Highlights of the High Average Power and High Brightness Beams

UCLA, Nov 8-11, 2004

Carlos Hernández García

CASA Seminar, December 3, 2004

Thomas Jefferson National Accelerator Facility

General Remarks

- Conference hosted by the Particle Beam Physics Lab, UCLA. Los Angeles, CA.

- Started on Monday with the four plenary talks:
  - Development of High-Average-Brightness Sources D. Nguyen
  - Overview J. Lewellen
  - JTO's Perspective and Investment in High Energy Laser Systems R. Nguyen
  - The Choice and The Future David Sutter
  - Tuesday
  - Applications, Efficiency and High Beam Brightness J. Rosenzweig
  - Wednesday
  - The Future (?) of high brightness, high power electron sources Claudio Pellegrini

Workshop was structured in three main working groups…

- Injector design
  - Chair: Ji Qiang (LBNL)
- Diagnostics, measurement and commissioning
  - Chair: Aaron Tremaine (LLNL)
- Materials, fabrication and integration
  - Chair: Carlos Hernadez-Garcia (JLab)

Unfortunately yet another workshop was turned into a talkshop

- Injector design group presented 8 talks
  - Multivariate Optimization of High Brightness High Current DC Photoinjector
    Ivan Bazarov
  - Study of Secondary Emission Enhanced Photoinjector
    Xiangyun Chang, Ilan Ben-Zvi, Andrew Burrill, Peter D. Johnson, J. Kewisch, Triveni S. Rao and YongXiang Zhao
  - HOMDYN - Higher Order Modes DYNamics
    Massimo Ferrario
  - Superconducting High Brightness RF Photoinjector Design
    M. Ferrario, J. B. Rosenzweig, J. Sekutowicz, G.Travish, W. D. Moeller
  - PARMELA
    Bob Garnett
  - High Current Energy Recovery Linac at BNL
    Dmitry Kayran
  - Normal-Conducting Photoinjector for High Power CW FEL
    Sergey Kurennoy (LANL)
  - IMPACT-T - A 3D Parallel Beam Dynamics Code for Modeling High Brightness Beams in Photo-Injectors
    Ji Qiang
  - A Few Comments on the Photoinjector Performance
    Xijie Wang

- Diagnostics, measurement and commissioning group presented 7 talks
  - SRF Gun Project
    Thorsten Kamps
  - Injector, Linac and Undulator Diagnostics and Beam Position Monitors
    Patrick Krejcik
  - Selected topics from the Photo Injector Test Facility PITZ
    Anne Oppelt
  - Coherent Edge Radiation from Compressed Electron Beams
    James Rosenzweig
  - UCLA/ATF chicane compression experiments
    James Rosezweig
  - 6D Phase Space Measurement Technique at the SLAC Gun Test Facility
    John Schmerge, J. Castro, J. Clendenin, D. Dowell, S. Gierman
  - Electron beam diagnostics for high average current accelerator
    Timur Shaftan

- Materials, fabrication and integration group presented 8 talks
  - BNL Photocathode R&D
    Andrew Burril
  - BNL 1.3 GHz SCRF Gun measurements
    Andrew Burril
  - Study of Secondary Emission Enhanced Photoinjector
    Xiangyun Chang, Ilan Ben-Zvi, Andrew Burrill, Peter D. Johnson, J. Kewisch, Triveni S. Rao and YongXiang Zhao
  - GaAs Photocathode Performance
    Carlos Hernandez-Garcia
  - SRF Gun Project
    Thorsten Kamps
  - Beam Source Requirements for High Beam Power Accelerators
    John Lewellen
  - Selected topics from the Photo Injector Test Facility PITZ
    Anne Oppelt
  - A High Power FEL System Based on Extension of Conventional Warm Accelerator Technology
    Gil Travish

Workshop talks can be accessed at

http://home.physics.ucla.edu/calendar/conferences/powerworkshop/

Then click on PRESENTATIONS

D. Nguyen (LANL) spoke of the three present developments for 100 mA CW injector

- JLAB-AES (135 pC, 750 MHz)
  - DC gun + 750 MHz cryounit
  - Most developed technology
  - Already demonstrated 9 mA CW operation
- LANL-AES (3 nC, 35 MHz)
  - Normal conducting RF photoinjector, 2.5 cell cavity plus three with three subsequent cells at 700 MHz
  - Thermal test to be performed next summer
- SRF guns (most immature technology up to date)
  - BNL-AES
    - Nb, CsTe, and of course the diamond cathode are being studied
  - Rossendorf
    - CsTe cathode

Jump to JTO's R. Nguyen talk

Challenges of the present technologies

- DC Photocathode Gun (JLAB)
  - Main challenge is vacuum preservation in the gun chamber and downstream beamline when running high CW currents (>10 mA CW)
  - QE degradation by back-ion bombardment at currents ~100 mA CW will be studied
  - Existing RF power technology needs scalability for accelerating 100 mA beam
- Normal Conducting RF Gun (LANL, PITZ)
  - Main challenge is cooling (localized power densities > 120 W/cm2 for 5 MV/m)
  - Secondary challenge is lack of cavity tunability
- SRF Gun (Rossendorf, BNL)
  - Early stages of development and testing. Low cathode QE requires non-existing laser powers in the UV for high average current. This is a limitation even for producing high peak current

Critical issues towards 1 Amp CW class injectors were addressed

- High QE, rugged cathode is non existent
- Can the cathode (any cathode) hold high constant gradient (> 10 MV/m)?
- High average power drive lasers with the required time structure do not exist to date
- Halo produced by scattered light from high average power drive lasers will be a big issue. This was addressed by modeling and measurements groups!
- Longitudinal emittance preservation is important (finally!, but not widely recognized by the audience, measurements performed at SLAC, J. Schmerge)
- Further development to couple RF power into cavities is needed

In search of the Holy Grail of cathodes and the eternal symbiosis between cathode and drive laser

Bottom line:

We do not have a high enough QE cathode, rugged enough to sustain long lifetimes under high average current operation

The other bottom line:

We do not have a high average power laser with the required time structure to drive existing 'low' QE cathodes

Drive laser status

- Presently developing lasers ~25 W at 532 nm (JLAB, BNL)
- LCLS, SPARC, BNL and Rossendorf are addressing peak power and pulse shaping at 266 nm
- Industry is developing separately high average power laser systems, but those systems lack the time profile needed by the FEL community

Cathode development status*

Material	QE	Laser λ	Lifetime	Vacuum
Cs_3Sb	10%	530 nm	2 hours	$<10^{-10}$
CsK_2Sb	10%	530 nm	<10 hours	10^{-10}
Cs_2Te	2-5%	260 nm	~weeks	$<10^{-8}$
Cu, Mg	<0.1%	260 nm	~months	$<10^{-8}$
Cs-GaAs	>10%	530 nm	3 macropulses*	$<10^{-11}$
Cs-Na_2KSb	>15%	530 nm	est. 20 hours	10^{-10}

* Tried once in an RF gun. Exhibited very high dark current.

How about JLab FEL Gun?

* By Dihn Nguyen (LANL)

Other concepts in cathodes

- Cesiated Metals, Cs dispenser cathodes (NRL U of Maryland)
- Needle photocathodes (Vanderbilt U. and Japan)
  - High brightness, but low average current
- Carbon nanotube cathodes? (JLAB and ODU)
- And of course, BNL's diamond cathode
  - Based on secondary electron emission from diamond film. Lots of calculations but experiments on secondary electron emission characterization just about to start

Some conclusions from Injector design (simulations) group

- There is no common platform to simulate injectors
- There is no unified PARMELA
- New codes: IMPACT 3D parallel beam dynamics
- How good is benchmarking, predicting machine behavior
- Why is there no funding for simulations?

Some conclusions from diagnostics group

- Not much high average power measurements expertise among high brightness people
- Machine protection recognized as a big issue for high average power accelerators/FELs
- Halo, specialized wire scanner for measuring halo only
- Emittance measurement, each lab has its own method

My personal conclusions:

- High average power injector community was underrepresented
- JLab FEL is one step ahead in high average current injectors, so the issues we presented towards 100 mA class injectors are not widely acknowledged
- Most people are still working on achieving smaller transverse emittance with high charge bunches (few nC) but they are ignoring the importance of longitudinal emittance in this regime

Conclusions cont'

- DC gun technology was recognized as the most mature technology, but not necessarily as the one to take us to 1 Amp CW class injectors (most people betting on SRF)
- Many simulation tools are being used/developed for FEL accelerators, but few have been benchmarked against actual machine behavior
- People recognized the lack of Injector Test Facilities
- Lack of interaction between working groups during the workshop

Finally, two announcements were made:

By R. Rimmer (JLab)

The Physics and Applications of High Brightness Electron Beams, Erice, Sicily, October 2005

High brightness electron beams are playing an increasingly critical role in two frontier fields: radiation generation methods and advanced acceleration schemes. Such state-of-the-art radiation production methods include various types of free-electron lasers, as well as inverse Compton scattering (ICS) of intense lasers, having diverse approaches to creating high peak and average power light sources. As they are capable of harder photon production, ICS sources are candidates not only for X-ray sources, but also high-energy physics applications. Likewise, high brightness beams are at the center of future accelerator schemes, e.g. based on high gradient wakefields, and electron cooling. Indeed, possibilities exist to create unique light sources based on advanced acceleration schemes, just as intense light sources enable advanced accelerator research. The goal of this workshop is to provide a comparative study of the generation, manipulating, modeling and measuring of high brightness electron beams, and the underlying methods linking the physics of these beam systems to the physics of advanced applications.

By J. Rosenzweig (UCLA)