### Highlights of the High Average Power and High Brightness Beams UCLA, Nov 8-11, 2004

Carlos Hernández García CASA Seminar, December 3, 2004

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#### **General Remarks**

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

Started on Monday with the four plenary talks:

- . <u>Development of High-Average-Brightness Sources</u> <u>D. Nguyen</u>
- . Overview J. Lewellen
- . JTO's Perspective and Investment in High Energy Laser Systems R. Nguyen
- . <u>The Choice and The Future</u> <u>David Sutter</u>
- . Tuesday
- . <u>Applications, Efficiency and High Beam Brightness</u> <u>J. Rosenzweig</u>
- . Wednesday

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. <u>The Future (?) of high brightness, high power electron sources</u> <u>Claudio Pellegrini</u>

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## 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)



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## Unfortunately yet another workshop was turned into a talkshop

- Injector design group presented 8 talks
  - <u>Multivariate Optimization of High Brightness High Current DC Photoinjector</u> Ivan Bazarov
  - <u>Study of Secondary Emission Enhanced Photoinjector</u>
     Xiangyun Chang, Ilan Ben-Zvi, Andrew Burrill, Peter D. Johnson, J. Kewisch, Triveni S. Rao and YongXiang Zhao
  - <u>HOMDYN Higher Order Modes DYNamics</u> Massimo Ferrario
  - . <u>Superconducting High Brightness RF Photoinjector Design</u> M. Ferrario, J. B. Rosenzweig, J. Sekutowicz, G.Travish, W. D. Moeller
  - PARMELA

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- Bob Garnett
- <u>High Current Energy Recovery Linac at BNL</u> Dmitry Kayran
- Normal-Conducting Photoinjector for High Power CW FEL Sergey Kurennoy (LANL)
- . <u>IMPACT-T A 3D Parallel Beam Dynamics Code for Modeling High Brightness</u> <u>Beams in Photo-Injectors</u>
  - Ji Qiang

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. <u>A Few Comments on the Photoinjector Performance</u> Xijie Wang





- Diagnostics, measurement and commissioning group presented 7 talks
  - . <u>SRF Gun Project</u> Thorsten Kamps
  - <u>Injector, Linac and Undulator Diagnostics and Beam Position</u> <u>Monitors</u> Patrick Krejcik
  - . <u>Selected topics from the Photo Injector Test Facility PITZ</u> Anne Oppelt
  - . <u>Coherent Edge Radiation from Compressed Electron Beams</u> James Rosenzweig
  - . <u>UCLA/ATF chicane compression experiments</u> James Rosezweig
  - . <u>6D Phase Space Measurement Technique at the SLAC Gun Test</u> <u>Facility</u>

John Schmerge, J. Castro, J. Clendenin, D. Dowell, S. Gierman

<u>Electron beam diagnostics for high average current accelerator</u> Timur Shaftan



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



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#### Workshop talks can be accessed at

<u>http://home.physics.ucla.edu/calendar/con</u> <u>ferences/powerworkshop/</u>

#### Then click on PRESENTATIONS



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# 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

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. CsTe cathode

### Jump to JTO's R. Nguyen talk



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### 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





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### 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

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#### 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



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#### Cathode development status\*

<u>Material</u>	<u>QE</u>	Laser $\lambda$	<u>Lifetime</u>	<u>Vacuum</u>
Cs₃Sb	10%	530 nm	2 hours	<10 <sup>-10</sup>
CsK <sub>2</sub> Sb	10%	530 nm	<10 hours	<b>10</b> <sup>-10</sup>
Cs <sub>2</sub> Te	2-5%	260 nm	~weeks	<10 <sup>-8</sup>
Cu, Mg	<0.1%	260 nm	~months	<10 <sup>-8</sup>

Cs-GaAs >10% 530 nm

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

>15%

530 nm

3 macropulses\* <10<sup>-11</sup> How about JLab FEL Gun?

est. 20 hours 10<sup>-10</sup>

\* By Dihn Nguyen (LANL)



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Cs-Na<sub>2</sub>KSb

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#### 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



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## 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?



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#### 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



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#### 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

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#### **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

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#### Finally, two announcements were made:



32nd ICFA Advanced Beam Dynamics Workshop on Energy Recovering Linacs Jefferson Lab, Virginia, USA March 19-23, 2005

#### **Charting New Territories**

Energy Recovering Linacs (ERLs) are emerging as a powerful new paradigm of electron accelerators as they hold the promise of delivering high average current beams with efficiency that approaches that of storage rings, while maintaining beam quality characteristics of linacs, as their 6-dimensional phase space is largely determined by electron source properties. Envisioned ERL applications include accelerators for the production of synchrotron radiation, free electron lasers, high-energy electron cooling devices, and electron-ion colliders. The ERL2004 workshop is the first of its kind, to address issues related to the generation of high brightness and simultaneously high average current electron beam, and its stability and quality preservation during acceleration and energy recovery.

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For more information please email erl@jlab.org www.jlab.org/intralab/calendar/archive04/erl/



#### 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 freeelectron 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.

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