Pilot Test Laser Results
With many thanks to all involved
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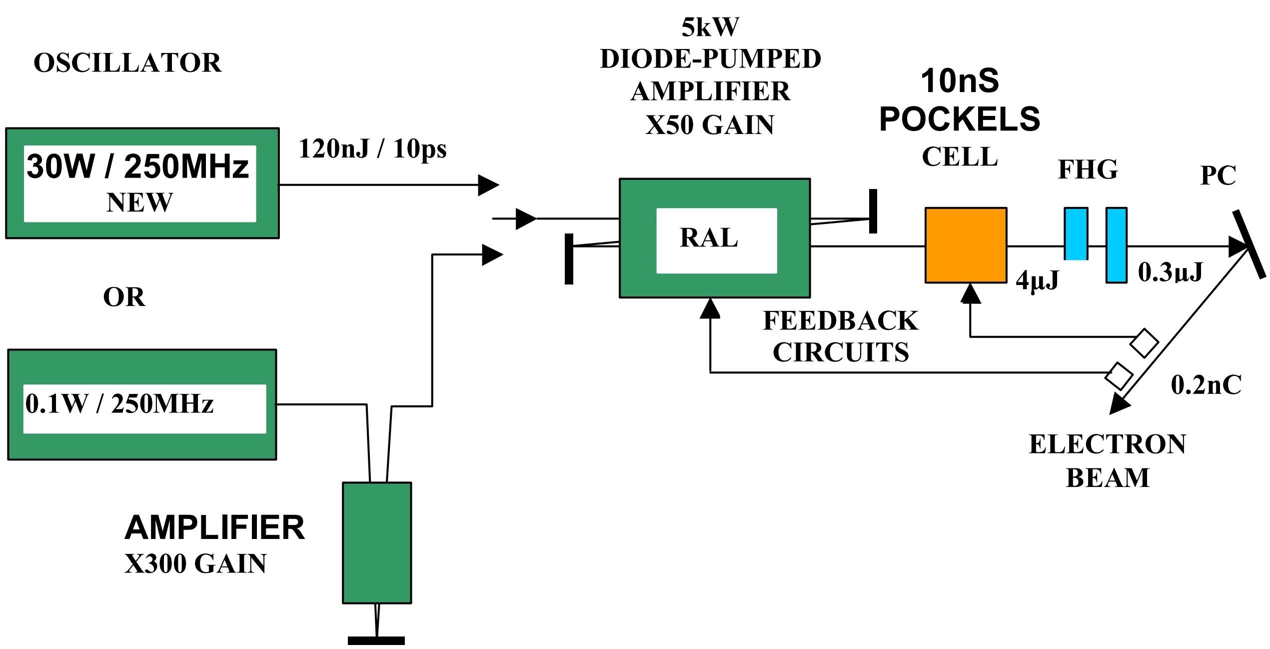
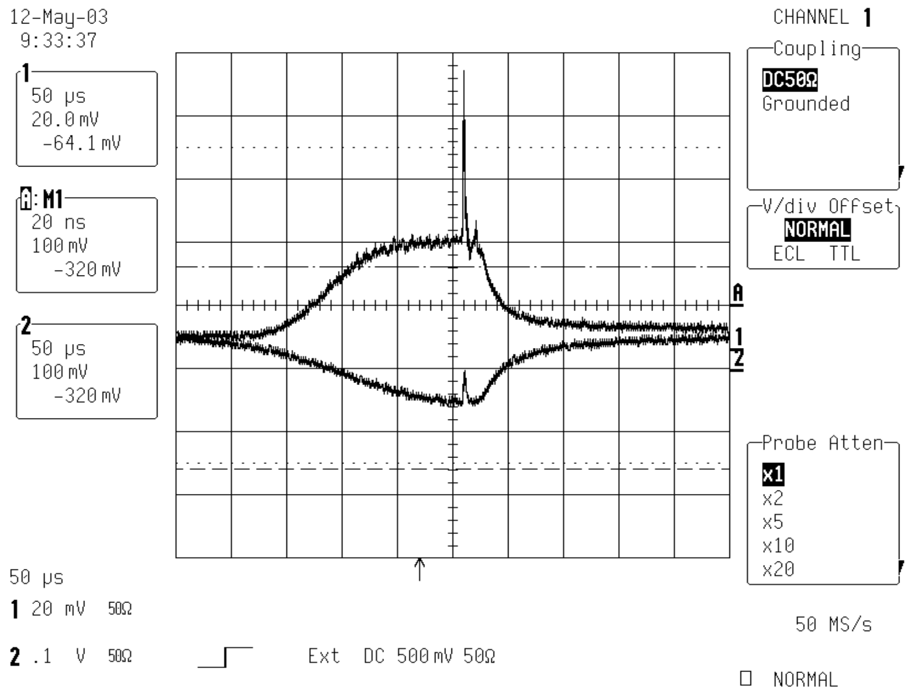
The feasibility study ended in 2002,and included topics:

Basic design features
Pumping Schemes
Amplifier Simulations
Thermal Effects
System Staging
Non-linear optics
Stability
Failure modes/protection
Oscillators
Timing

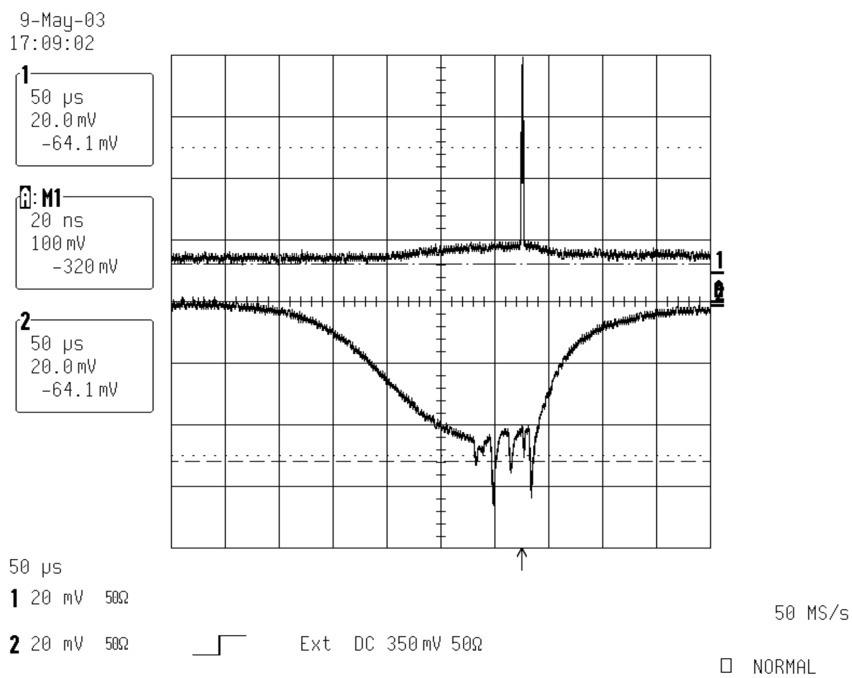
Hardware was produced and tested at RAL, but under conditions that are different to those of CTF3. (cw injection…)

The Pilot Test was planned in order to demonstrate a small scale injector in operation, confronting the simulations and suppositions with reality, with this step completed, we could then confidently extrapolate to a real CTF3 scale system.





Good amplifier performance: but note the amplitude ripples on the flat top of the pumping profile.

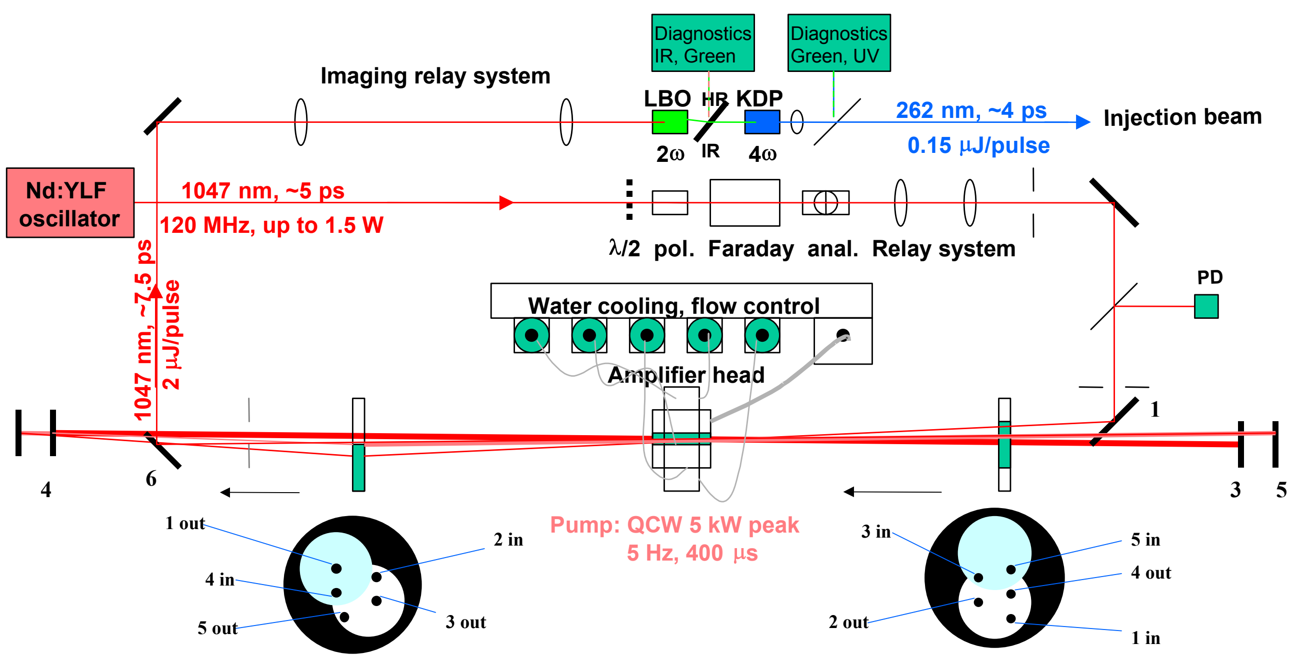


Optical feedback into the amplifier: oscillations occur at high gain, a laser cavity has been formed, one reflective surface was usually found to be the lens before the Harmonic generators or the beam dump after them, the other end of the cavity is impossible to find.

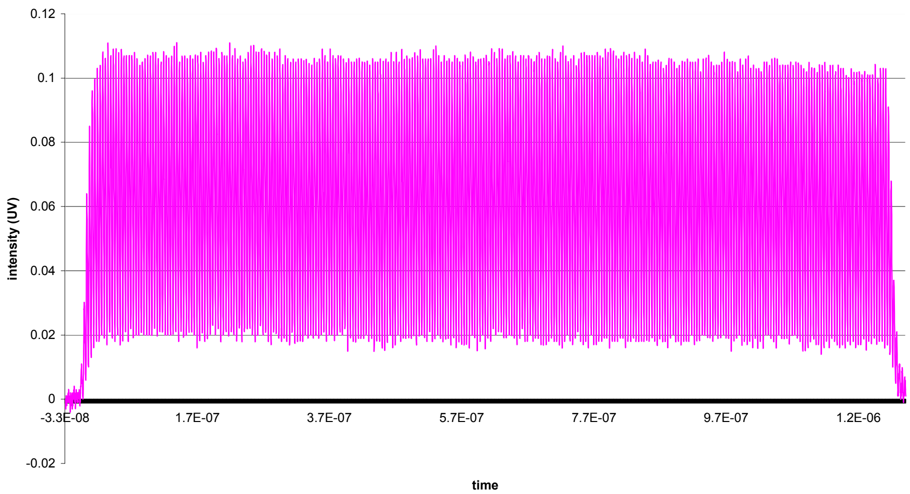
Given the available equipment and budget, the target performance was established:

Target Parameters	Units	Worst case	Nom.	Best case
Charge / pulse	nC	0.072	0.15	0.36
Number of pulses	-	350		
Distance between pulses	ns	4		
Macro-pulse width	μs	1.4		
QE_{min}	%	4	5	6
Wavelength	nm	262		
$W_{cathode}$ / pulse	nJ	18	30	60
Optical path transm.	%	50		
IR/UV conversion eff.	%	3	5	10
Stabilization transm.	%	80		
W_{OUT} / pulse (Amplifier)	nJ	1500		
Total Amplifier Gain	-	≤6000x		
W_{OUT} / pulse (oscillator)	nJ	0.4		

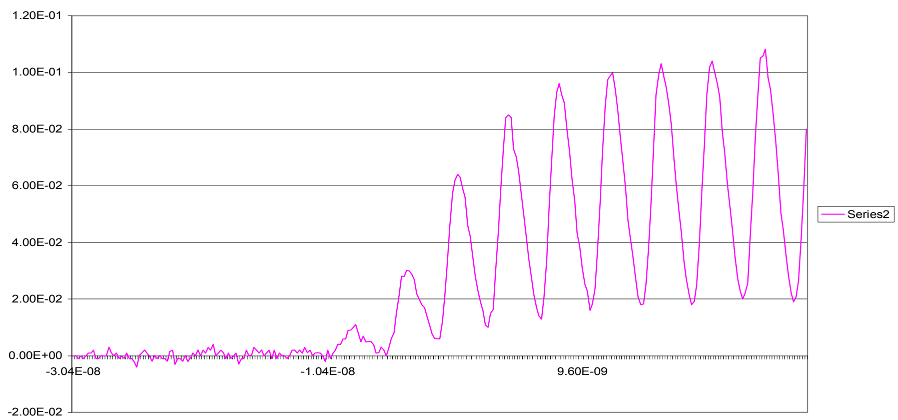
This was assuming either a high-power oscillator or a separate pre-amplifier, neither of which materialised. In order to compensate, the RAL amplifier was set to a 5-pass mode, where operation in saturated gain mode would be harder to achieve, (G=~5.7, 5 times).

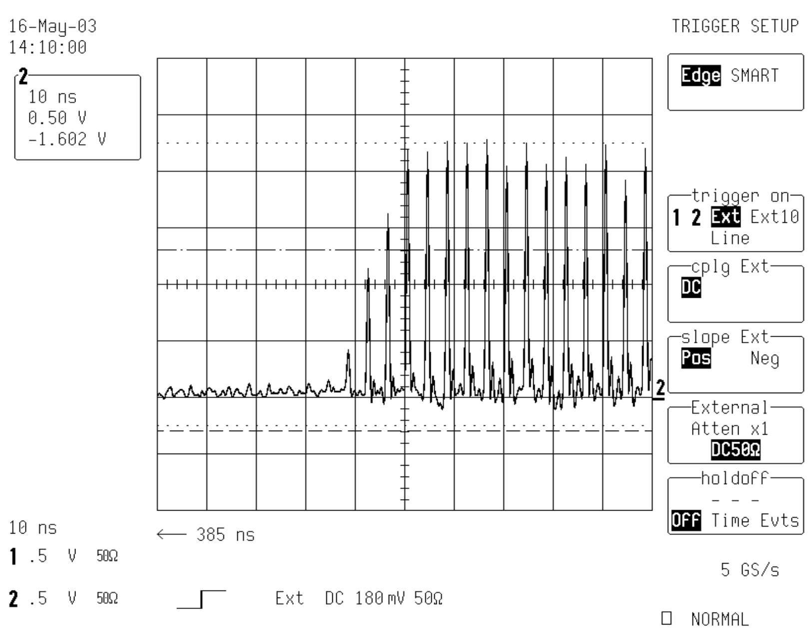


1.2us pulse train



Start of train, bandwidth limited

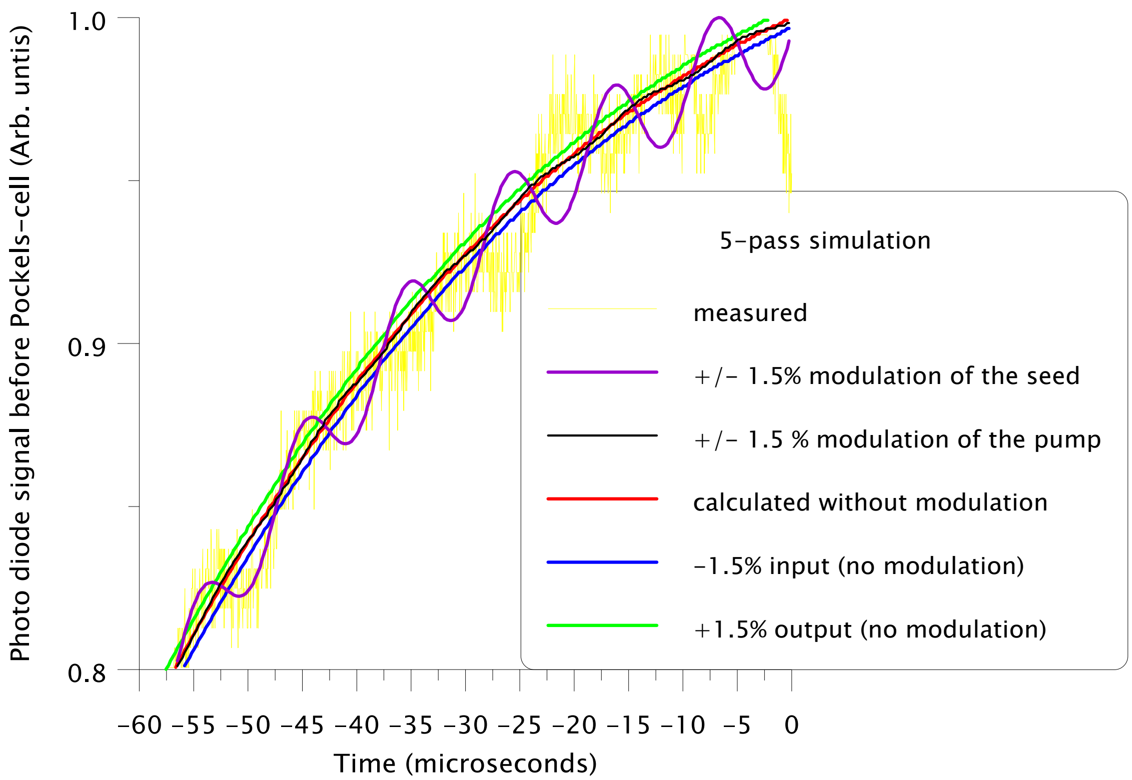




	target	actual	
IR Energy/pulse	1.5uJ	1.2uJ	
UV Energy/pulse	60nJ	16.8nJ	
WCM Charge/pulse	150pC	70pC	
Stability	<1%	1.9% rms	

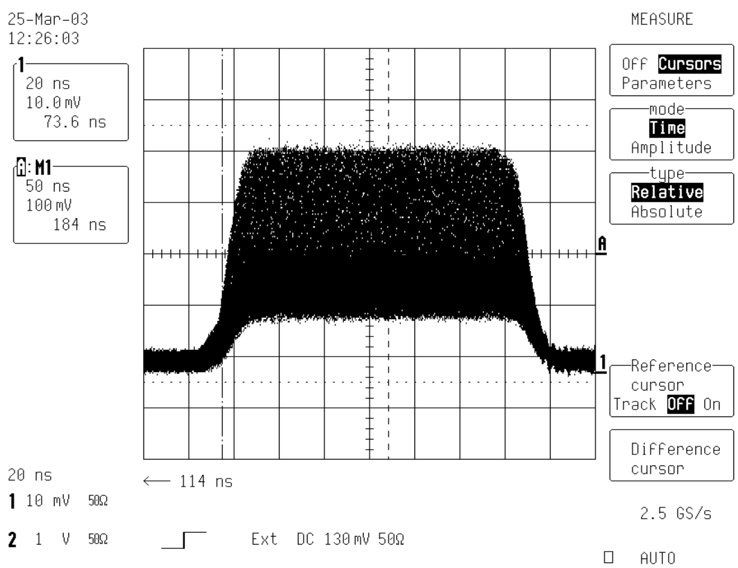
Why not better?

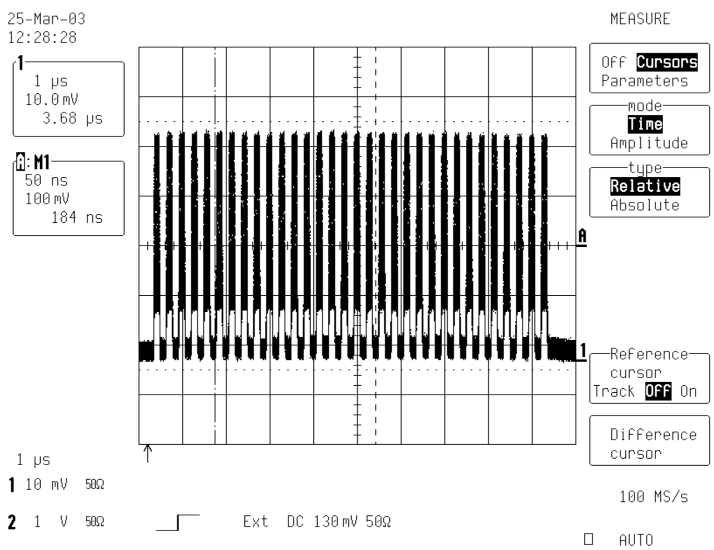
- **5–Pass amplification: Strong saturation not possible: more sensitivity to input variations**
- **Ditto: it is not possible to control the beam size through the 5 passes, beam size and position change with each pass in the amplifier.**
- **Damaged pump diodes, giving lower output and lower gain, non-uniform beam profile and therefore poor conversion.**
- **Damaged 2HG crystal, possible source of reflections back to amplifier, causing instabilities, and contributes to poor conversion efficiency.**
- **Oscillations on LWE output (1.5%rms) at 10uS period, not synchronised to RF. Switching off the Klystron reduced these by 50%, so some interference to the LWE unit is suspected, also influenced by mode locking setting.**

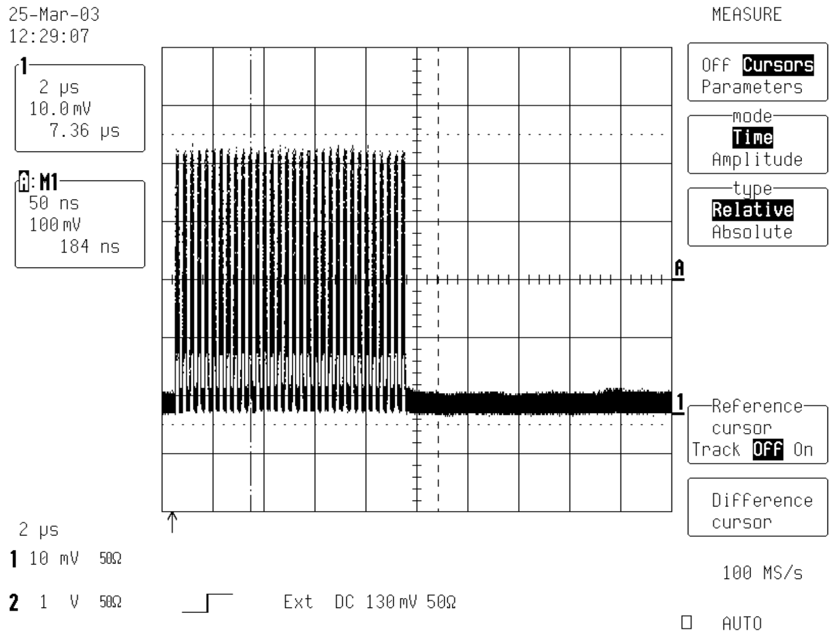


Another important advantage of a laser photoinjector for CTF3 is the possibility of phase coding using Pockels cells. A suitable HV pulse generator was purchased, and tests made on different Pockels cells.

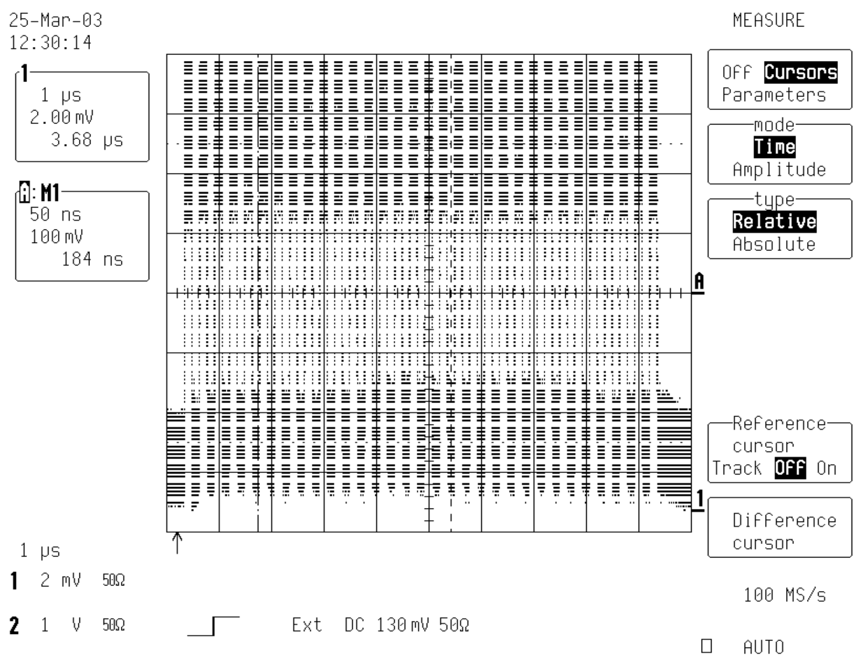
Gsanger CPC5 BBO serial # 012, purchased 1996,
Transverse Pockels Cell, Aperture 4.8mm,
Dry cell for use at 262nm (AR coatings on windows and crystal),
L/2 voltage(262) = 2.8kV
n.b. L/2 in double pass at 630nm (test conditions) = 3.35kV, beyond stable range of HV pulser, 100% transmission cannot be achieved in these tests.



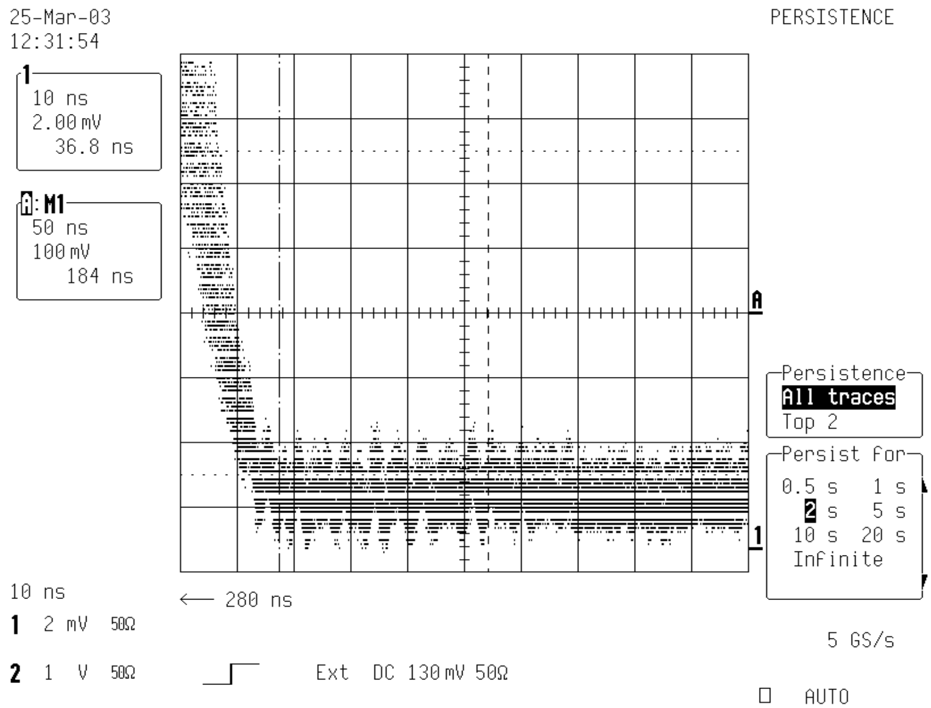




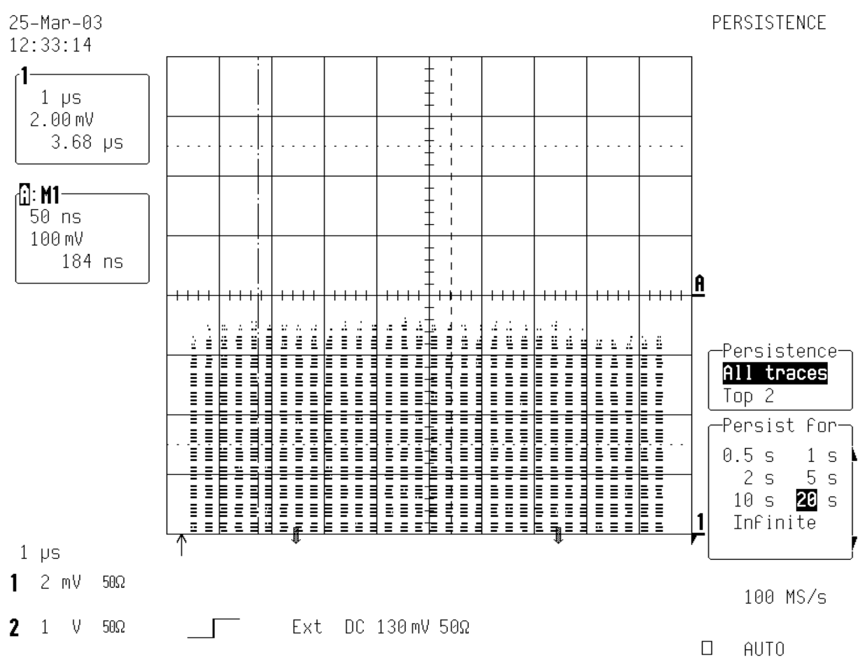
No ringing after train



expanded scale: near-constant baseline ~1mV/43mV

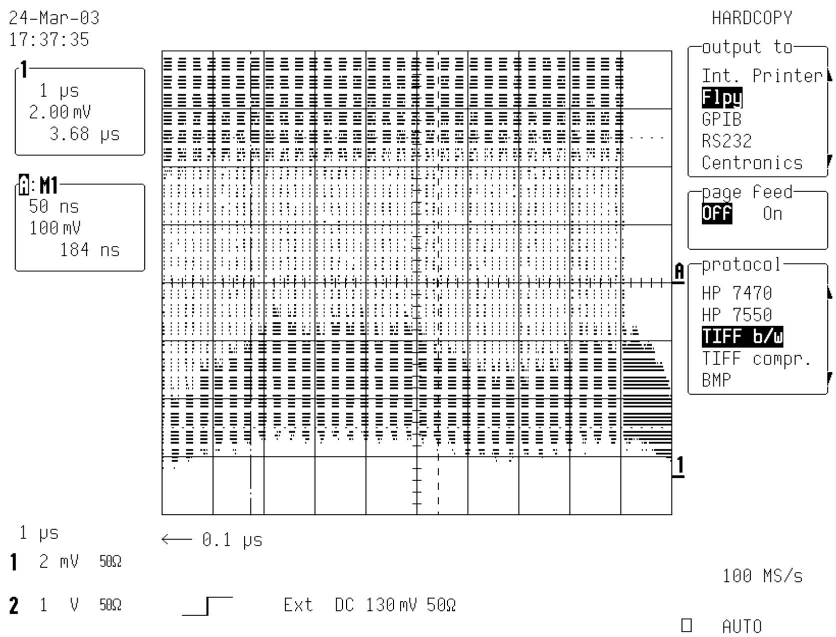


Detail: end of first pulse; high frequency ringing, ~350MHz



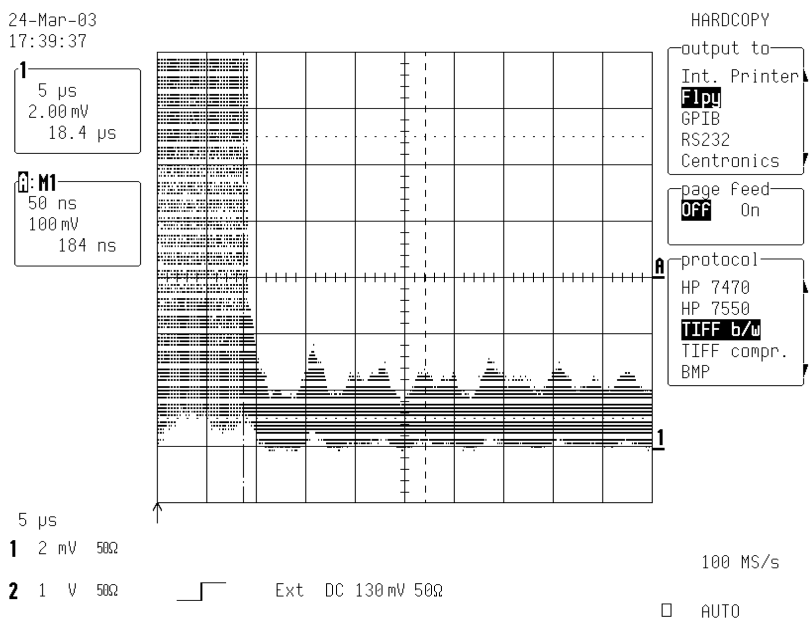
Expanded scale, pulse transmitted intensity, <1mV, 2.5%
(should improve if l/4 voltage could be used)

Gsanger (LINOS) LM8 IM serial #1780



Train “off” transmission varies due to mechanical ringing causing polarisation changes, 4mV/35mV 11% error

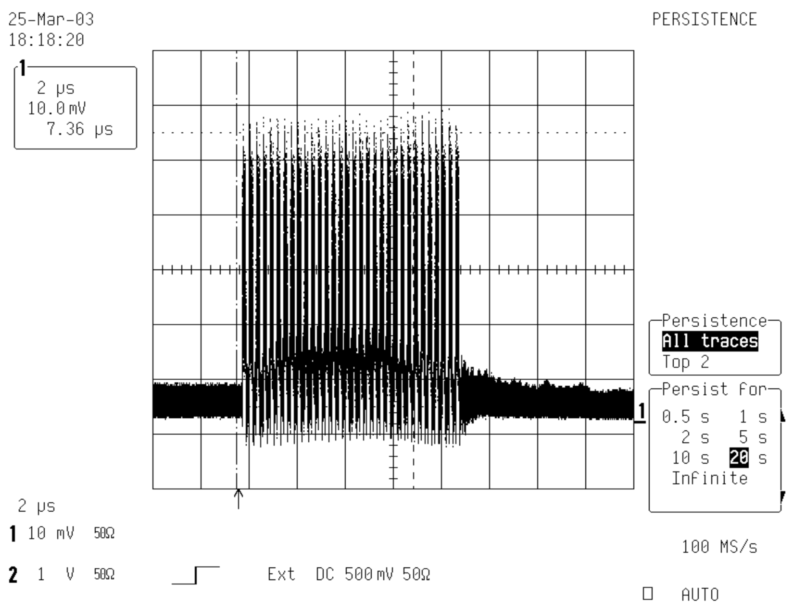
“On “transmission changes due to crystal vibrations 2mV=6%

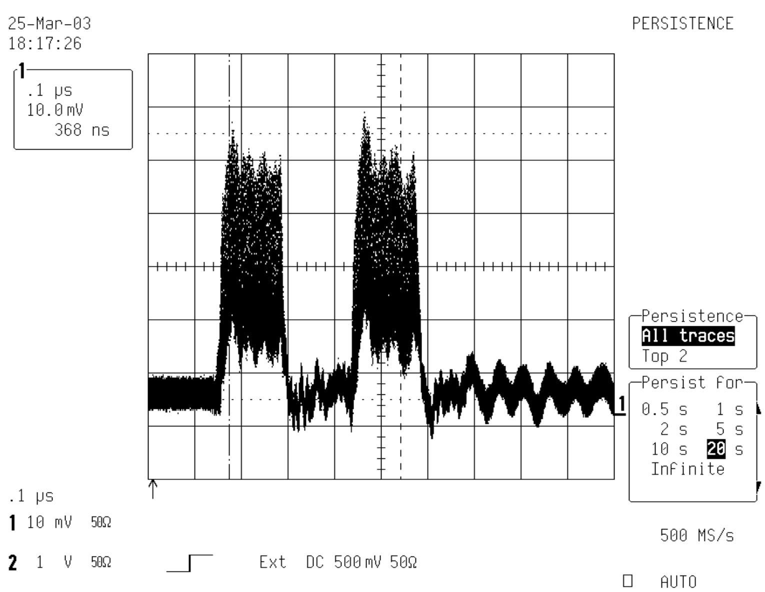


“ Off “ oscillations continue after last pulse, damped oscillation for 50us

Cleveland Crystal CX819 ser.# 0287
KD*P, longitudinal
For operation at 262nm, l/2 voltage= 3.5kV, Cap. 6pf
Calculated L/4(630nm)=4.2kV: cannot achieve best performance in HeNe tests (as pulser max. 2.9kV).

“Best performance” at 2.0kV, note this unit tested under non-optimum conditions, cell has smaller dimensions than can be accommodated in test housing, some EMC induced into measurement system. Provisional data:





Conclusions

☹ Our estimates of laser performance were out by x2, but for reasons that should not apply in CTF3 laser case.

☹ The work was made much harder due to the lack of good instrumentation (detectors and scopes). Detector bandwidth limitations, low frequency cutoff, sensitivity and oscilloscope aliasing and sampling effects mask real artefacts. This will be far worse with higher frequency operation.

☹ We had already foreseen the need for inter-stage isolation and imaging; lack of budget, space and time encouraged us to take a shortcut, which lead to the predictable problems.

☹ Harmonic generation had not been thoroughly tested at RAL, much more space was required on the table than could be provided.

☺ A 1.2us, 300 pulse-train was generated, the laser system was capable of producing a 150us train.

☺ Pockels cells were used to effectively suppress leading pulses to better than 1% and to minimise the heating effects in the Harmonic generator crystals, which is essential for good control of the conversion efficiency.

☺ Pockels cells have also demonstrated the ability to perform the CTF3 phase-coding with 20ns rise and fall times, with 2% residual signal, due to acoustic vibrations. This performance should be improved in collaboration with the manufacturers.

☺ *The PILoT test has shown that if care is taken to include all of the elements isolation between stages, relay imaging and correction of astigmatism in the amplifiers, the predicted performance is attainable, and that it is reasonable to extrapolate from this test to a CTF3 scale system.*