 MeV electron bunch based on self-trapping of plasma electrons using a steep plasma density transition. A first experiment occurred during spring 2004. However, due to beam stability issues and large chromatic-induced emittance dilution as the beam is being compressed, the experiment was not conclusive. Improvements of the experiment are under consideration. In the meanwhile the experimental set-up is being used to study transverse focusing by a plasma lens operating in the under-dense regime.

In parallel to the FNPL experimental program, we worked on the development of a polarized electron source based on an rf-gun. The major challenges being to sustain the high quality vacuum ($10^{-11}$ tor) needed for operating a Gallium Arsenide photocathode in the rf-gun. Such a low pressure can be reached by cooling the rf-gun to Nitrogen temperature. Preliminary cooling tests and pressure measurements were performed.

***Changes to the list of personnel:***

UCLA:
- THOMPSON MATT is now Physicist (Ph.D)

DESY:
- CARNEIRO JEAN-PAUL should be removed

FERMILAB:
- DESLER KAI and HUENING MARKUS should be removed
- FLILLER RAY should be added as Physicist (Ph.D)
- KAZAKEVICH GREGORY should be added as Physicist (Ph.D)
- KOETH TIM should be added as Graduate Student

NIU:
- BAROV, NIKOLAI should be removed

UNIVERSITY OF ROCHESTER:
- LI, JIANLIANG should be added as Physicist (Ph.D)

***publications for 2004:***

Y.-E Sun, P. Piot, K.-J. Kim, N. Barov, S. Lidia, J. Santucci, R. Tikhoplav, J. Wennerberg, "Generation of angular-momentum-dominated electron beam from a photoinjector," Physical Review Special Topics - Accelerators and Beams 7: 123501-1 - 123501-7 (2004).

Y.-E Sun, K.-J. Kim, P. Piot, "Limiting effects in the round-to-flat beam transformation," Prepared for 22nd International Linear Accelerator Conference (LINAC 2004), Lubeck, Germany, 16-20 Aug 2004. Fermilab preprint fermilab-conf-04-212-ad .

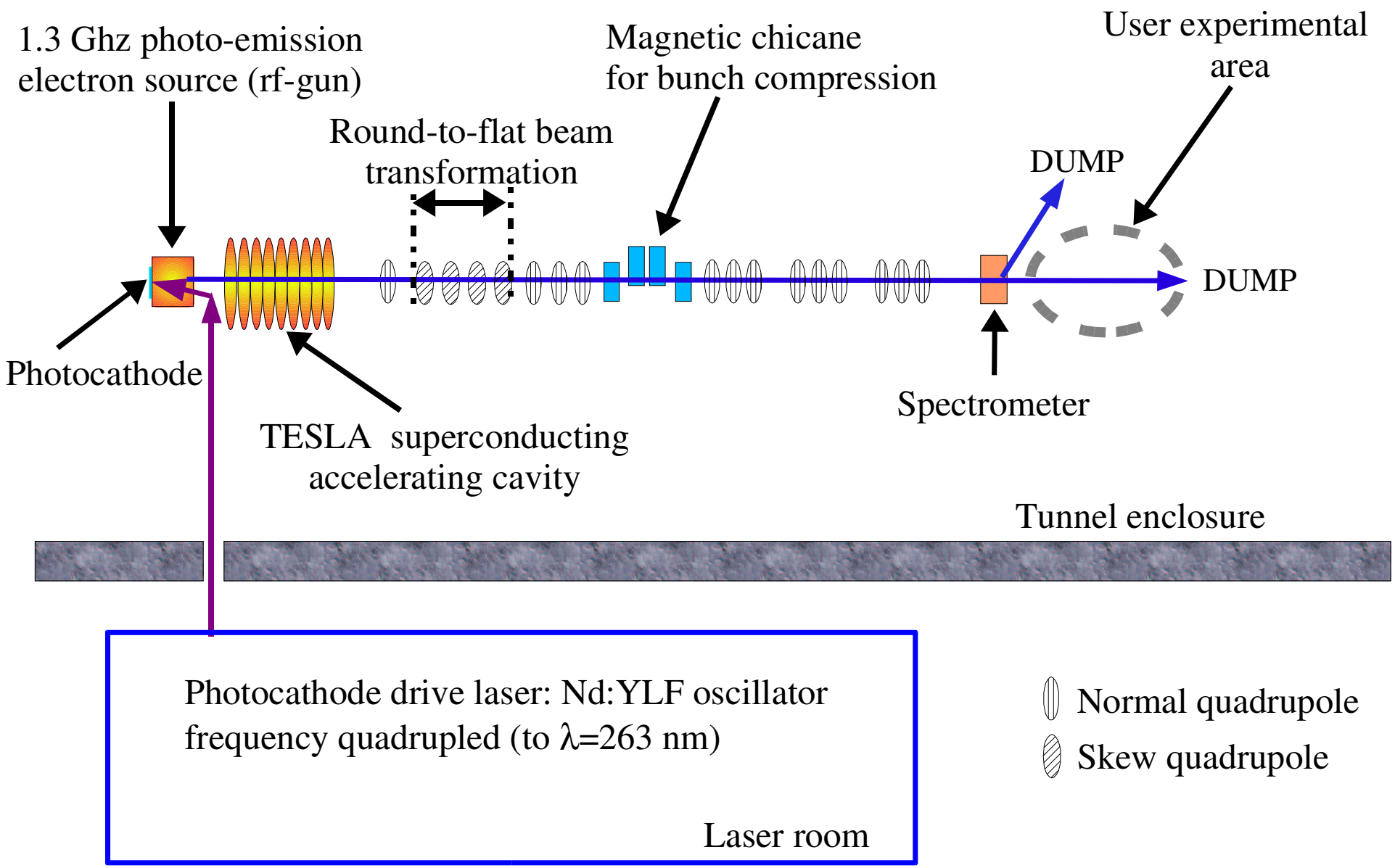
Y.-E Sun, K.-J. Kim, P. Piot, H. Edwards, K. Desler, M. Huening, J. Santucci, J. Wennerberg, N. Barov, R. Tikhoplav, S Lidia, " Progress report on the flat beam experiment at Fermilab/NICADD photoinjector laboratory," Prepared for 22nd International Linear Accelerator Conference (LINAC 2004), Lubeck, Germany, 16-20 Aug 2004. Fermilab preprint fermilab-conf-04-192-ad .

R. Tikhoplav, A.C. Melissinos, P. Piot, N. Barov, D. Mihalcea," Investigation of the longitudinal beam dynamics in a photoinjector using a two-macroparticle model," Prepared for 22nd International Linear Accelerator Conference (LINAC 2004), Lubeck, Germany, 16-20 Aug 2004. Fermilab preprint fermilab-conf-04-191-ad .

M.C Thompson,J.B Rosenzweig,G. Travish,N. Barov,H. Edwards,P. Piot,J. Santucci,R. Tikhoplav," Status of the UCLA/NICADD Plasma Density Transition Trapping Experiment," in proceedings of the 11th Advanced Accelerator Concept workshop (AAC 2004), StonyBrook, NY-USA 21-26 Jun 2004. AIP conference proceeding 737 p. 440-446 (2004)

M. Huening," On using NEA Cathodes in an RF Gun," Presented at 9th European Particle Accelerator Conference (EPAC 2004), Lucerne, Switzerland, 5-9 Jul 2004.

N. Barov, J.B. Rosenzweig, M.C. Thompson, and R Yoder,"Energy loss of a high-charge bunched electron beam in plasma: Analysis," Physical Review Special Topics - Accelerators and Beams 7: 061301-1 - 061301-11 (2004).


1.3 Ghz photo-emission
electron source (rf-gun)
Magnetic chicane
for bunch compression
User experimental
area
Round-to-flat beam
transformation
DUMP
DUMP
Photocathode
TESLA superconducting
accelerating cavity
Spectrometer
Tunnel enclosure
Photocathode drive laser: Nd:YLF oscillator
frequency quadrupled (to λ=263 nm)
Laser room
Normal quadrupole
Skew quadrupole