Working Group 5 Summary: High Brightness Electron Guns

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Condensed and presented by Carlos H-G

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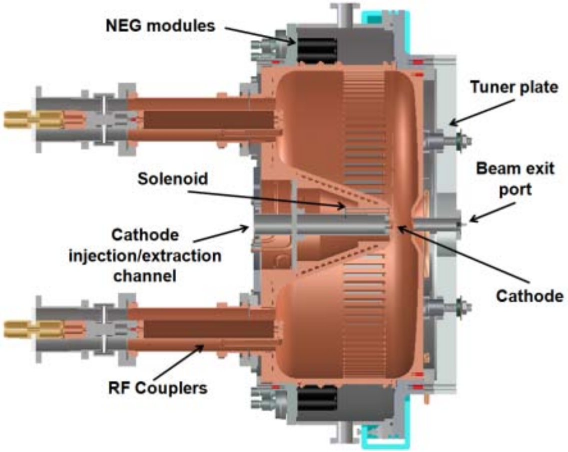
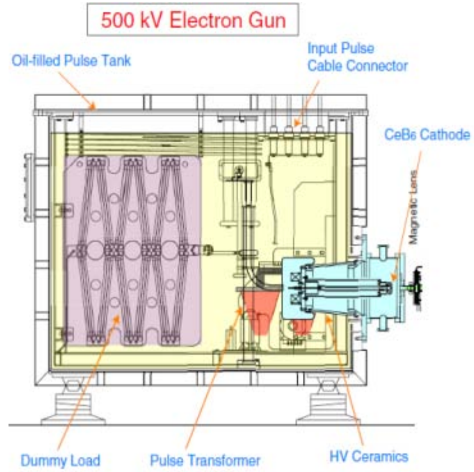
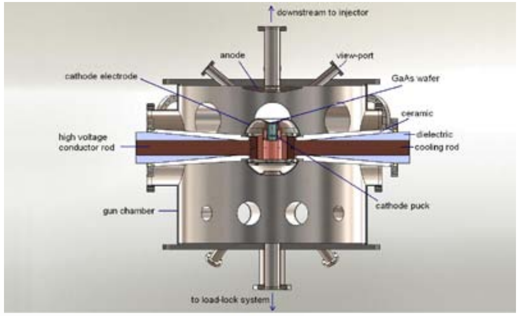
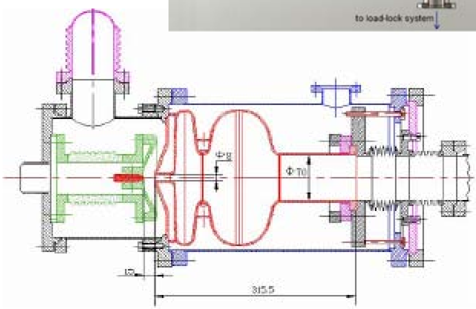
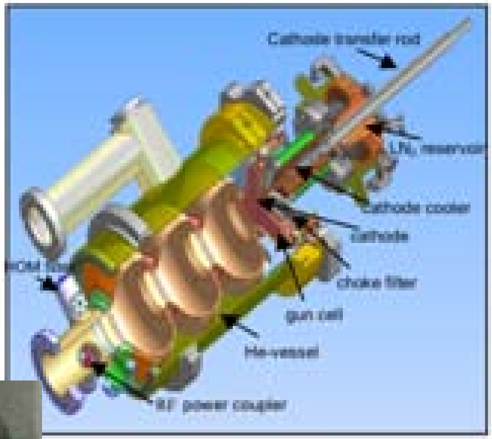
…Exciting Times for Electron Sources

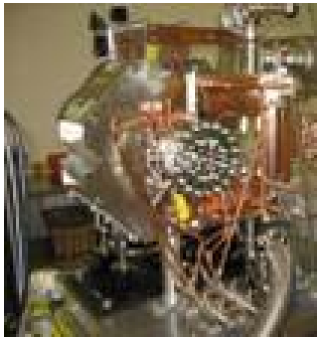












Working Group Charge

Question to those who attended FL2010:

"Where you able to achieve this goal at the end of the Workshop?"

“Identify promising R&D areas that may be high risk but offer high value and could have significant impact on future light source designs.”

High risk/high return...

Question: was that the recent stock market strategy?

Gun Requirements

In storage ring based light sources the injector typically contains a booster ring that dramatically relaxes requirements on the e^- gun. Such electron sources were not addressed by the WG.

A category apart is represented by the injector requirements for plasma wakefield accelerators where in all present schemes the accelerated electrons are "generated" in the plasma itself (see E. Esarey talk).

A large overlap between gun requirements for ERL and FELs based light sources exists.

The required beam quality, in terms of 6D brightness (emittance, energy spread and bunch length) is very similar for both the low and the relatively higher charge regimes.

A discriminating factor is often the repetition rate that forces designers to significantly different technological choices.

Low Repetition Rate Regime

Low repetition (<~ 1kHz) X-ray FEL based sources already found their "champion" guns in high frequency (>~ 1 GHz) normal conductive RF guns.

The spectacular results achieved by the FLASH and LCLS are in significant part due the quality of their 1.3 GHz and 3 GHz photo-injectors

The high gradients >~ 100 MV/m achievable with such guns have fully proved their capability to deal with the space charge in the high charge regime (from several hundreds pC to ~ nC)

In the low charge regime (tens of pC down to pC levels) the space charge effects are much smaller and the limiting performance factor starts to become the intrinsic or thermal emittance of the cathode.

In this low reprate regime it is possible to use low QE (but robust) metal cathodes with present laser technology

Low charge bunches requires beam diagnostics with adequate sensitivity.

Low Repetition Rate Highlights

After the brilliant results of the LCLS, also the PITZ Gun has achieved and surpassed the requirements for the European X-FEL in both the high and low charge regimes (S. Schreiber talk Monday afternoon).

Spring-8 “pulsed DC” gun, the only operating high brightness electron gun using a thermionic cathode, has shown long and reliable operation (H. Maesaka talk)

X-band RF guns have the capability of peak fields up to ~ 200 MV/m. Beam dynamics studies shown the capability of short bunches that could potentially reduce the required compression in the downstream linac (F. Zhou talk)

Low Repetition Rate Challenges

Develop and use lower thermal emittance cathodes (specially for the low charge regime)

Develop diagnostics with sensitivity required by pC class bunches

Optimize RF structures for higher repetition rates without dramatically reduce the gradients

High Repetition Rate Challenges

Several schemes have been proposed to generate the required beam quality at high repetition rate.
but none of such schemes have demonstrated that capability yet!

All proposed schemes show accelerating fields smaller than those in high frequency normal conductive low frequency RF guns.
This situation has important consequences in beam dynamics and requires longer bunches at the cathode to control space charge effects, and higher compression factors in the downstream accelerator.

Present laser technology forces the use of high QE (>~ 1%) photocathodes

Such cathodes are usually represented by “delicate” semiconductor cathodes which require extremely low vacuum pressures to operate with a reasonable lifetime.

Beam diagnostics at high repetition rate can be challenging in terms of bandwidth, very high beam power and required dynamic range.

High Repetition Rate Highlights

JAEA DC gun with a new segmented ceramic held for many hours 500 kV voltage without any evidence of discharge or dark current. Extremely promising result (N. Nishimori talk)

The Rossendorf group proved reliable operation of Cs_2Te photo-cathodes in a SRF gun (J. Teichert talk)

Los Alamos has conditioned to full RF power a 700 MHz CW normal conducting gun.

Significant interest and effort in the development of low frequency 100-200 MHz NC CW RF guns to operate with either thermionic or photocathodes. (F. Hannon, A. Nassiri and F. Sannibale talks)

Synergy with industry can allow for outstanding accomplishments. A full SRF gun system was designed and received within one year! (J. Lewellen talk)

Several schemes pursuing high brightness beams at high repetition rates are doing very important steps towards the goal. High chances of a near future success.

High Repetition Rate Challenges

Prove high brightness/high repetition rate operation in both low and charge regime

DC guns: increase the operation energy to higher values

SRF guns: prove high gradient operation with high QE photocathodes and the fields required for emittance compensation

NC low frequency guns: prove vacuum performance and RF performance.

Develop beam diagnostics for high repetition and/or high power beams.

Cathodes, Photo-Cathode/Laser Systems

Impressive intensity and quality of the research in this field conducted by a small number of groups.

Strong effort to move cathode science from the present significantly "empirical phase" to a situation with a better physical understanding of the photoemission process.

Cathode fabrication experts and other discipline scientist joining forces.

Characterization tools such as ARPES and others offered by synchrotron light sources are now being used.

Relevant efforts in understanding, QE, thermal emittance and lifetime limiting phenomena

(H. Padmore, K. Harkay, D. Dowell, T. Rao, J. Smedley talks)

Cathodes, Photo-Cathode/Laser Highlights

CsBr coatings on metal cathodes give several tens QE enhancement factors in Cu and other metals, and several hundreds in Nb (D. Dowell talk)

Significant progress in the development of suitable **multi-alkali antimonide photocathodes** with high QE (>~ 1%) and photo-emitting in the visible (T. Rao and D. Dowell talks)

Diamond "amplifiers" are ready for being tested in several guns (J. Smedley talk)

Thermionic cathodes successfully proved high brightness performance at Spring-8 and are now under consideration for the injector of the ANL X-FELO (N. Sereno talk)

Laser distribution control techniques have achieved a reasonable level of capability sufficient to generate measurable improvements of beam quality and are "routinely" used (W. White, C. Vicario talks).

Cathodes, Photo-Cathode/Laser Challenges

A significant effort and R&D is still necessary for a better understanding of the photo-emission in different photocathodes, for the improvement of cathode preparation, and for cathode characterization.
Significant margin for improvement.

Coordination between cathode producing groups, injector designers and injector facilities can synergistically boost the research.

Laser shaping techniques improvement required especially in generating fully ellipsoidal distributions.

Laser capability of fast switching between pulses with different characteristics should be investigated.
High benefit to multiuser facility with tailored FEL beamlines.

Beam Dynamics

The eigen-emittance description of the 6D emittance of a beam, shows potential for a proper emittance exchange between different planes in order to properly match the phase space requirements for optimal lasing in FEL schemes (B. Carlsten talk)

Further work is in progress for the definition of the characteristics of the beamline required for the proper phase space manipulation.
Non-linear effects (space charge, collective effects, …) that could affect the scheme performance need to be investigated.

Injection in Plasma Wakefield Accelerators

Numerous schemes for the injection of electrons in the extremely small plasma "bucket" are under evaluation and experimental test.
(E. Esarey talk)

The solution of such a problem could allow the proper control of the characteristics of the beam from the plasma wakefield accelerator and could allow such accelerators to operate in a FEL scheme.