Status of the CTF3 Photoinjector Laser at CCLRC Central Laser Facility

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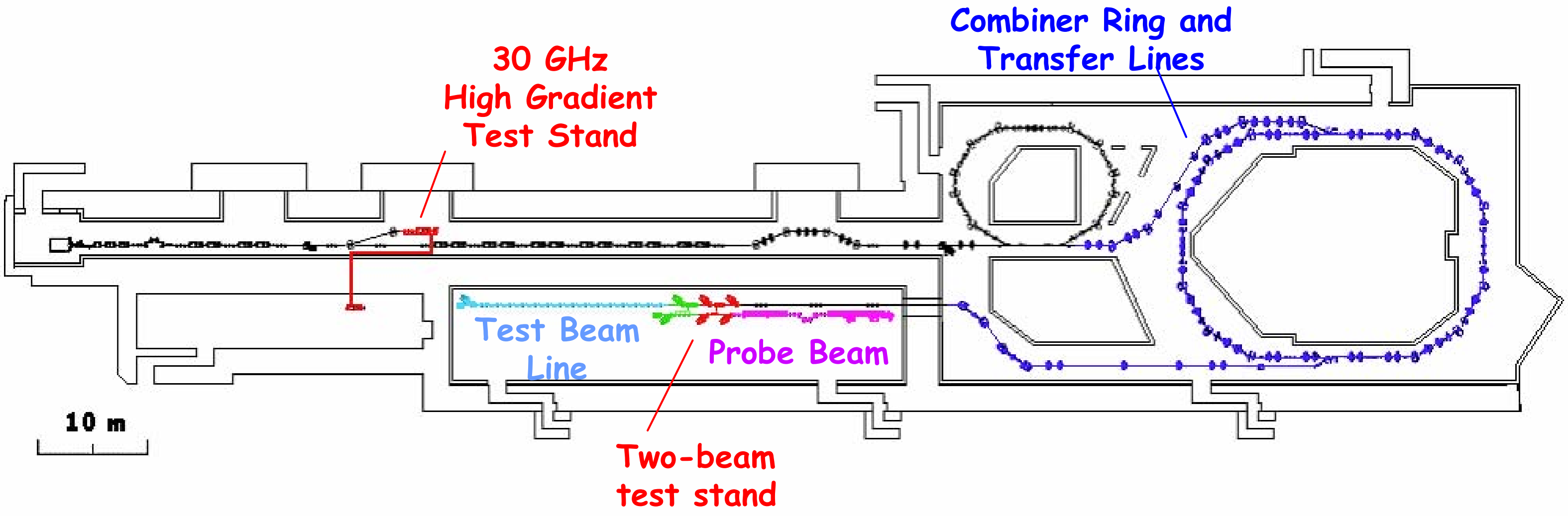
Plan

- Laser system requirements
- Design overview
- Time structuring and stabilisation
- Status of system components
- Deliverable schedule
- Summary and issues

Requirements



- CTF3 will deliver 141 ns long trains of electron bunches at 15 GHz – 2120 pulses in total
- The CTF3 photoinjector, and hence the laser, will operate at 1.5 GHz. So (with an extra 212 pulses) the macropulses from the laser will be 1.55 μs long
- The electron bunch frequency is increased in two combiner rings, the first of which needs the micropulses to be phase coded (333 ps delayed)
- Optimum operation of CTF3 requires very low bunch charge variation (~0.1% rms)

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Laser requirements

Photocathode material	Cesium Telluride
Laser output wavelength (UV)	262 nm
Laser fundamental wavelength (IR)	1047 nm
Laser material	Nd:YLF
Electron bunch charge	2.33 nC
Laser micropulse duration	~6 ps
Laser pulse energy (UV at cathode)	0.37 μJ
Laser pulse energy (IR from final amp)	10 μJ
Average IR laser power in macropulse	15 kW
Laser macropulse rate	1 Hz – 50 Hz

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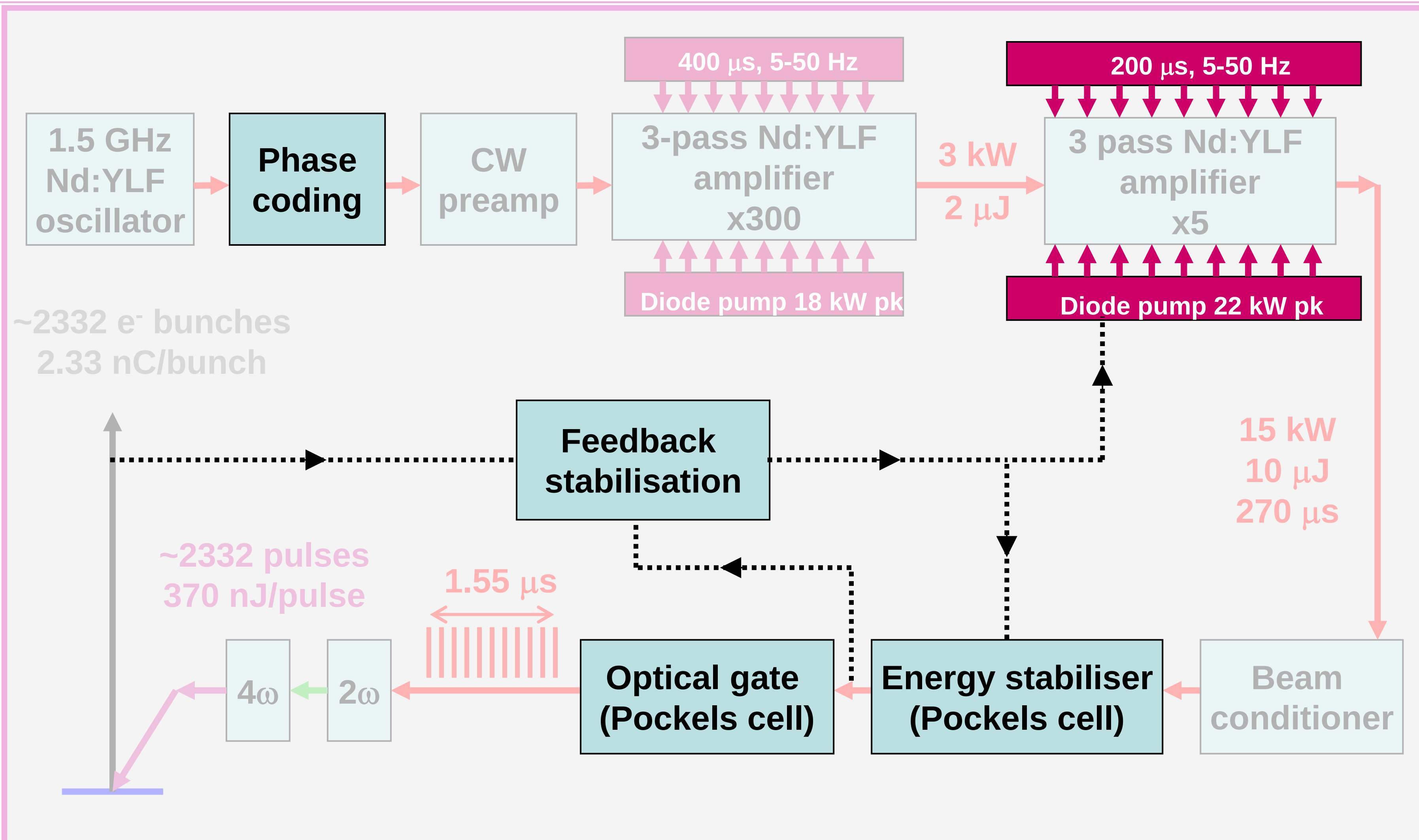
Beam modulating components
Layout



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Modulator requirements

- SPEED:

  The gating can rise and fall in a few pulses

  The coding must take place between 1.5 GHz pulses i.e. very quickly

  The stabilisation should be as fast as possible, but will be limited by signal processing hardware

- LASER POWER HANDLING:

  Quasi steady-state operation means gating must happen after Amp 2. Thermal limits mean it must happen before the doubler. The gating modulator must therefore handle the highest laser power

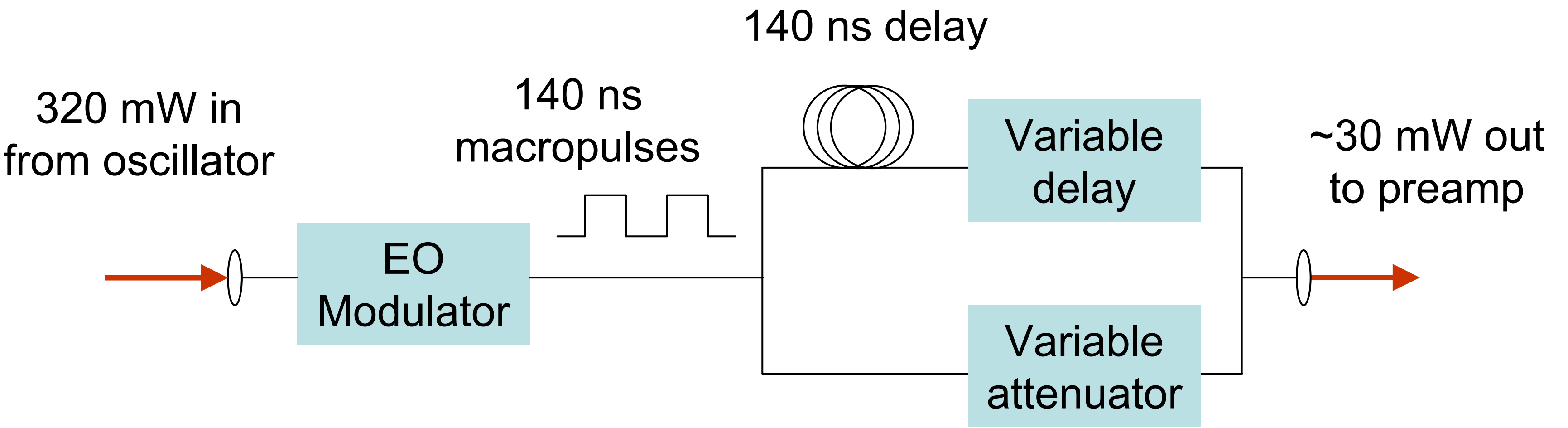
  Fast, periodic coding means fibre-modulation, with a power limit of ~1 W

  Voltage limits at high slew-rate require the stabilisation modulator to follow Amp 2. Feedback using the full 270 μs macropulse (if implemented) would require the modulator to handle the highest laser power

- PHASE AND AMPLITUDE NOISE:

  These must be minimised

Fibre 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
- Issues include few ppm delay stability, operating point maintenance and polarisation preservation

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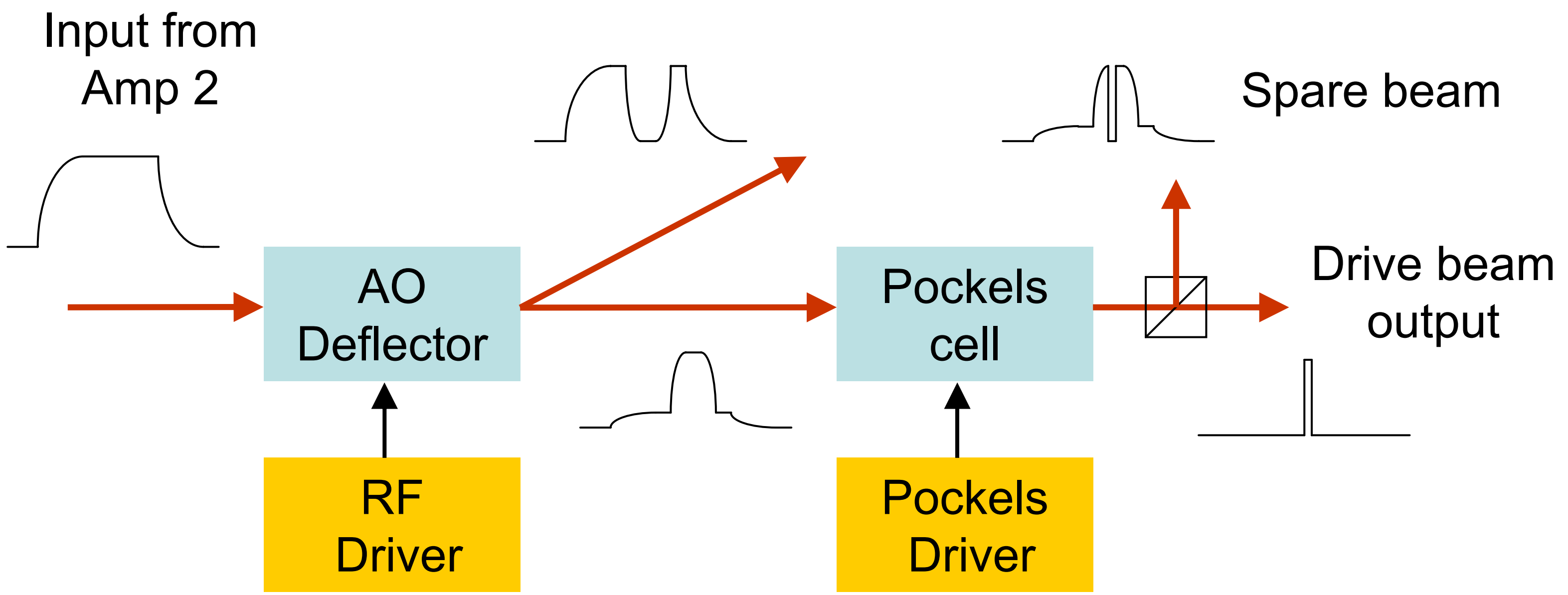
Gating



- AO deflector could reduce power loading by >80% for most of the macropulse
- Pockels cell aperture is a compromise between speed and power handling
- Choice of Pockels cell material affects “ringing” (fluid-damping not possible at these powers)

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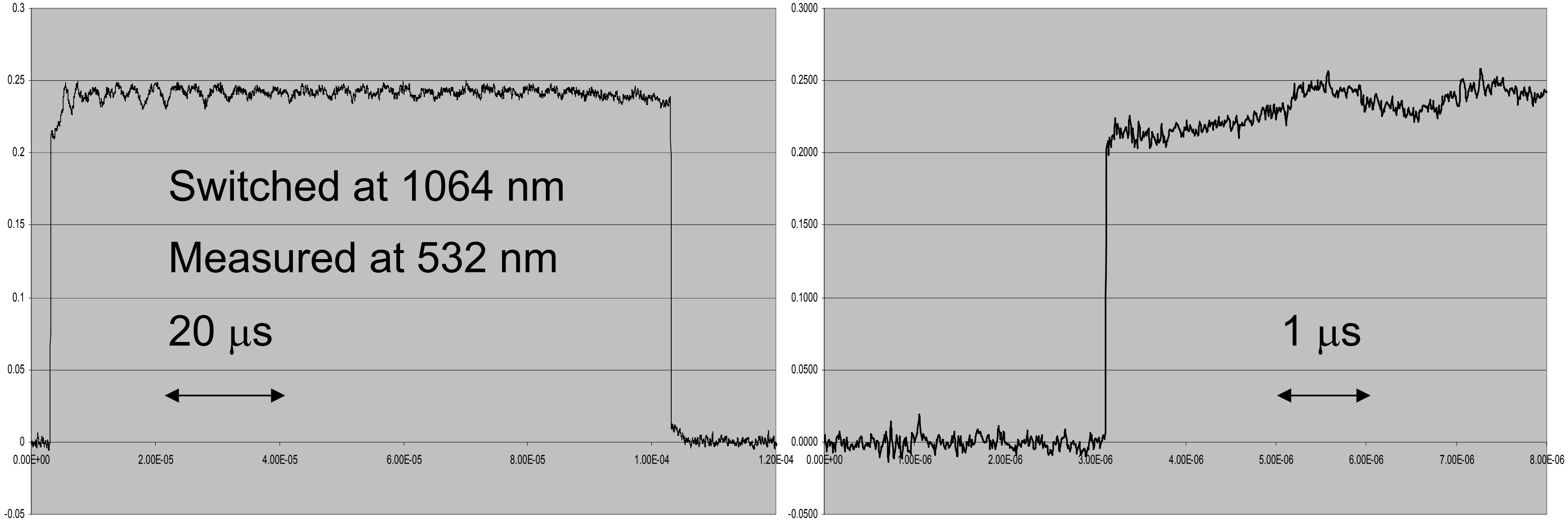
Pockels cell ringing



- KD*P is a stable, sensitive EO material but is prone to crystal lattice motion (ringing) which causes birefringence oscillations
- BBO rings less, but has limited aperture and needs high drive voltage
- RTP rings the least, but is an “experimental” material, needing DC biasing and tight thermal control

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Stabilisation 1

ADVANTAGES

Scheme is simple and compact, so could be fast

Sensing before the gate minimises switch-on transients

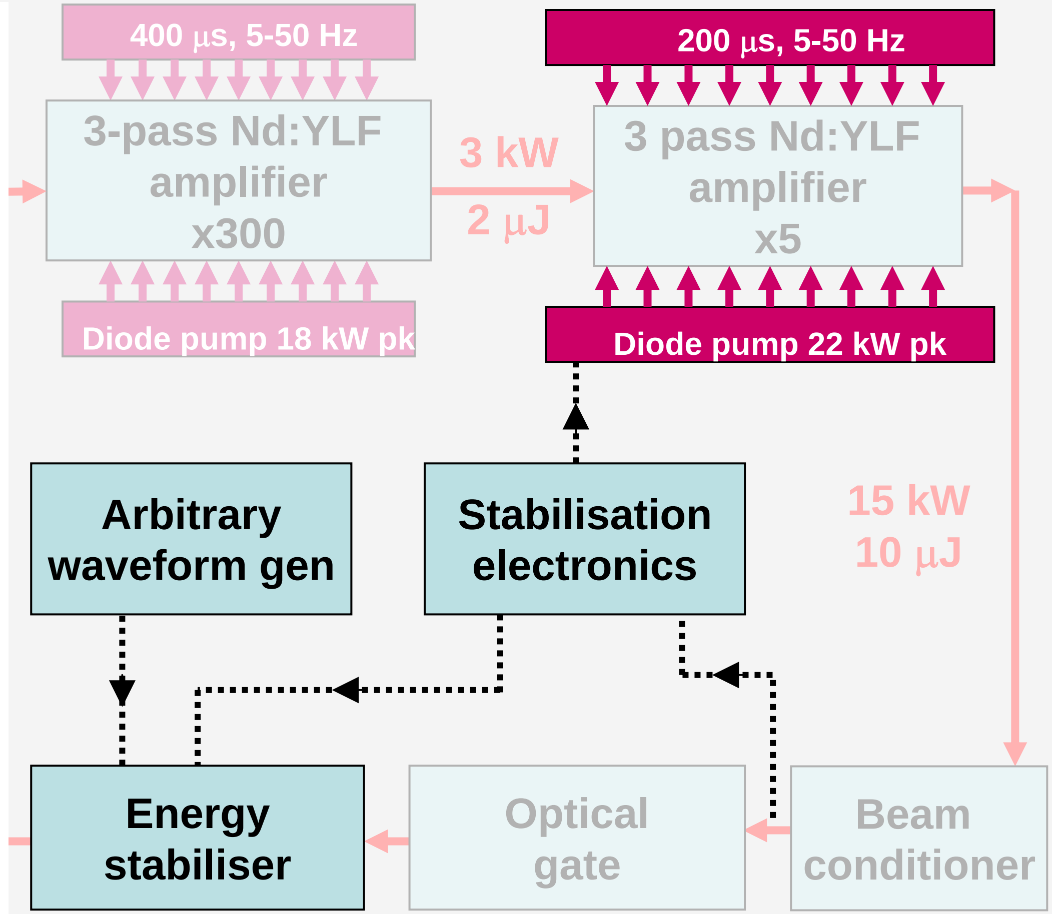
Laser power at the stabiliser can be low

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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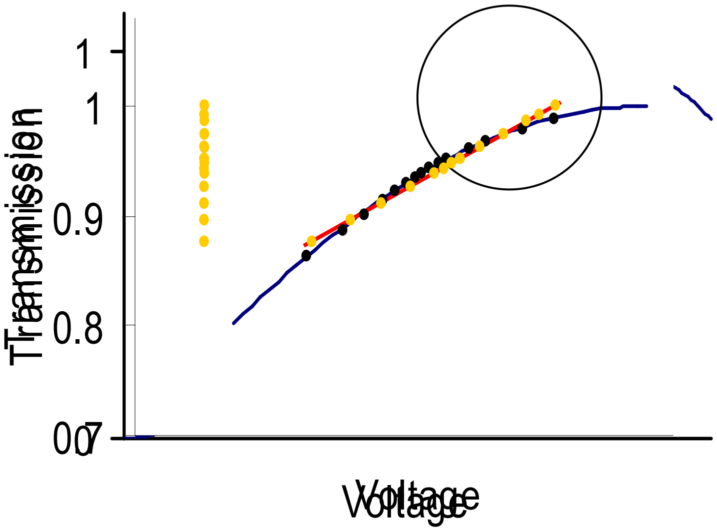
Pockels cell linearity



- Pockels cell is linear around T=0.5, but losses are high

- When transmission is higher cell response is nonlinear, but perhaps a linear approximation is acceptable ?

SIMPLE MODEL

- Choose the laser noise level and generate a normally-distributed set of pulses
- Calculate a linear fit to the cell voltages needed to correct the pulse energies
- Generate a second set of pulses, normally distributed with the same σ as the first
- Use the linear fit to generate the correction voltages for the new pulses
- Calculate the “corrected” pulse energies and their rms noise

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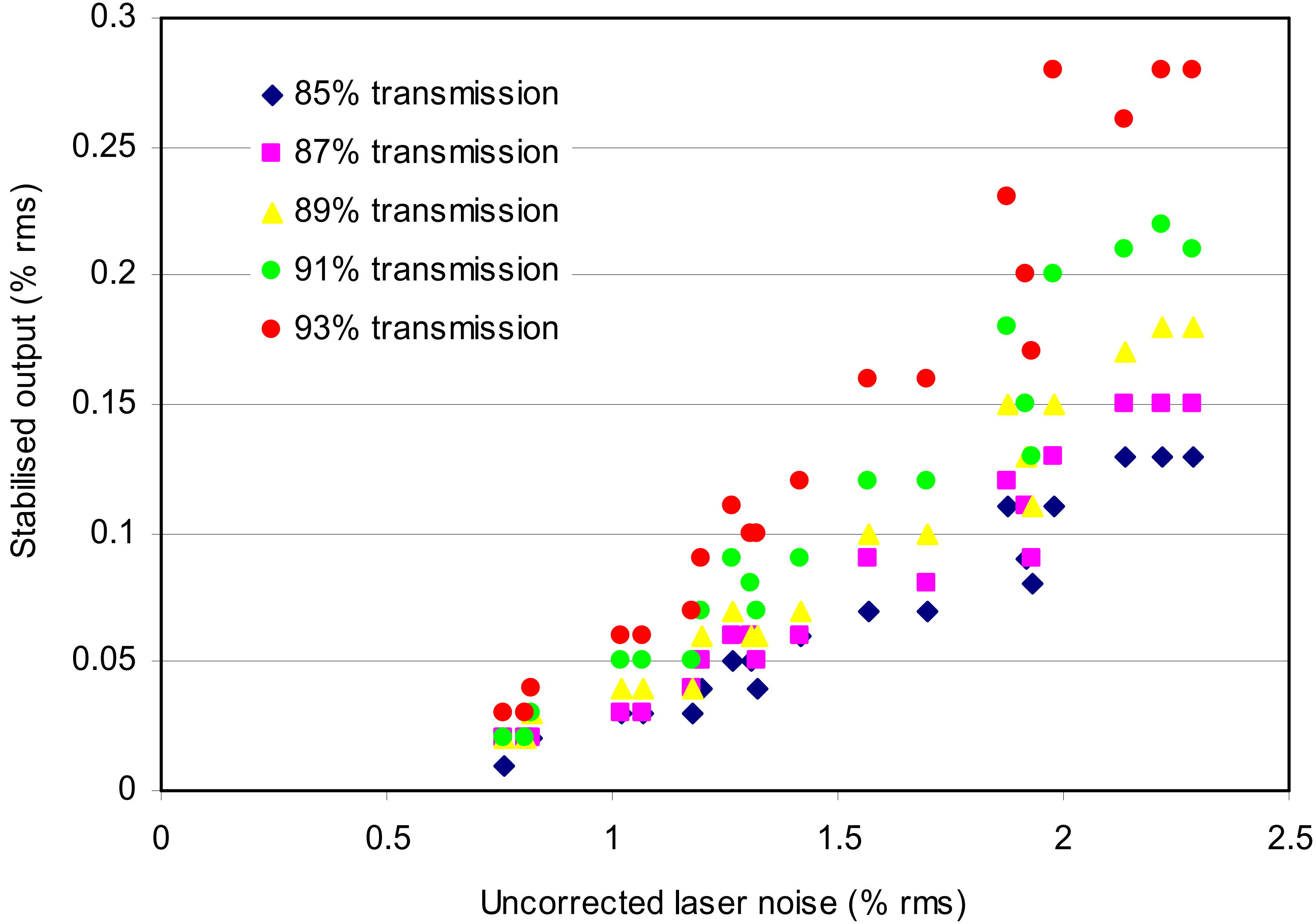
Linear noise reduction



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Stabilisation 2

ADVANTAGES

Bunch charge sensing covers all elements and has high sensitivity

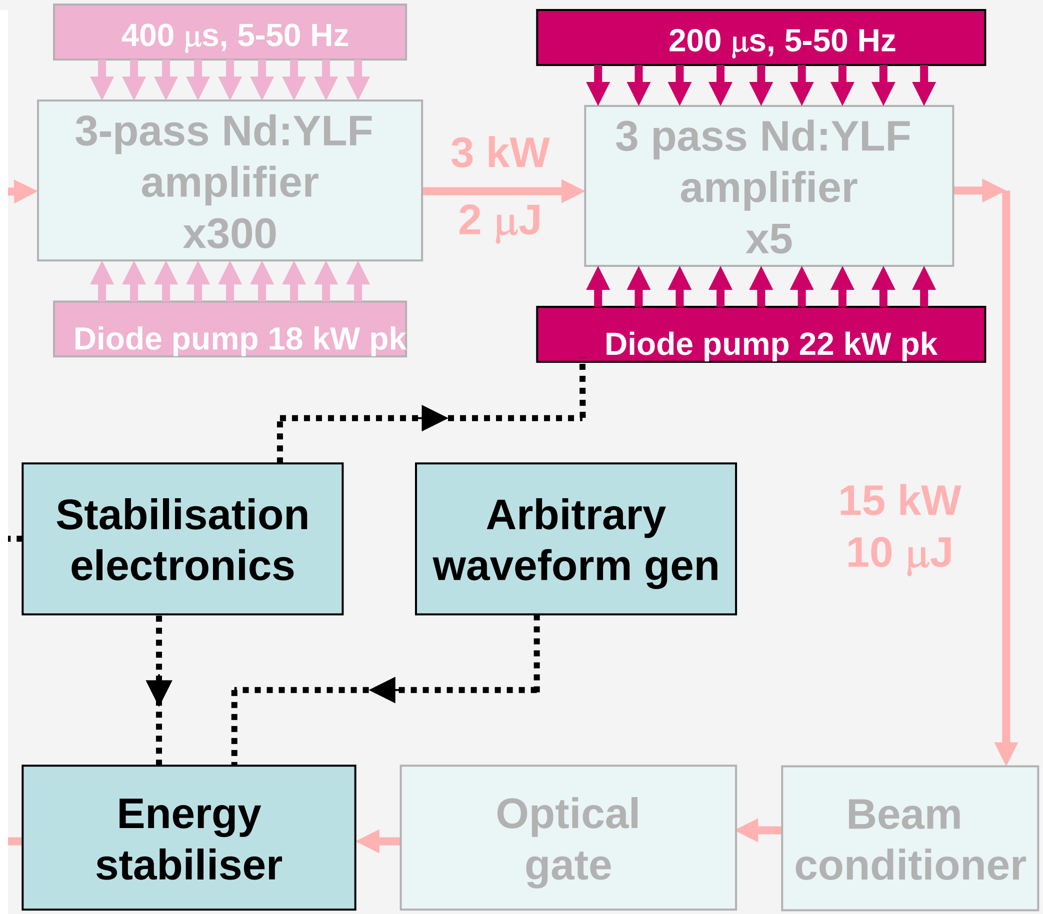
Sensing after the stabiliser allows full feedback correction

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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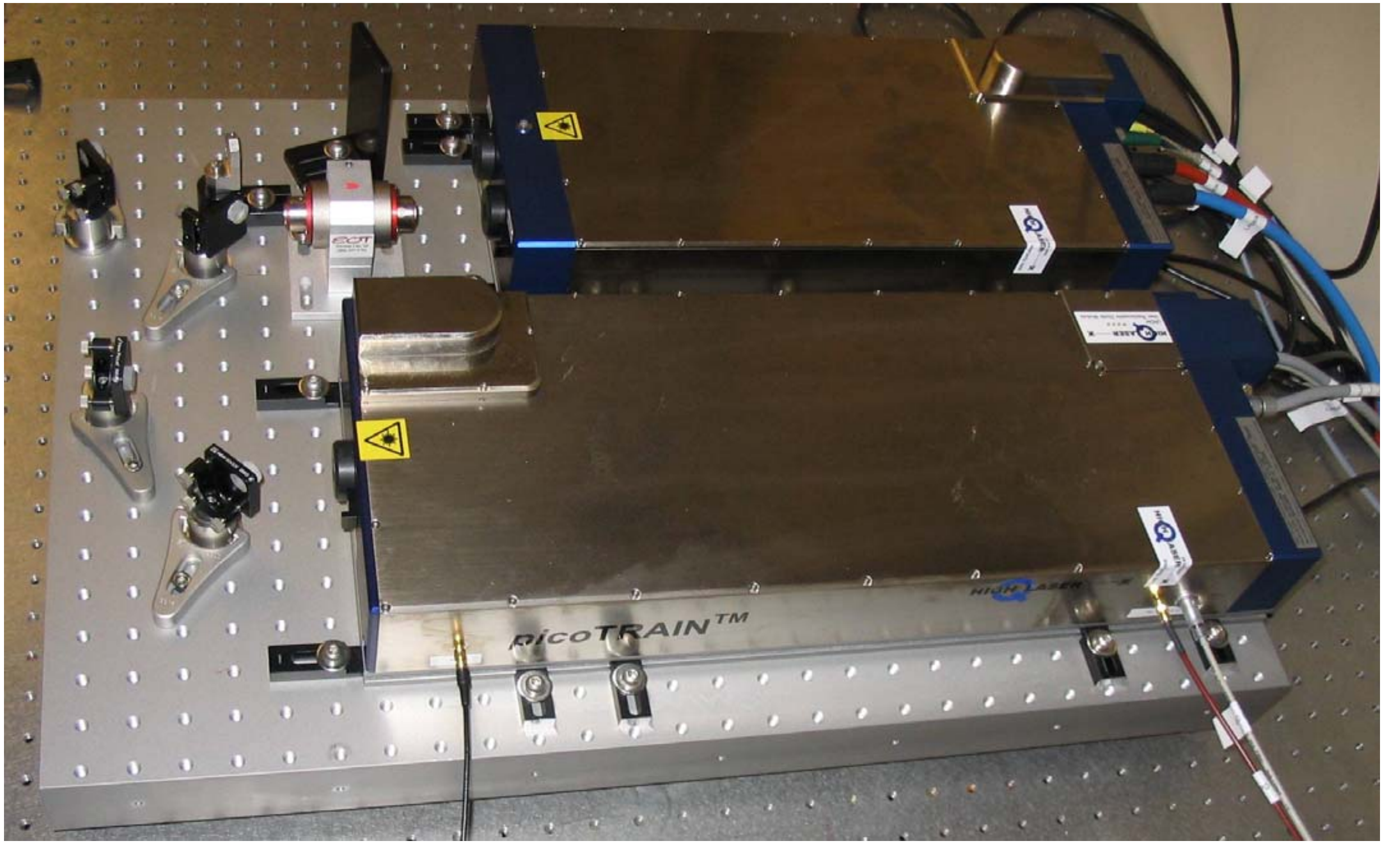
Stabilisation issues

- 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 μs pulse looks challenging (BW> few MHz into 20pF Pockels cell load needs 10s of mA drive for 100s of volts change)

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

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

Status – Oscillator/Preamplifier



- Delivered, installed and commissioned in Q2 2005
- Has met all specifications
- Seems capable of accommodating coding hardware

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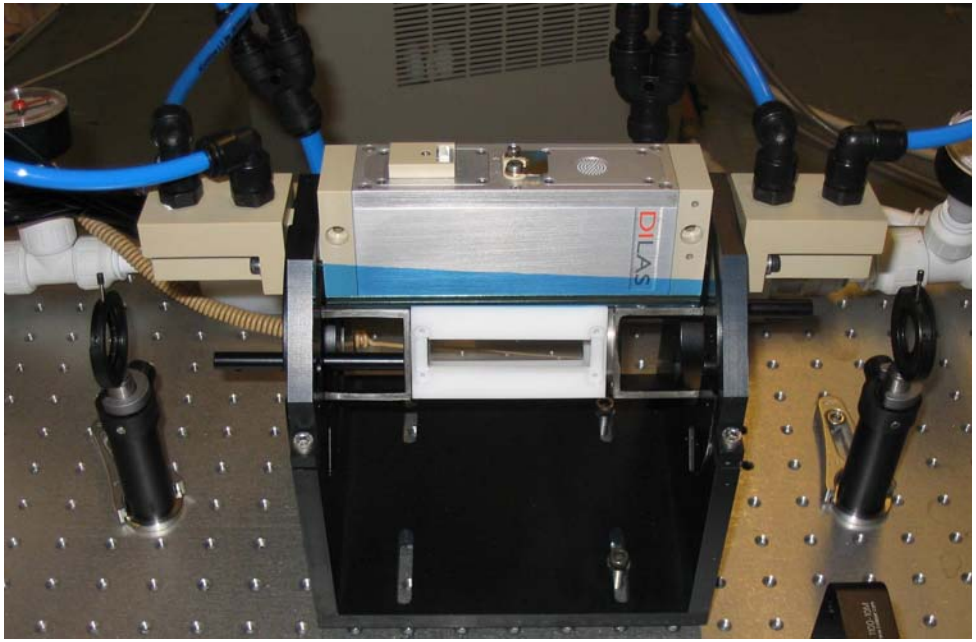
Status - Diodes



- Amp 1 and Amp 2 diodes delivered
- Amp 1 diode chiller delivered and installed
- Water connected and tested to one Amp 1 diode stack
- Diode wiring designed with shielding to satisfy Low Voltage Directive
- Amp 1 drivers delivered and tests under way

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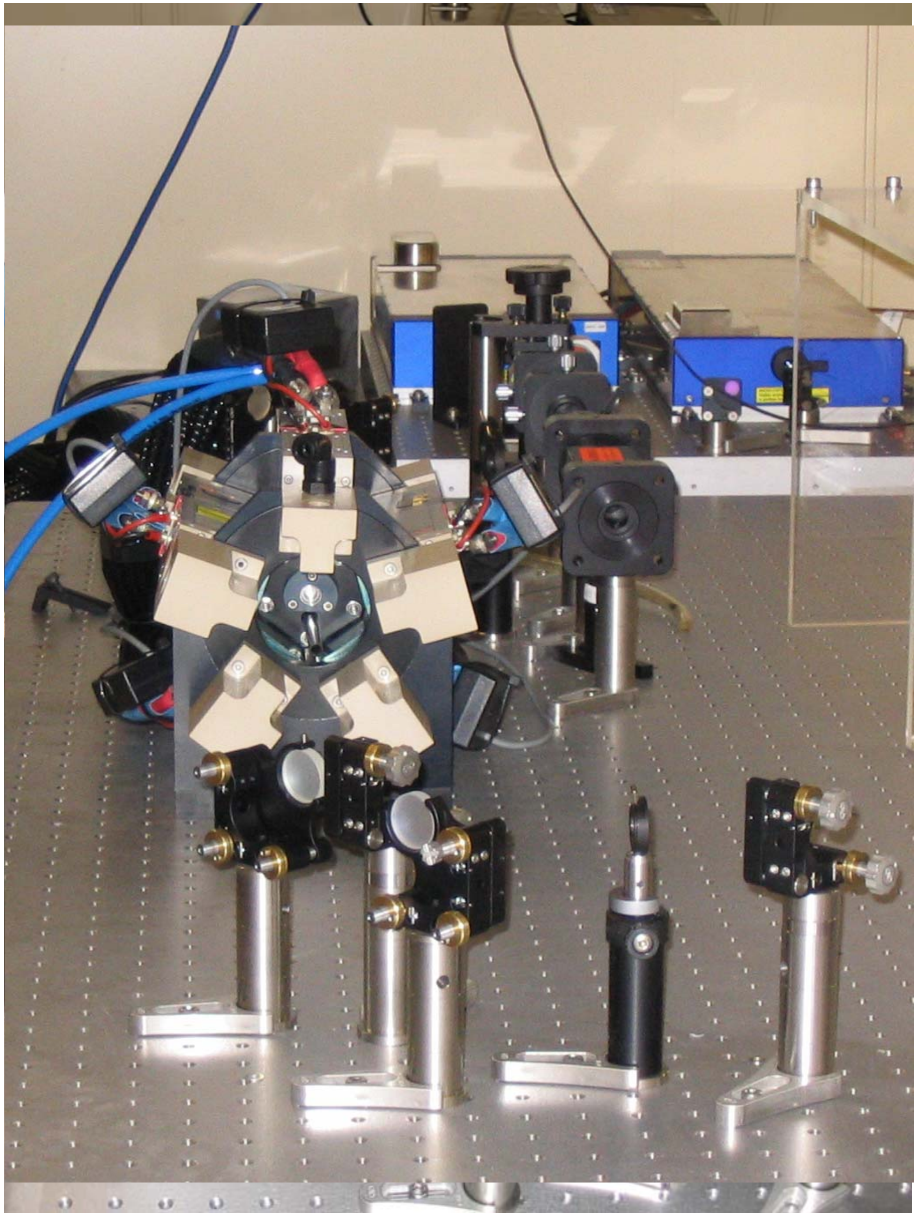
Status – Amplifiers



- Designs complete
- All Amp 1 components delivered
- Amp 2 components in procurement or delivered (diode chiller outstanding)
- Amp 1 mechanical assembly tested
- Amp 1 diode plumbing, wiring and interlocking under way

Status – HG and Thermal Lensing

- HG design complete – 2ω and 4ω based on Type 1 BBO
- Crystals ordered
- Thermal transients, particularly in 4ω crystal, still uncertain (rotated crystal pair will be tested against single crystal for 4ω)
- Option for Type 2 2ω in KTP for polarisation multiplexing to 3 GHz

- Lensing will be compensated at 5 Hz macropulse rate
- Original plan: diagnose lensing and correct after Amp 2 testing
- Updated plan:
  - a) model the lensing process to establish limits
  - b) procure mounts and a range of lenses
  - c) validate with Amp 1 measurements
  - d) implement correction and confirm HG

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Summary and Issues

SUMMARY

- Oscillator and preamplifier commissioned
- Power Amplifier 1 under assembly/test and most Amplifier 2 components either delivered or in procurement
- Gating, coding and stabilisation subsystems planned and in pre-procurement or procurement
- HG crystals ordered and thermal lensing compensation begun
- Control and interfacing under development

ISSUES

- Stabilisation control architecture to be decided
- Stabilisation system will need optimising in final environment
- Tight procurement will be needed to maintain delivery date
- Recovery of coding system losses

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