The CTFII Laser system

November 1998
CTF Note 98-18
S.C.Hutchins PS-LP

The CLIC Test Facility (CTF)

The CTF is a small installation, the aim of which is to enable tests to be made on various aspects of the technology that would be required in a future linear collider[1]. The operating principle of the accelerating sections is a two-beam system, where energy is extracted from a powerful train of electron bunches (the Drive Beam, DB) which are spaced at 333ps. The drive beam passes through 30GHz resonant cavities, generating the microwave power used to accelerate the Probe (or Physics) Beam.

Laser-driven photo-cathodes are used to generate the electron bunches, the photo-emissive surface being placed at the back of a 3GHz RF accelerating cavity[2]. The photo-cathode material must have low dark current emission as well as a good performance in the high power RF field. Cs2Te is used for the DB and CsI+Ge for the PB, these materials function with an acceptable quantum efficiency when illuminated with UV light, for this reason the laser output is converted to the 4^{th} harmonic at 262nm.

The CTFII laser overview

The CTFII laser[3] is a “Master Oscillator- Power Amplifier” (MOPA) system in which 2 pulses are selected from a 250MHz Nd:YLF mode locked oscillator. Their separation is 4ns; the pulse length 8ps and they have an energy of only 0.5nJ per pulse. They are amplified in a Regenerative Amplifier (RA), followed by power amplifiers to attain the level of 7mJ per pulse, which is a gain of over 10^7, the amplifiers are all pumped by flashlamps. The power density is 10 GW/cm^2 at the final power amplifier, which is close to the damage threshold, the beam is limited to 4.5mm diameter, due to the size of the components. The wavelength is converted from 1047nm to the 4^{th} harmonic at 262nm. The 2 UV pulses are then progressively “split” with appropriate delays in a “Pulse Train Generator” (PTG) to produce the Drive Beam train of 48 pulses with 333ps separation. The separation is exactly a 3GHz RF period, so that each light-pulse will illuminate the photocathode at exactly the same RF phase, the resulting electrons will then be equally accelerated. The timing for the laser and the 3GHz RF generator are driven from the same master oscillator to ensure synchronisation. The residual green light from the initial 4^{th} harmonic generator is used to produce a pulse for the Probe beam. This initially passes through a Pockel’s cell that rotates the polarisation of the second green light pulse by 90°. The two pulses traverse a pair of Brewster polarisers that reject the second pulse. The remaining pulse is converted to UV by a BBO crystal. The two beams are imaged to their respective cathodes, for the Drive beam the distance is 32m with a magnification of 2x. The Probe beam must arrive at the accelerating section in the linac when the 30GHz power has been generated, so its path length is 35m.

Details of the laser: injection, amplification, beam paths

The injection line.

The seed pulses are produced by a Lightwave Electronics Corp. model 130 mode-locked laser, which is synchronised with a 250MHz signal from the same oscillator that generates the 3GHz RF drive power for the linear accelerator. In this way the RF and the laser pulses are fixed in relative phase, the absolute phase can be varied by adjusting the optical path length or by the use of an RF phase-shifter. The output level of 100mW CW is stable to better than 1%, but the unit is sensitive to acoustic vibrations, optical feedback and temperature variations, which affect the timing stability. The 0.5nJ pulses first pass through an optical isolator, to avoid reflections back into the oscillator cavity.

The pulses to be amplified must be selected from the pulse train to avoid creating satellite pulses. The pulse selection is made by "Pockels cell 3" (PC3). The laser output makes a double pass through a Faraday rotator and the PC3 cell which rotates the polarisation by 90 degrees when the Pockels cell is driven by a 3.4kV pulse. The beam then passes through a Brewster angled thin film polariser, the horizontally polarised pulses pass through and the vertically polarised pulses are rejected. The high voltage pulse duration can be adjusted to select one or two pulses from the 250MHz beam. The optical path length for the double pass through the cell and the limited rise-time of the high-voltage pulse must be accommodated in the 4ns between the pulses.

The selected pulses then pass to the grating pulse stretcher. For the most efficient extraction of the laser energy, Chirped Pulse Amplification (CPA) is employed in the RA and the single pass amplifier (A1), this enables the bandwidth of the laser emission spectrum to be fully used. An imaged anti-parallel grating pair[4] placed between the LWE oscillator and the Regenerative Amplifier (RA) provides the positive group velocity dispersion, and a parallel grating pair between the two amplifier sections to compensate back to a short pulse. The peak energy of the IR pulses is below the damage threshold of the gratings at this position in the amplifier chain, unless the beam becomes focussed.

Diagnostics of the injection are currently limited to the observation of the unused part of the train- the "train + hole" where the action of the pulse selector can be monitored, the current configuration places the pulse selector before the pulse stretcher. The energy of the selected pulse is so low that no further measurements can be made on it. No data is therefore available on the length of the stretched pulse, the efficiency (transmission) of the grating system or the spectral characteristics of the injected pulse. A comparison of the spectra of the injected pulse and that of the output from the RA would indicate the optimum settings for the RA, as the bandwidth of the YLF rod changes with the pumping energy intensity.

Amplification: The Regenerative Amplifier

For most stable operation the injected (seed) signal should be as large as possible to minimise the amount of amplification that then required from the laser. Ideally the number of round-trips could then be reduced, as each passage through the amplifier adds a small amount of wavefront distortion which reduces the quality of the beams' transverse profiles.

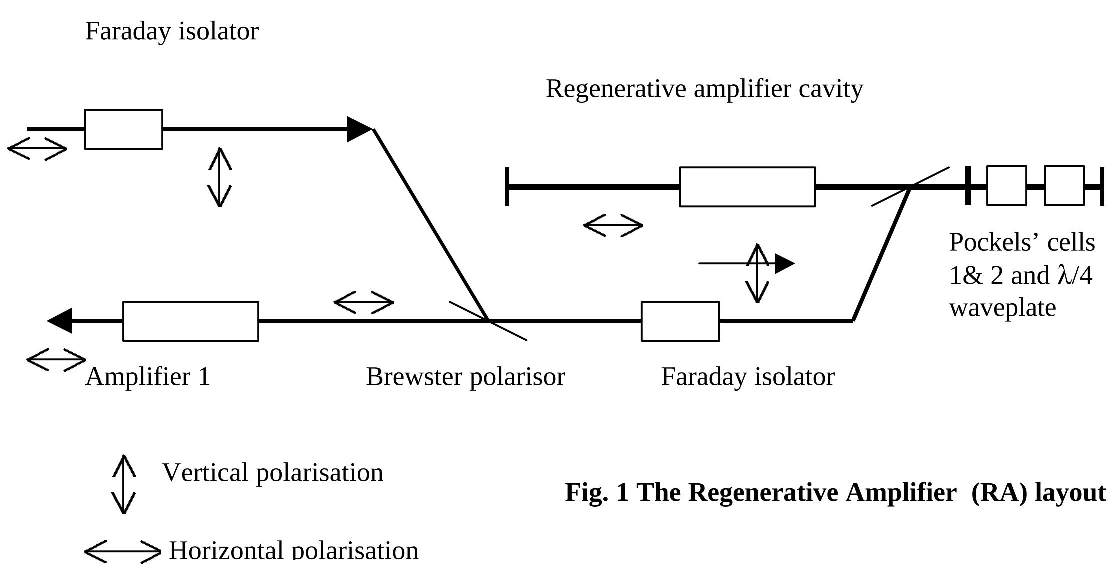
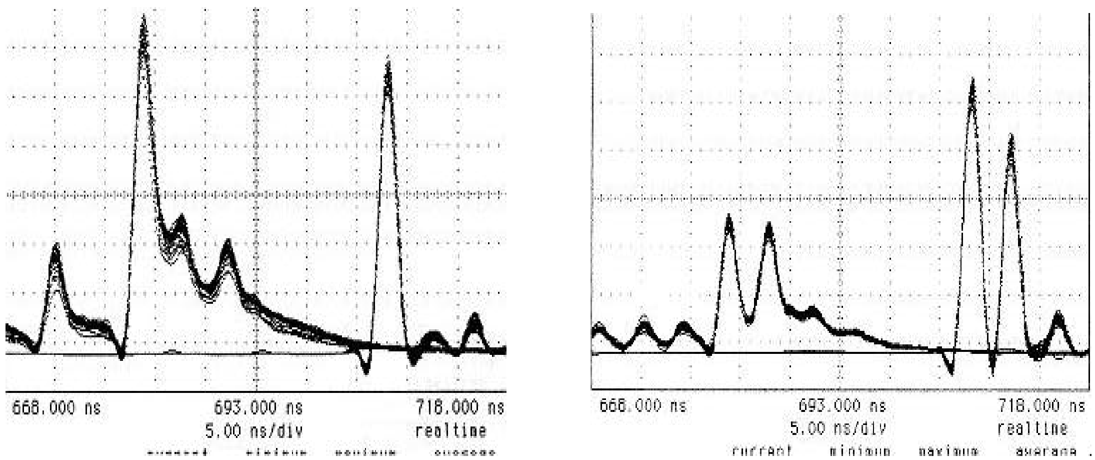


Fig. 1 The Regenerative Amplifier (RA) layout

Amplified Spontaneous Emission (ASE) in the regenerative amplifier can cause a "pedestal" pulse whose length is that of the cavity, to minimise this the injected seed pulses should be as intense as possible.

The selected pulses are injected into the RA via a pair of thin film polarisers, and a Faraday rotator. The cavity contains 2 Pockels cells, the operation of the RA requires that the polarisation be switched from a low-Q state (high loss) before injection, to the low-loss high-Q state during amplification. To extract the amplified pulses the polarisation of the amplified pulses must be rotated a second time. This could be done with one Pockels cell, if the drive circuitry could pulse for the exact time of the amplification cycle and with a constant voltage on the cell. In practise it is easier to use two cells which are both under bias before laser operation, and each is rapidly discharged at the appropriate instant.



figs. 2,3 regenerative amplifier monitoring, single pulse mode (left) and double pulse mode (right), the left-hand peaks are the IR signal from the RA, the right side are the UV pulses at the output of the laser.

PC1 controls the polarisation in the cavity before and during the amplification time. Before the amplification period the polarisation is set to inject pulses into the cavity. Pulses arrive on the cavity axis, to pass through the Pockels cells (which are initially biased to give a $\lambda/4$ rotation at each passage), and a $\lambda/4$ waveplate. The combined action of these three elements turns the pulse(s) to horizontal polarisation at the polariser, where they are then transmitted to the amplifying medium. A subsequent pass through the Pockels cell area would rotate the pulses a second time, thus ejecting them from the cavity. To avoid the amplification of these pre-pulses, only the pulses to be amplified are presented to the cavity, all others having been rejected by the action of PC3.

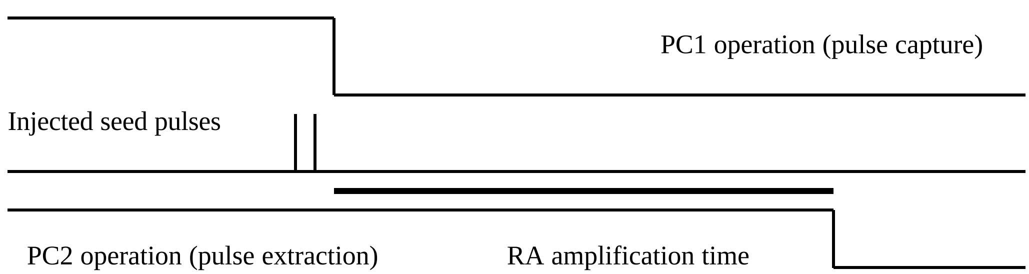


Fig.4: timing of RA sequence

When both pulses have passed into the amplifying section of the cavity, PC1 is discharged, “closing the gate”, effectively “locking in” the seed pulses. As the cavity round-trip time is 8.6ns, and there is a 4ns spacing between the two pulses, the commutation must be complete in less than 4ns, given the physical size and location of the two cells. Any residual voltage, or ringing, on PC1 during the amplifying period would cause depolarisation of the injected pulses resulting in a loss of gain.

The RA amplifies the seed pulses from 0.5nJ (or less, due to losses in the gratings, pulse selector and isolators) to about 300uJ per pulse, a gain of 600,000. This is achieved during 60 round–trips in the RA cavity, an average gain per pass of 11%. The RA timing and flash-lamp power are chosen to give the highest pulse to pulse energy stability. The output timing is set for 60 round-trips and the RA flashlamp voltage is adjusted to the level where the gain per pass becomes zero. This indicates that the energy stored in the laser material has been depleted by the passage of the amplified pulses. Further round-trips in the RA would result in a lower output. The flashlamp drive level also compensates for losses in the cavity due to damage, misalignment and flashlamp ageing. When optimised the level should be as low as possible, any increase indicates that some action may be required.

The optimum operating voltage for the flashlamps is confirmed by changing the timing of Pockels cell 2 (PC2) to a later point, (see fig.4). The signal then observed is that of light “leaking” from the RA cavity due to depolarisation, as any vertically polarised component is rejected by the Brewster polariser in the RA cavity.

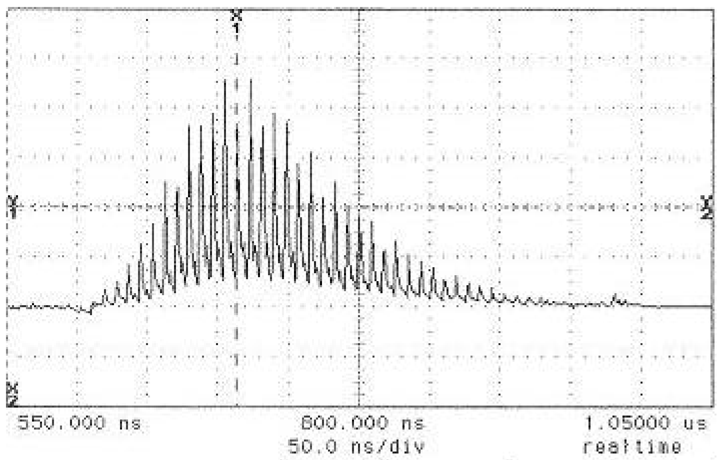


Fig. 5: RA with PC2 delayed, showing gain envelope of the laser.

Amplification: Amplifier 1 and the pulse compressor

The amplified pulse exits the RA when PC2 has changed its polarisation, it then passes through a Faraday rotator and waveplate which combine to rotate the polarisation again so that the pulse traverses another Brewster-angled thin film polariser. This arrangement separates the injection and extraction paths. The amplified pulse has a beam size of about 1mm diameter, the beam must be expanded to avoid optical damage in the following elements. A beam expander composed of two lenses of -190mm and +250mm focal length provides a beam magnification to 1.3mm diameter. The diameter of the amplifier rod is 4mm (same as the RA), that of the second amplifier is 6.35mm. The beam must be expanded to minimise the power density at the second amplifier also, for this reason the beam expander is set to produce a beam having a size of 3.5mm diameter at the second amplifier.

A small electrical shutter is placed before amplifier #1, this is a safety interlock for the CTF. In the case that the main optical shutter between the laser room and the CTF malfunctions, this small shutter blocks the beam path.

Amplification: Amplifier 2 and the Harmonic Generators

The available energy has been increased by changing the second amplifier from single to double pass. As well as the extra energy, pulse to pulse stability and the transverse profile are improved. In a single pass amplifier configuration the light pulse could not extract sufficient energy at a gain of 10, at higher gains the energy fluctuations increased. By operating the amplifier in a near-saturated gain configuration, pulse to pulse amplitude variations from the regenerative amplifier were reduced and the available energy per pulse increased.

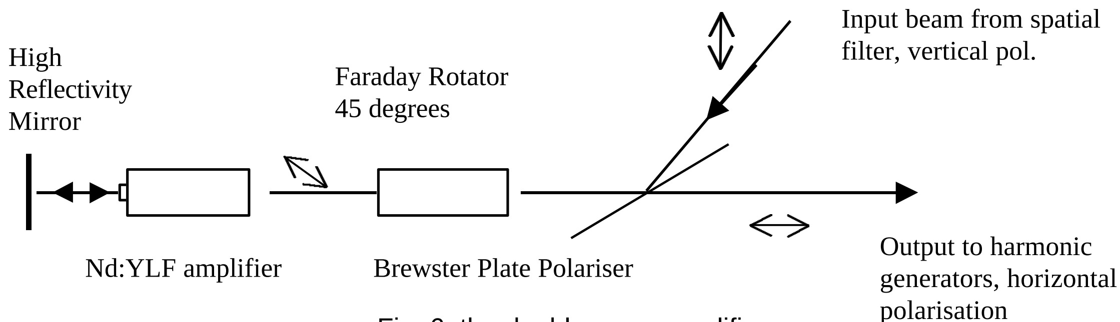


Fig. 6, the double–pass amplifier

The pulse amplified in this way has its transverse profile improved for our application, from a Gaussian towards a broader “flat top” distribution, which makes more efficient use of the photocathode surface.

To achieve double pass operation in Nd:YLF requires that both passages through the material are of the same polarisation, as the material is birefringent and for the two polarisations operates at two different wavelengths. To separate the input and output beams a polarisation selection was used.

In this configuration, a Brewster plate is used to enter the amplifier section, this is immediately followed by a Faraday rotator which advances the polarisation angle by 45 deg., the Nd:YLF rod also has to be rotated to this angle, the incoming beam is then amplified through the rod, is reflected off the end mirror, and passes a second time with the same polarisation angle through the amplifier rod. On the second pass through the Faraday rotator the polarisation is rotated by a further 45 degrees to become vertically polarised. The amplified pulse is then transmitted through the Brewster plate.

The horizontal polarisation of the output beam is rotated by 45 degrees by a $\lambda/2$ waveplate before the KDP doubling crystal to enable Type II harmonic generation.

The probe beam

The aim of CTFII is to demonstrate the two-beam principle of using a powerful train of electron bunches to generate the 30 GHz power required to accelerate the probe beam pulse. To create the probe beam a separate RF gun using CsI+Ge photo-cathodes is employed. This material can be used without requiring a costly vacuum transfer chamber. The quantum efficiency is only be 0.01%, the required electron charge is 5nC so that UV energy of 40uJ is required.

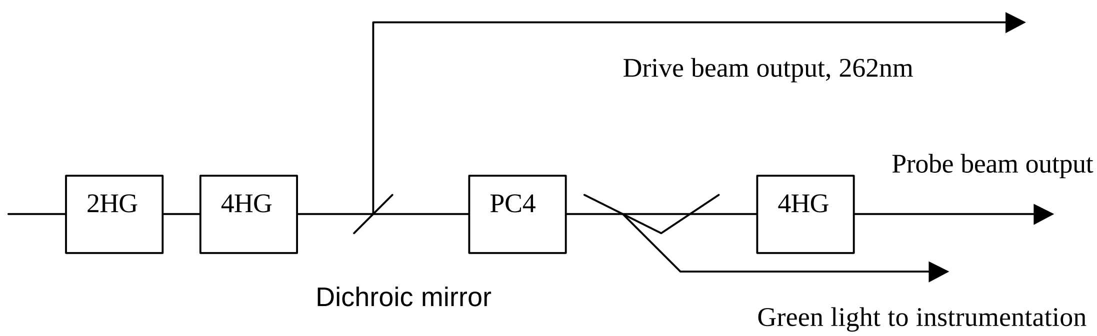


Fig. 7, probe beam generation

In the harmonic conversion process, the efficiency of conversion from the 2nd to 4th harmonic is only 20%. This gives the possibility of generating the extra energy required for the probe beam by passing the “unused” 524nm light at the output of the 4th harmonic generator through a separate 4th harmonic BBO crystal.

The UV light for the Probe beam is generated by a second 4th harmonic conversion on the remaining 2nd Harmonic green light. As the laser will normally be working in its 2-pulse mode, two UV pulses would be produced for the probe beam, at a fixed separation of 4ns The instrumentation for the probe beam is perturbed by this second pulse, which is therefore suppressed.

A Pockels cell (PC4) switches the polarisation of the second pulse by 90 degrees. The switching must be completed in the 4ns between the two pulses. This is achieved in a single pass through the cell, the half-wave voltage at the second harmonic being the same as the quarter wave voltage at the fundamental, 3400V. The suppression cannot be made at the 4th harmonic, where a fast switch of only 1700V would be needed, as the optical transmission at 262nm is poor. The two pulses then pass through a double, thin film Brewster angled polariser. This rejects the second pulse towards a diagnostic point, and passes the first pulse to BBO 4th harmonic generator. The beam exiting the generator is a mixture of fundamental, second and fourth harmonics which are separated by a Pellin-Brocca prism.

The Pulse train generators

The present PTG system was devised by S.Schreiber and K.K.Geissler[5] and comprises 4 parts which together create the 48-pulse train of 16 ns. If fewer pulses are required, one of the parts may be unused, as in the 24 bunch mode of CTF operation. The usual requirement for CTFII is the full train, which is needed for the drive beam to produce the 30GHz power for probe beam operation.

The first part of the system is the laser working in the 2-pulse mode, where 2 pulses are selected from the 250 MHz pulse train to injection seed the laser. In this way 2 UV pulses are generated with a separation of 4 ns which are on the same RF phase but timing between them cannot be adjusted.

PTG 1 was the first 262 nm generator to be installed, using 0° AOI amplitude splitting mirrors (the light is split into two paths irrespective of its polarisation), of 50% reflectivity, three “splittings” produce 8 pulses from 1 on 8 different paths, each path has a different delay in multiples of 333 ps.

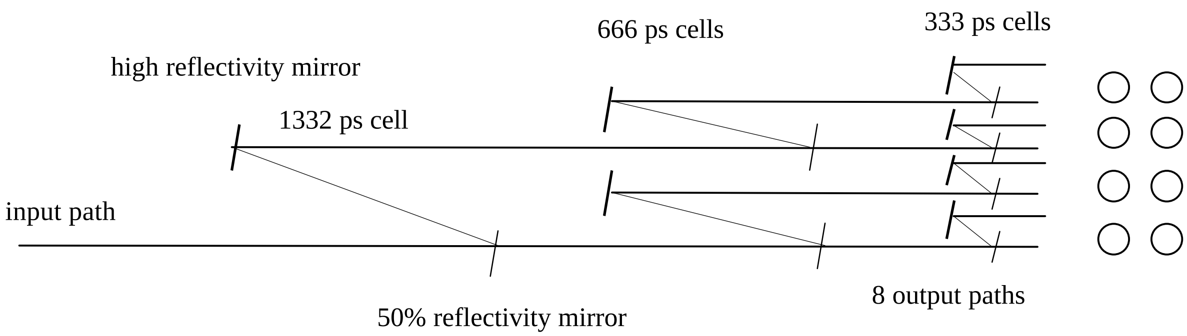


Fig.8 Pulse train generator 1(PTG1) schematic diagram

PTG 2 uses the same 50% amplitude splitting mirrors to produce 16 pulses on 16 different paths, the second set of 8 being delayed by 2.666ns so that the second 8 follow on from the first group. This train has a length of 5.333ns but as the laser generates its second pulse 4ns after the first one, the last 4 pulses in the train are not used, wasting 25% of all the laser energy.

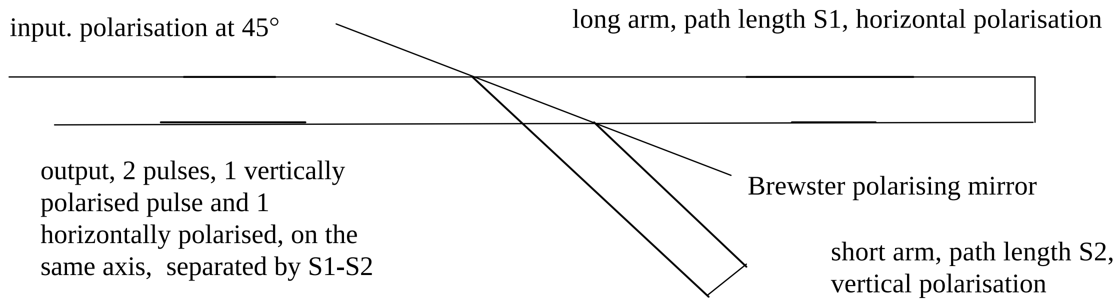


Fig.9 Pulse train generator 3 (PTG3) schematic

PTG 3 (fig.8) is based on polarisation splitting mirrors at the Brewster angle with recombination onto the same optical path, the two resultant pulses having opposite polarisation. The difference in length between the two arms is variable and has been set to generate "long" laser pulses when ΔS = 10ps, two pulses in the same RF cycle with ΔS =33ps and the "normal" 48 pulse mode with ΔS = 8ns. Due to the physical size of the beams after PTG1 it is only possible to have PTG 3 as the first element, although historically it was the last to be implemented.

The 48 pulse train is generated from the two pulses which are amplified in the laser, which are separated by 4ns, these are divided into 4 pulses in PTGIII, where the delay in the long arm is 8ns. These 4 pulses are all on the same axis, the image of the aperture at the output of the laser is projected (or relayed) to the cathode by the lens L3 with a magnification of 2.

PTGI then splits this single axis train into a 4x2 matrix where each axis has a different delay in multiples of the 3 GHz RF period. Each one can be independently steered to the cathode, in this way four bursts of 8 pulses are produced, with a gap of 2ns between each burst, 32 pulses in all. A continuous train would require that each of the four single axis pulses be split into 12, having an equal spacing of 333ps between them. To achieve this the 4x2 matrix is again split to produce a 4x4 array of beams, the extra delay is 2.66 ns which places the delayed 1st pulse of each burst at the correct time to become the 9th.

The following figure illustrates this:

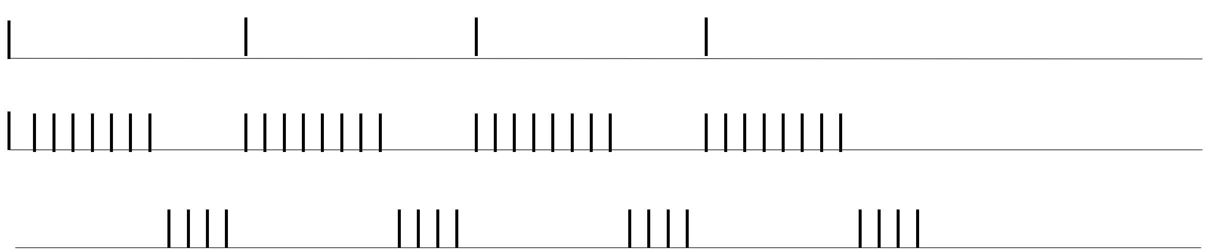


Fig.10, the 48-pulse generator

The first line represents the 4 pulses at the output of PTGIII, their spacing is 4ns, the first two pulses were generated in the laser, the second pair by polarisation splitting in PTGIII. The second line represents the 8 pulse lines from PTGI, each of these is on a different axis. The third line is the output from PTGII, again these are on 4 new axes. The pulses are in a 3x4 matrix, in which all the pulses are made to overlap at the cathode. This 3x4 matrix may be referred to as a 12-pulse generator.

The Drive beam laser Path

A spatial filter and UV collimator are placed at the output of the laser, followed by a remotely–controlled variable attenuator. The attenuator is a motorised waveplate and polarisor, adjustments of drive energy do not affect imaging on the cathode or change the optical delay to cathode, as combinations of fixed attenuators would.

The distance from the laser to the cathode is 25m, ideally the beam would be relay-imaged to the cathode to preserve energy distribution and minimise beam movements. Due to the nature of the pulse-train generators' multiple paths, this is not possible. The last position in the path that can accommodate a lens is between PTG3 and PTG1. To image the laser output to the cathode with a single lens at this position, some extra path is added between the laser and the lens.

A 6.8 m lens forms an image of the energy distribution at the output of the laser, onto the photocathode, with a magnification of 2.2x. The optical distance between the laser and the lens is 9.2m and contains PTG3, which has a mono-axial output. The total laser-photocathode distance is 32m. PTGs 1 and 2 are placed after the lens. The different path lengths of the sections of the Pulse Train Generator generate slightly different magnifications at the cathode. This could be partially corrected by an optic in the long arm of PTG3.

The beam path descends directly down to a small optical table in the CTF. From the central table the path follows to a second table at 3.5 meters distance, opposite the central magnet of the electron bunch compressor, which is 7 m from the cathode. The x-y positioning system is mounted on the second table. The beam passes through a 2% sample plate, which provides an image of the beam on the "virtual cathode". The sample is sent on a reference path the same length as the distance to the cathode. The sample plates are at near 0^{o} AOI to be polarisation insensitive and are anti reflection coated (AR) one side and for 2% reflectivity the other. The virtual cathode is a CsI florescent screen, which is monitored by a CCD camera for beam position and energy distribution of the beam[6].

From the x-y position stages, which also raise the laser pulse train to the height of the drive beam axis, the train is sent to a window integrated into the vacuum chamber of the bunch compressor. This window is on the axis of the Drive Beam, avoiding the horizontal offset and aperture restrictions of the current CTF, which allows the maximum range of x-y position movement for centring the beam and for measurements of the photocathode efficiency distribution. The window is of fused silica, 36mm dia. clear aperture, braised onto an anti-magnetic stainless steel tube, which forms an integral part of the vacuum chamber.

It is possible to have an anti reflection coating on both faces of this window, as this area is not UHV cleaned. This is contrary to the probe beam in CTFII, where it is only possible to have an anti reflection coating on the inside of the window despite the easy access to both faces. This section is UHV cleaned at 150°C and the coatings cannot withstand this temperature in air.

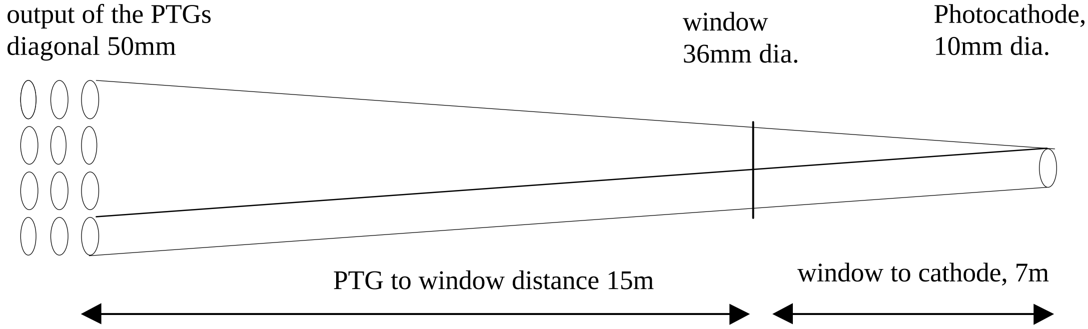


Fig.11, the 12 beam-paths converge at the cathode

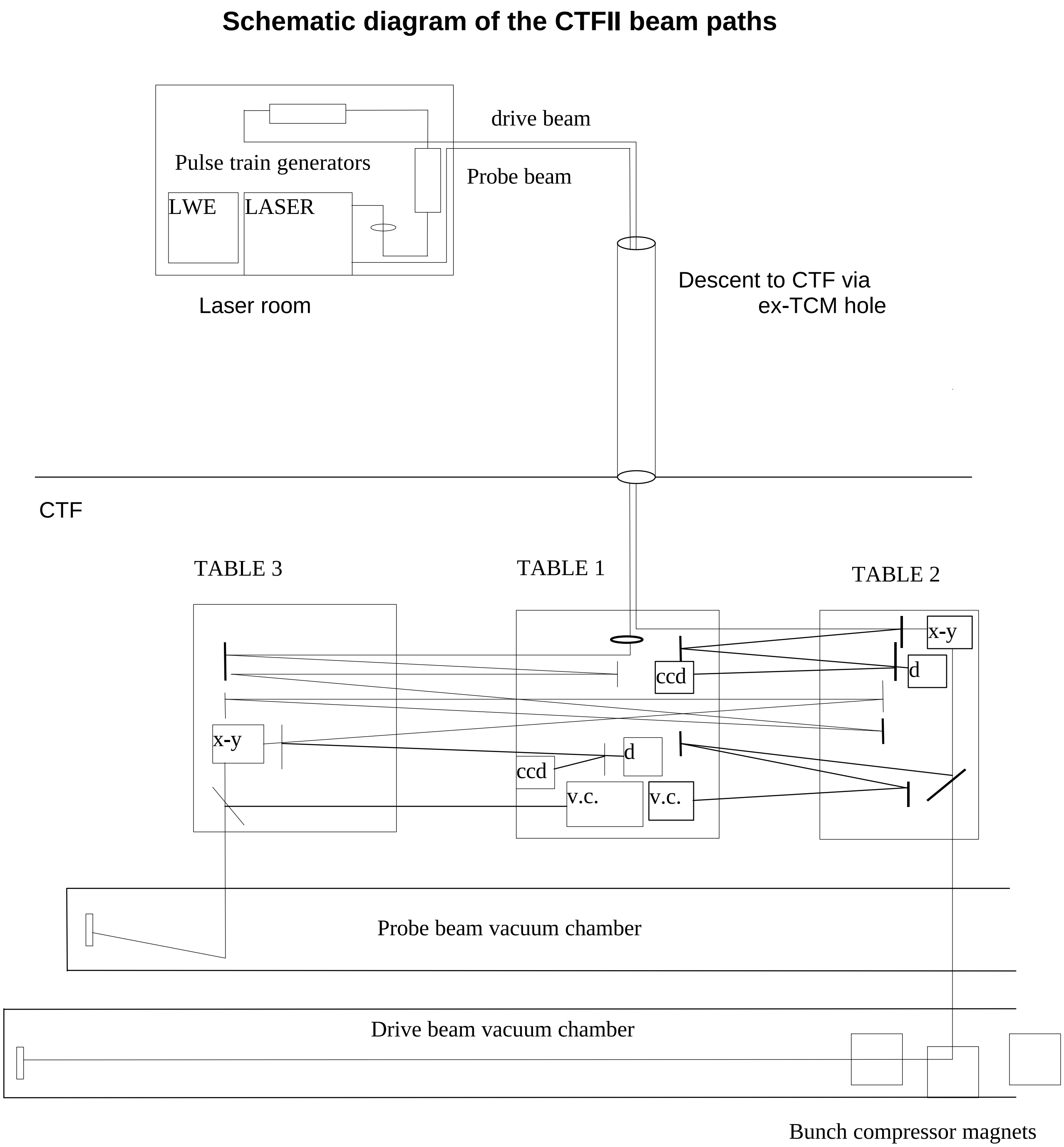


FIG. 11, The Optical layout, showing Drive and Probe beam paths, virtual cathodes (v.c.), energy detection (d), x-y positioning(x-y) and monitoring of the beam profile (ccd). The paths are arranged that the virtual cathodes are the same distances as the real photocathodes, the probe beam is delayed 12ns after the Drive beam to allow for the filling time in the CLIC Accelerating Structure, (CAS).

The vacuum chamber window is polished to optical quality, as with 7m between it and the cathode, the smallest fault will cause distortion of the beam. The electron beam is diverted off axis in the electron bunch compressor[7] allowing the window to be on-axis and yet not obstruct the beam. To avoid radiation damage to the window, which would reduce its transparency, an interlock is provided from the first magnet of the bunch compressor to the Klystron modulators. This ensures that no RF can be applied to the cannon and accelerating sections when this magnet is off, as radiation would reduce its transparency. Despite these measures noticeable darkening of the window has occurred, the transmission has reduced from 96% to 86% at present.

The limiting aperture for the beam diameter is the window. The diagonal which at the output of the PTGs is 50mm and at the cathode 10mm, is 23mm at this point, leaving 6mm range either side of the centre position to align the laser. This is assuming a 10mm dia. spot on the cathode.

The Probe Beam laser path

The probe beam path is also equipped with a variable attenuator, made from a motorised waveplate and polariser. This beam is also equipped with a motorised attenuator and also with a fine phase adjustment, which is a variable delay path of +/- 100mm optical length. This allows independent phase adjustments between the Drive and Probe beams.

To allow for the filling time of the CLIC Transfer Structure (CTS) the probe beam must arrive at its photocathode 12ns after the first pulse of the Drive beam arrives at its photocathode. This will then place the probe beam at the entrance to the CLIC Accelerating Structure when this is fully “charged”. The Probe beam path will therefore be 9.2m +22m +12ns =35m counted from the exit of their respective spatial filters. This delay is achieved by passing the beam between the three tables in the CTF.

To achieve a good control of the beam quality, relay imaging is used. Two lenses of 4m focal length are used. The are placed on the first table, the first at 8.5m from the laser output forms an intermediate focus at 5m, and the second at 18m from the laser, giving an image magnification of the aperture in the laser room of ~1x.

A 2% sample plate is placed after the x-y positioning stage to provide a virtual cathode image, as for the Drive Beam. The beam passes into the vacuum chamber via a large 100mm. dia. fused silica window. A final 45-degree mirror is placed slightly off-axis inside the chamber to avoid the electron beam. The distance from cathode to the window is 1.4m.

Observed Behaviour of the laser system

The pulse to pulse amplitude stability of the laser when correctly aligned is 3% rms., the laser maintains this alignment for several days if there are only small temperature changes. To achieve even this level of stability the regenerative amplifier runs continuously, only being switched off for weekends. The fine-tuning consists of adjustments to the injection alignment and occasionally the cavity mirrors themselves need to be slightly corrected. The laser system is temperature sensitive, which results in mechanical alignment changes as well as polarisation and timing drifts.

The stability of the laser is conditioned by the performance of the flashlamps. The traces recorded in Figure 9 are, on the left, the RA flashlamp current and RA light output, and on the right, a close-up view detailing the shot-to-shot variation in the current and pump light intensity. These variations are due to changes in the flashlamp discharge, as the output of the high-voltage switch into a simulated load has better stability. The variations are not simple amplitude movements but are the result of differing impedances of the flashlamp during consecutive pulses. The amplitude variations are 5% p-p, this would cause output variations of 20% at 262nm. Measurements of the integral of the flashlamp current show a variation of 1% p-p, which is consistent with the 3% output variation normally observed.

Physically, the integrator mechanism is the fluorescence lifetime of the Nd:YLF material which is 450us.

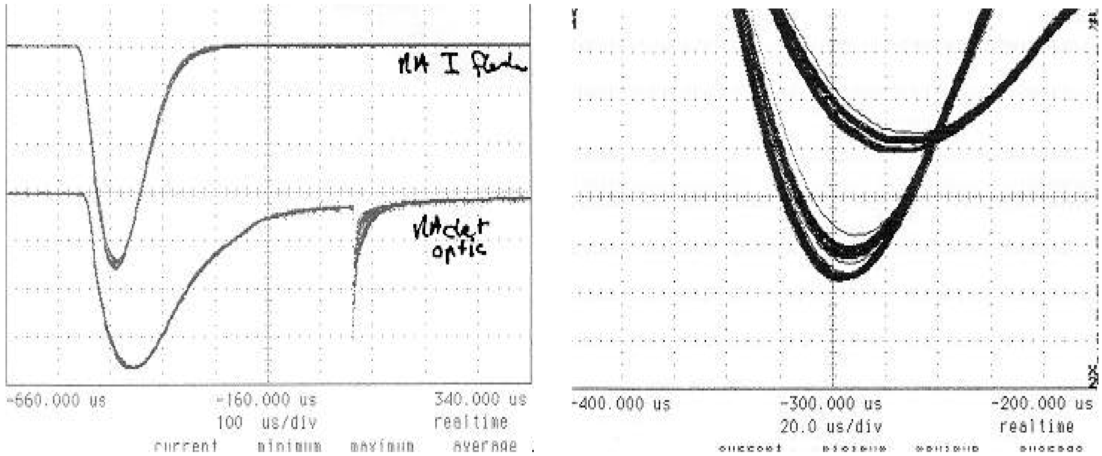


fig.9, flashlamp stability

The performance of the flashlamps is affected by the operating current, temperature and the age of the lamps themselves. It may be possible to reduce the jitter by increasing the ionisation current.

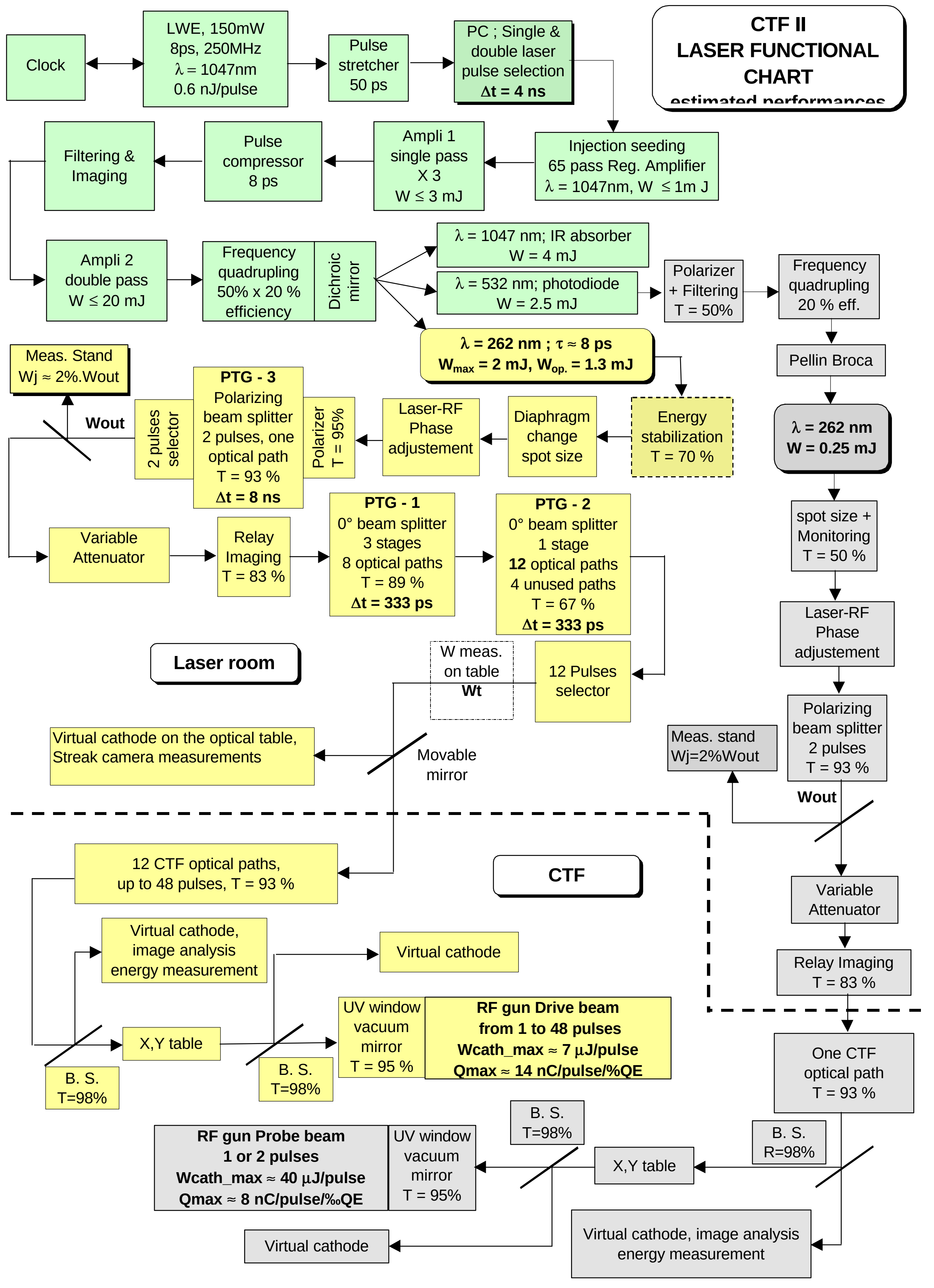
The regular adjustments include the fine timing of the Pockels' cells, of which PC3 is the most critical. The 0 to 100% risetime of the HV pulser is 3ns, this must be placed exactly between two pulses in the optical pulse train from the LWE laser which are spaced at 4ns. The normal HV timing jitter is 2-300 ps, the width of the flat top of the pulse of 500ps. As the optical pulse must make two passes through the cell to achieve polarisation rotation, the time of flight from the Pockels' cell to the mirror and back is 600ps, so that the two passes "straddle" the peak.

There is a timing drift, which may be due, in part, to temperature changes, so that adjustments of +/- 0.5 ns are needed to keep the peak of the HV pulse exactly on the pulse to be selected. When the timing is off by 0.5ns the Pockels cell rejects some of the wanted pulse and passes part of the leading or trailing pulses, this results in amplitude variations and can lead to unwanted satellite pulses.

The current arrangement of the Lightwave oscillator-pulse stretcher-pulse selector limits the range of measurements that can be made on the seed pulse before it enters the regenerative amplifier. If more was known about its state, it could be possible to improve the performance of the laser system by matching the amount of wavelength chirp to the bandwidth of the laser material.

---

[1] CERN/PS CTF 98-009 "CLIC, a 0.5 to 5 TeV compact linear collider"
[2] CERN/PS CTF 98-036 "Photo-cathodes for the CERN CLIC test facility"
[3] CERN/PS CTF Note 96-14 "The CTF Laser"
[4] Martinez,O.E. IEEE J.Q.E. QE-23 1385 (1987)
[5] CERN/PS CLIC Note 245 "The synchro laser system for CTF"
[6] CERN/PS/LP 93-62 Chevallay, E. "Etude …analyse d'images video"
[7] CERN CTF 94-030, "Bunch compressor for the CLIC Test Facility"


CTF II
LASER FUNCTIONAL
CHART
estimated performances
Clock
LWE, 150mW
8ps, 250MHz
λ = 1047nm
0.6 nJ/pulse
Pulse
stretcher
50 ps
PC ; Single &
double laser
pulse selection
Δt = 4 ns
Injection seeding
65 pass Reg. Amplifier
λ = 1047nm, W ≤ 1m J
Ampli 1
single pass
X 3
W ≤ 3 mJ
Pulse
compressor
8 ps
Filtering &
Imaging
Ampli 2
double pass
W ≤ 20 mJ
Frequency
quadrupling
50% x 20 %
efficiency
Dichroic
mirror
λ = 1047 nm; IR absorber
W = 4 mJ
λ = 532 nm; photodiode
W = 2.5 mJ
Polarizer
+ Filtering
T = 50%
Frequency
quadrupling
20 % eff.
λ = 262 nm ; τ ≈ 8 ps
Wmax = 2 mJ, Wop. = 1.3 mJ
Pellin Broca
Meas. Stand
Wj ≈ 2%.Wout
Wout
2 pulses
selector
PTG - 3
Polarizing
beam splitter
2 pulses, one
optical path
T = 93 %
Δt = 8 ns
Polarizer
T = 95%
Laser-RF
Phase
adjustement
Diaphragm
change
spot size
Energy
stabilization
T = 70 %
λ = 262 nm
W = 0.25 mJ
Variable
Attenuator
Relay
Imaging
T = 83 %
PTG - 1
0° beam splitter
3 stages
8 optical paths
T = 89 %
Δt = 333 ps
PTG - 2
0° beam splitter
1 stage
12 optical paths
4 unused paths
T = 67 %
Δt = 333 ps
spot size +
Monitoring
T = 50 %
Laser-RF
Phase
adjustement
Laser room
W meas.
on table
Wt
12 Pulses
selector
Polarizing
beam splitter
2 pulses
T = 93 %
Virtual cathode on the optical table,
Streak camera measurements
Movable
mirror
Meas. stand
Wj=2%Wout
Wout
12 CTF optical paths,
up to 48 pulses, T = 93 %
CTF
Variable
Attenuator
Virtual cathode,
image analysis
energy measurement
Virtual cathode
Relay Imaging
T = 83 %
X,Y table
UV window
vacuum
mirror
T = 95 %
RF gun Drive beam
from 1 to 48 pulses
Wcath_max ≈ 7 µJ/pulse
Qmax ≈ 14 nC/pulse/%QE
B. S.
T=98%
B. S.
T=98%
One CTF
optical path
T = 93 %
B. S.
T=98%
B. S.
R=98%
RF gun Probe beam
1 or 2 pulses
Wcath_max ≈ 40 µJ/pulse
Qmax ≈ 8 nC/pulse/‰QE
UV window
vacuum
mirror
T = 95%
X,Y table
Virtual cathode
Virtual cathode, image analysis
energy measurement