Photoinjector Laser for CTF3
Plan

• Background

• Current status of laser elements

• Plans (July, Q3-4 2006)
Laser system schematic

1.5 GHz Nd:YLF oscillator → Phase coding → CW preamp → 3-pass Nd:YLF amplifier x300 → 200 μs, 5-50 Hz

Diode pump 18 kW pk → 3 kW → 2 μJ → Diode pump 22 kW pk → 15 kW

10 μJ → 270 μs

~2332 pulses 370 nJ/pulse → 1.55 μs → 4ω, 2ω → Optical gate (Pockels cell) → Feedback stabilisation → Energy stabiliser (Pockels cell) → Beam conditioner

~2332 e⁻ bunches 2.33 nC/bunch
Practical layout

- High Q preamp
- High Q oscillator
- Faraday
- Coding
- Amplifier 1 (Amp 1)
- Amplifier 2 (Amp 2)
- Noise control
- 1.54 μs slicing
- 1 pulse slicing
- Thermal lensing correction

300 cm
Oscillator/Preamplifier

- Delivered, installed and commissioned in Q2 2005
- Has met all specifications (power, beam quality, timing and amplitude stability)
- Seems capable of accommodating coding hardware

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• Amp 1 and Amp 2 diodes, drivers and chillers delivered
• Amp 1 diode set fully operational
• Amp 2 chiller being commissioned
Amplifier 1

- Amp 1 operational and tested at 5 Hz and 50 Hz
- Cause of rod failure at 50 Hz awaiting further investigation
- Expected output has been delivered (actually slightly exceeded)
- Near-field uniformity should improve with better rod

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Amplifier 1

- Measured output from Amp 1 exceeds target power (3 kW from 3 passes)
- Output saturates in agreement with model

- Pumping arrangement delivers good uniformity across the rod
- Near-field profile is flattened by saturation but shows some effects of rod inhomogeneities
• 1.54μs Pockels cell and driver delivered
• Initial test confirms triggering and basic operation
• Risetime, extinction ratio, throughput and level of induced noise remain to be established (noise level in above trace is misleading)
• Power handling, with additional AOM, remains to be confirmed
Pockels cell ringing

- Note: BBO shows no sign of piezo-ringing
- This compares with fluid-damped KDP behaviour above, albeit on a much longer timescale

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AO Q-Switch

QS41-5C-S-SS2

- Industry standard for Nd:YAG lasers
- 24, 27, 41 or 68MHz
- More than 30,000 sold world-wide

AO deflector could reduce power loading on Pockels cell by up to 80% for most of the macropulse

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Amplifier 2

- Amp 2 chiller being commissioned
- Amp 2 components all delivered and pre-assembled, except for cylindrical lenses
- Diode testing then amplifier testing to be carried out over next month
- Thermal lensing measurements will follow

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Pulse coding

- Fibre modulation, based on telecoms technology, is fast but lossy and limited in average power
- Measurements on the High Q system suggest 10dB loss before the preamp results in <3dB output reduction
- Delay can be adjusted by varying the fibre temperature (~0.5ps/°C)
- Attenuation can be controlled by varying the fibre bending losses
- Modulator is delivered and fibres are due. Fibre testing will be carried out off-line at RAL

320 mW in from oscillator

140.7 + 0.333 ns delay

Variable delay

Variable attenuator

~30 mW out to preamp

320 mW in from oscillator

140.7 ns macropulses

EO Modulator

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The single pulse cell needs a small aperture (for speed) so cannot handle high laser power, hence it should be crossed with the 1.54μs cell

HV drivers are slew-rate limited, so slicing in the IR is challenging

Finite rise and fall-times may convert timing jitter to amplitude noise
• Slicing in the UV allows the easiest driver design
• But electro-optic materials are vulnerable to UV damage
• Subsequent frequency conversion is not available to remove ghost pulses
• Slicing in the green should be possible with a double-crystal cell
• This halves the drive voltage, so the requirements are the same as for the UV
• The poorer extinction ratio is mitigated by the subsequent frequency doubling
• This is currently the preferred option
Frequency multiplying

- Crystals are available for two frequency quadrupling schemes:
  
  2 × type I in BBO  
  (preferred)

  Type II in KTP + type I in BBO  
  (allows two IR polarisations, perhaps for 3 GHz multiplexing)

- Frequency multiplying will follow successful pulse slicing and control of thermal lensing
Amplitude stabilisation

ADVANTAGES

- Scheme is simple and compact, so could be fast
- Sensing before the gate minimises switch-on transients
- Laser power at the stabiliser can be low

DISADVANTAGES

- No automatic correction of residual error towards zero
- Manual tuning of gain & offset
- Elements after the sensor do not have their noise corrected

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- Elements after the sensor do not have their noise corrected
Amplitude stabilisation

ADVANTAGES
Bunch charge sensing covers all elements and has high sensitivity
Sensing after the stabiliser allows full feedback correction

DISADVANTAGES
No correction signal until the macropulse begins
Long signal paths mean slow response and increased EM noise pickup
More sophisticated control electronics required

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• High speed, high voltage electronics are easier to implement when linear

• Pockels cells’ response is linear near T=0.5 but losses are high

• Simple modelling shows that noise reduction with linear electronics can be acceptable for T≈0.9 if the uncorrected noise is <2% rms

• High speed amplifiers are available* which would allow amplitude correction inside 270 μs macropulse

• Noise control system should be designed around the measured noise spectrum

* e.g. Leysop 250: 275 V, 6 MHz BW into 100 pF

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Safety and machine protection

• Safety interlocks consistent with CERN standards will need to be implemented

• Laser pulse monitoring could allow fast HV switch-off to protect accelerator should laser fail

• HV monitoring can inhibit laser pulses: pulse slicing Pockels cell probably gives fastest response
<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oscillator &amp; preamplifier</td>
<td>Complete</td>
</tr>
<tr>
<td>Synchronisation</td>
<td>Complete</td>
</tr>
<tr>
<td>Amplifier 1 (5 Hz)</td>
<td>Complete</td>
</tr>
<tr>
<td>1.54 μs slicing (no AOM)</td>
<td>Imminent</td>
</tr>
<tr>
<td>Amplifier 2 (5 Hz)</td>
<td>Imminent</td>
</tr>
<tr>
<td>Coding principle</td>
<td>Imminent</td>
</tr>
<tr>
<td>Thermal lensing correction</td>
<td>Ship laser to CERN</td>
</tr>
<tr>
<td>Frequency multiplying</td>
<td></td>
</tr>
<tr>
<td>Coding finalisation</td>
<td>After delivery</td>
</tr>
<tr>
<td>Amplitude stabilisation</td>
<td>After delivery</td>
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<tr>
<td>Single-pulse slicing</td>
<td>After delivery</td>
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<tr>
<td>50 Hz testing</td>
<td>After delivery</td>
</tr>
<tr>
<td>Safety and machine protection</td>
<td>After delivery</td>
</tr>
</tbody>
</table>

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THE END
Original laser schematic

Slide presented at PHIN collaboration meeting, Frascati, May 2004
(see http://www.infn.it/phin/coll_meet.html)

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Diode pump 18 kW pk

3 kW, 2 μJ

200 μs, 5-50 Hz

3 pass Nd:YLF amplifier x5 → Diode pump 22 kW pk

15 kW, 10 μJ, 270 μs

Feedback stabilisation

~2332 e− bunches
2.33 nC/bunch

~2332 pulses
370 nJ/pulse

4ω → 2ω → Optical gate (Pockels cell)

1.55 μs

Energy stabiliser (Pockels cell)

Beam conditioner
Stabilisation issues

- **Architecture**: complex vs simple, versatile vs optimised, digital vs analog
- **Correction between macropulses** is practical, but much of the noise spectrum may be inaccessible
- **Correction during 1.55 $\mu$s pulse** looks challenging (BW > few MHz into 20pF Pockels cell load needs 10s of mA drive for 100s of volts change)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Output</th>
<th>Drive</th>
<th>BW</th>
<th>Gain</th>
<th>Slew</th>
<th>Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbatech T-501-F</td>
<td>±200 V</td>
<td>200 mA</td>
<td>&gt;0.5 MHz</td>
<td>50</td>
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<td>1.2mV rms</td>
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<tr>
<td>Leysop 250</td>
<td>275 V</td>
<td>100 pF</td>
<td>6 MHz</td>
<td>&gt;100</td>
<td>3500</td>
<td></td>
</tr>
<tr>
<td>New Focus 3211</td>
<td>±200 V</td>
<td>110 mA</td>
<td>0.5 MHz</td>
<td>40</td>
<td>650</td>
<td>&lt;100mV p-p</td>
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<tr>
<td>Tegam 2350</td>
<td>±200 V</td>
<td>40 mA</td>
<td>0.2 MHz</td>
<td>50</td>
<td>&gt;250</td>
<td></td>
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<tr>
<td>Trek Inc 603-2</td>
<td>250 V</td>
<td>80 mA</td>
<td>0.15 MHz</td>
<td>50</td>
<td>&gt;100</td>
<td>&lt;20mV rms</td>
</tr>
</tbody>
</table>

- **Correction during 270$\mu$s macropulse** looks practical, but needs sensing before the optical gate and, probably, before the modulator (unless it can take the full laser power)

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