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PILOT Test Preparation

S. Hutchins, G. Suberlucq

Abstract

The photo-injector option of the CTF3 drive beam will require a laser system, the different parts of which are currently under evaluation at RAL (UK), CERN and Strathclyde University. The aim of these studies is to produce a design report for the laser system. In the course of this work several key elements will be produced: a power amplifier, an oscillator, and elements for detection and control of the optical intensity. It was foreseen to assemble some of these elements in order to verify their operation as a unit. The test was then extended to include a photo-injector in order to demonstrate the stability of a long train of electron pulses produced under these conditions. This test, called PILOT, (Photo-Injector Long Train) was presented during the first photo-injector workshop in September 2001. The aim is to generate a pulse train in CTF2 of 1.4 µs duration, which is the maximum RF pulse length from the LIPS RF pulse compressor. This paper outlines the tests planned for May 2003 and the support that will be necessary.

PILOT Test Preparation

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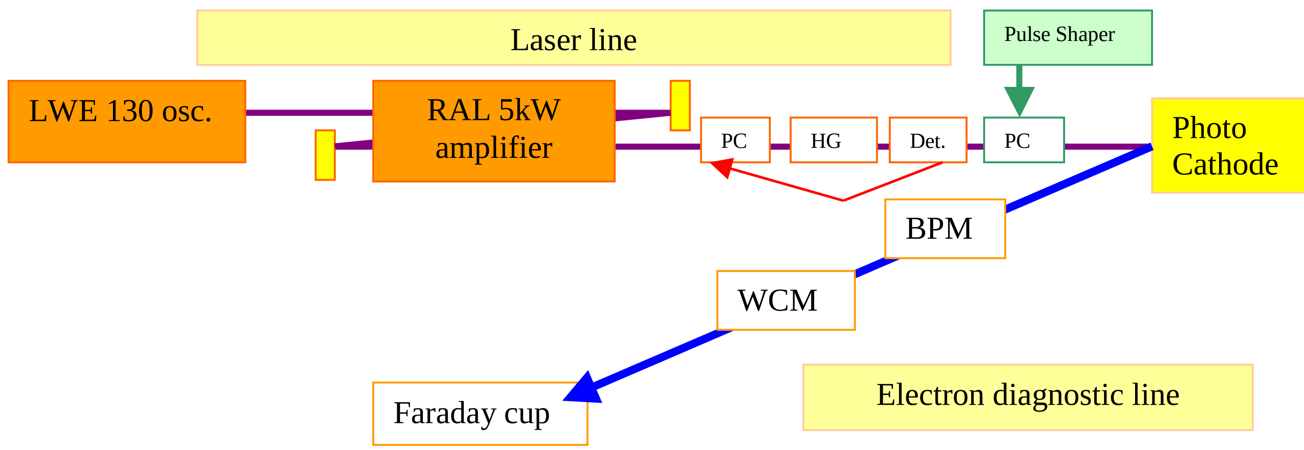

Figure 1. PILOT 2003

Due to budget restrictions PILOT is now delayed to 2003. Although the CTF2 will be dismantled at the end of 2002, enough parts can be made available to perform the test using the Drive beam RF gun, which has photo-cathodes with higher quantum efficiency (QE ≥ 4 %). This paper summarises the resources now required for the test, as it is no longer a "parasitic" activity of normal CTF2 operation. It is currently planned that much of the equipment and personnel will transfer to CTF3 activities and will therefore remain nominally available.

PILOT services

This test implies that many services currently needed for CTF2 will be required for use in April-June 2003, specifically:

- Modulator 98
- A synchronized "clean" 250 MHz signal (100 mW) for the laser oscillator
- Timing; both general (power supplies, etc.) and Precision (Pockels Cells, etc.)
- Controls for: timing, modulators, power, vacuum, instrumentation, etc.
- Low-level RF

- Photo-cathodes
- 30°C demineralised cooling water (gun, waveguides and timing)
- Cooling water for MDK98
- Power supplies for solenoids
- Diagnostics: WCM, BPM and Faraday Cup
- Vacuum (+ bakeout)
- Access control

The need for these services also implies that they should continue to be supported by the relevant teams, also that work planned in the CTF2 area will have to be re-scheduled to match the PILOT program.

PILOT test objectives

The aim of the test will be to show reliable production of a long pulse train, having pulse intensity variation of 1% and similar shot-to-shot variation. The limitations of the beam diagnostics, beam loading in the RF Gun and available laser power from the 5 kW amplifier, leave the possibility of producing a 250 MHz frequency, 0.2 nC/bunch, 1.4 µs pulse train of 350 pulses. The equipment should be installed at CERN in the shutdown of 2003, for use when CTF3 operations resume in April 2003. The equipment will be installed in the CTF laser room, on the existing laser table. The tests will be divided between two areas: optical and beam-based measurements to give the best understanding of the performance of the equipment used and allow a confident extrapolation to a machine-scale (CTF3, CLIC) installation.

The target parameters for PILOT are now as follows:

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	

It can be seen that under certain unfavourable conditions the target charge per pulse would be reduced to 0.072 nC. This situation only occurs if (1) the Harmonic conversion efficiency is at the lowest estimate and (2) the photocathode efficiency is at its lowest level. If situation were to present itself, the solution would be to change the photocathode for a fresh one, as is planned for CTF3, also the feedback stabiliser may be removed. In the more favourable case where conversion and photocathode efficiencies are high, the amplifier output must be reduced to avoid beam-loading effects in the RF gun (max. 0.2 nC/bunch).

Hardware: Beam line

The beam line would consist of a short (1.2 m) series of elements starting from the existing Drive beam gun position. The RF gun would be powered by MDK98, no accelerating sections would be used. Electron optic will be provided by the solenoid(s) and the steering dipoles.

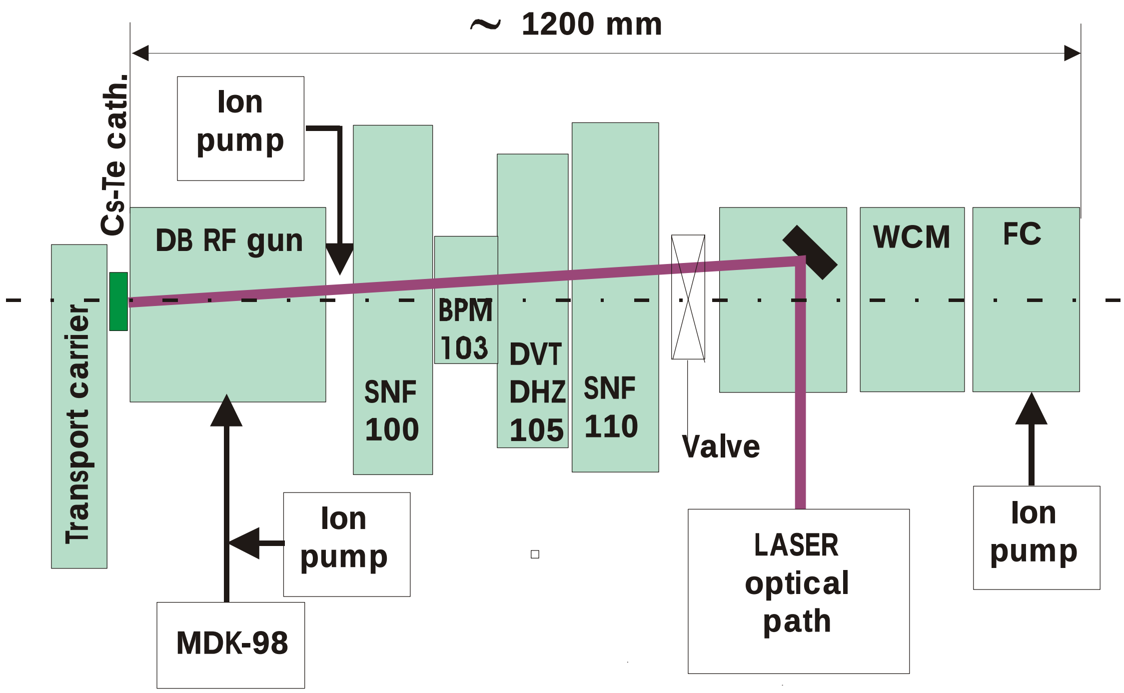

Figure 2: Reduced CTF2 drive beam layout for Pilot test

A wall current monitor (WCM), Beam Position Monitor (BPM) and Faraday cup will analyse the electron beam pulse train. The parameters of most interest are the amplitude stability within the train, the total beam charge and their variation from shot to shot. Some variations will be due effects other than the laser, such as instrumentation, the modulator voltage flat top, gun temperature, etc. which will also need to be recorded in order to establish their relative importance in a system. These will be compared to the equivalent UV signals in order to identify sources of instabilities and determine the eventual performance of a system for CLIC/CTF3.

Hardware: Optical

The power oscillator under development at Strathclyde University will not be used for PILOT tests as it is cannot be synchronized to the RF in the gun. It may be possible to test the oscillator and amplifier together at RAL during 2002. The oscillator that will be used for PILOT tests is the LWE-130 currently used in CTF2. Harmonic generation equipment can be supplied from CTF2 after October 2002 (KDP for 2HG, BBO, CLBO for 4HG).

The 5 kW diode-pumped amplifier developed at RAL[v] will be used in a 4-pass configuration, with the expected 100 mW input signal a gain in excess of 6000 is possible, giving output pulse intensities of between 1 and 2 μJ. The amplifier will be operating in a saturated mode giving good stability of the output pulse train: 2.5% output variation for a 90% input change. The measured IR micropulse stability of 0.7% also depends on environmental factors, such as cooling temperature, vibration, etc.

A feedback stabiliser has been developed at RAL, which significantly improves the flat top profile of a long pulse train; it has been used with a control signal from the IR output, for the PILOT tests the UV output could be used. The present system does not have sufficient bandwidth to act in the shorter 1.4 μs train of the PILOT tests, but provides a key feature needed for a CLIC system where the control signal will be derived from the electron beam.

In order to avoid RF breakdown in the gun and also to maintain a good vacuum level, the cathode should not be illuminated before the pulse train starts. This will be achieved with a synchronised Pockels cell switch, either at the end of the harmonic generation chain using UV light, or earlier using green or IR light. The UV option may not be possible due to UV performance (absorption, damage) of the Pockels cell materials. The latter case is not compatible with the feedback stabiliser, due to the short pulse train and limited bandwidth of the equipment, but the pulse amplitude variation during the 1.4us will be very small, even without the feedback control.

The optical path from the laser table to the photo cathode will use CTF2 components from existing drive and probe beams. The beam path will be less complex than any of the currently installed lines, which may provide an operational margin on the mirror reflectivity losses.

Project Steps for the PILOT test:

The proposed schedule for the PILOT tests is outlined in the following table, which takes note of the various limitations of material and personnel availability and is designed as a low-budget test.

October 2002	CTF2 operation ends	
November 2002	Ship LWE130 and other CTF2 equipment to RAL	
Dec.02 - March 2003	Prepare beam line in CTF2	Optical tests at RAL
April 2003	Ship equipment to CERN and install	
May 2003	PILOT Tests: 4 weeks	

The program cannot be started earlier, as some of the equipment will be in use in the CTF and tests cannot start before the end of the shutdown when essential services will be restored. The intervening time is profitably spent preparing the beam line in CTF2 and preparatory optical tests at RAL.

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[i] *The photo-injector option for CLIC: past experiments and future developments*, H.H. Braun, E.Chevallay, S.C. Hutchins, P. Legros, G. Suberlucq, H.Trautner, CERN, Geneva, Switzerland, I.N. Ross, Central Laser Facility, RAL, Didcot, U.K., E. Bente, University of Strathclyde, Institute of Photonics, Glasgow, U.K ; CERN/PS 2001-033 (PP) CLIC Note 487, proceedings of PAC 2001

[ii] *Laser requirements for the CLIC and CTFIII projects*; S.C. Hutchins CTF Note 98-16

[iii] *Feasibility Study for the CERN CLIC Photo-injector Laser System.* I.N.Ross, Central Laser Facility, Rutherford Appleton Laboratory, CERN CLIC Note 364

[iv] *Report on the Photo-injector workshop, CERN, 24-25th Sept 2001,* S.C. Hutchins, CTF3 note 2001-36 (Laser)

[v] *Interim Report on Amplifier Development at RAL,* I.N.Ross, RAL Steering group minutes, March 2002.