Report on the CTF3 Photo-injector Workshop, 24-25\textsuperscript{th} September 2001

Ian Ross, Central Laser Facility, RAL

Selection of transparencies from the workshop for the CTF3 working group
Summary and Outlook

• No technological problem for RF gun
• Laser is feasible with some technical challenges
• Cathodes are able to produce the required current density
• Cathodes resist the laser intensity

A photoinjector seems to be feasible and to be a good technical solution:

• Better emittance
• No satellites
• Lower costs
• Less Radiation
CLIC DRIVE BEAM PHOTO-INJECTOR

Main Linac accelerators

Drive beam decelerators

67ps bunch spacing, 1952 bunches/train
1 Train (130ns) per Drive Beam Decelerator

Delay line +
Combiner rings

Drive Beam Accelerator
937MHz, 3.9MV/m, 91 units

Accelerator Section

RF gun
937MHz

Electron Bunch compressor (1.5ps)

Optical delay,
1 RF cycle

PHV drive function to Pockels Cell

4th Harmonic
Generator

Pockels Cell Gate

468.5MHz
Oscillator

Amplifier Chain

Rutherford Appleton Laboratory
THE CLIC PHOTO-INJECTOR LASER SYSTEM

468.5MHz, 50W Nd:YLF Laser Oscillator

RF + Timing

A1, Gain = 20

1kW diode power

A2, Gain=10

12kW diode power

A3, Gain = 5

47kW diode power

Pockels cell function driver

4\(\mu\)m

RF Gun

Feedback stabilisation

Rutherford Appleton Laboratory
State of the Art

Commercial Systems

10W cw $TEM_{00}$ Nd:Vanadate - for pumping TiS (eg Millenia)
1kW cw Nd:YAG - for engineering applications
1J/100Hz Nd:YAG - for engineering applications

Demonstrated Systems

Oscillators- 5kW multimode
200W cw $TEM_{00}$
50W cw modelocked $TEM_{00}$

MOPA- 10J/100Hz
10mJ / 15 fs / 1kHz

Designed Systems

Oscillators- >10kW

MOPA - >100kW
Schematic of laser

- Pump diodes operated at 300W quasi-CW: 200μs pulse at 100Hz
- Cavity length: 24 cm
Combined differential + proportional stabilisation of quasi-cw Nd:YLF laser

- Peak power after stabilisation (in 200μs) = 60W (300W pump)
5kW DIODE-PUMPED TEST AMPLIFIER
Saturated gain-distribution at single pass amplification
Thermal-lensing effect in the Nd:YLF rod

Vertical fringes:

Horizontal fringes:
FOURTH HARMONIC GENERATION

- Predicts 25% efficiency overall
- Literature reports 25% efficiency
- Requires optics to give square flat-top beam
- Design assumed 10% - achievement of say 20% would substantially cut the cost of laser.
Conversion efficiency

Input, uJ: beam dia 1.8mm FWHM

Gsanger KD*P, 30mm
Gsanger BBO, 3.5mm
Gsanger KD*P, 30mm(2)
Clev.Cryst.BBO, 1.1mm
Gsanger KD*P
Gsanger BBO 3.5mm
BBO Gsanger 4.5mm
Cathode test for high average current I

Reminder for CLIC:
1mC per macropulse,
75 mA on average
For CTF 3: 5.2 µC, 26 µA

Cathode plug was cleaned
by Ar⁺ bombardement
Thickness Te: 10nm
Thickness Cs: 8nm

Average current: 750 µA
Total charge: 1.2 kC
Current density: 21 mA/cm²
Laser power density: 6 W/cm²

QE_{\text{min}} = 1.5%
Experiences:

Cs-Te cathodes with 10nm Te, 15nm Cs:
Qe ≈ 10% → ≈ 1.5%

Cs-Te cathodes with 2nm Te, 6nm Cs:
Qe ≈ 10% → ≈ 1.5%

Only a thin (some nm) active interface really consisting of photoemitting Cs$_2$Te?

Solution:
Evaporate both elements at the same time
Gain in QE

Classical evaporation process; 8 MV/m; DC gun measurement
- Mean lifetime of 6 photo-cathodes, including high charge test

Classical evaporation process; 105 MV/m; CTF2 Drive Beam RF gun measurement, estimated working time with charge production:
1 working day over 2, 8 hours / working day
- Mean lifetime of 7 photo-cathodes

Co-evaporation process; 8 MV/m; DC gun measurement
- No 137: the first one, on new substrate
- No 139: ICE

幅图: QE (%) vs. Working time (h)

- No 137
- No 139
- No 130

*QE_{min} = 1.5%*
CTF II, configuration for PILOT experiment

high charge drive beam

low charge probe beam

1.5\mu s_{v_b} bunch
q_b=0.1-0.2 nC
45 MeV
\sigma_z=0.9 mm

30 GHz RF pulses of up to 150 MW
3-15 ns pulse length

30 GHz accelerating structure
L=0.2855m
Photo injector option needs a convincing proof of principle experiment for the laser system.

The most convincing experiment is a working photo-injector demonstrating the main features on a reduced scale.

Those features are (in order of importance)

• long bunch train phase locked with RF
• reliable operation for many hours
• laser power stability during train & stability pulse to pulse
• phase switching every 140 ns

If this can be shown the photo-injector option for CTF3 will be followed up.

The injector variant which will be most successful in CTF3 will be the one for the CLIC drive beam
These constraints imply for the PILOT experiment:

– installation on the CTF II probe beam
– impact on the operation of CTF II laser system has to be minimised
– experiment has to be ready for October 2002 at the latest
– parameters for the laser system

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \nu_B )</td>
<td>MHz</td>
<td>249.88</td>
</tr>
<tr>
<td>( q_B )</td>
<td>nC</td>
<td>0.2</td>
</tr>
<tr>
<td>( W_B ) on cathode @ 264 nm</td>
<td>( \mu J )</td>
<td>0.32</td>
</tr>
<tr>
<td>( P_{LASSER} ) on cathode @ 264 nm</td>
<td>W</td>
<td>80</td>
</tr>
<tr>
<td>( \nu_{REP} )</td>
<td>Hz</td>
<td>5</td>
</tr>
<tr>
<td>( T_{PULS} )</td>
<td>( \mu s )</td>
<td>1.5</td>
</tr>
</tbody>
</table>
PHOTO-INJECTOR LASER FOR ‘PILOT’ TESTS

OSCILLATOR

30W / 250MHz
NEW

OR

0.1W / 250MHz

AMPLIFIER
X300 GAIN

120nJ / 10ps

5kW DIODE-PUMPED AMPLIFIER X50 GAIN

10nS POCKELS CELL

FEEDBACK CIRCUITS

RAL

FHG

0.3i J

PC

0.2nC

ELECTRON BEAM

4i J

Rutherford Appleton Laboratory
‘PILOT’ CTF2 TESTS

AIMS

Demonstrate stable pulse train operation yielding 0.2nC per electron bunch from the photo-cathode at a frequency of 250MHz and for a train length of 1.5ìs.

Demonstrate optical feedback stabilisation of the optical pulse train to 1%.

Demonstrate beams on the photo-cathode spatially uniform to 30%.