Laser setup to drive PHIN and CALIFES photoinjectors at CERN

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Introduction

Compact Liner Collider (CLIC) concept is under development at CERN. The main task of **CLIC Test Facility 3 (CTF3)** [1] is to demonstrate the feasibility of the key CLIC technology challenges for the two-beam scheme, i.e., acceleration of the main electron beam using the RF power emitted from strong deceleration of the second beam, referred to as a drive beam. **PHotoINjector (PHIN)** is a standalone setup that is dedicated to perform the studies of the RF-photoinjector option for the CLIC drive beam production [2]. **Concept d'Accélérateurs Linéaire pour Faisceau Sonde (CALIFES)** is a part of CTF3 accelerator complex and dedicated to produce main electron beam, CALIFES uses RF-photoinjector as an electron source. The electron beam and required laser parameters are shown in the table for CALIFES, PHIN and CLIC respectively. Cs2Te photocathodes that are used in the mentioned above RF-photoinjectors are driven by 4th harmonic (UV light) of picosecond Nd:YLF laser. The laser setup that is capable to drive the 2 RF-photoinjectors (PHIN and CALIFES) was built at 2006 at CERN. Since that time it was upgraded several times. In this poster the current status and some results of CLIC feasibility studies are presented.

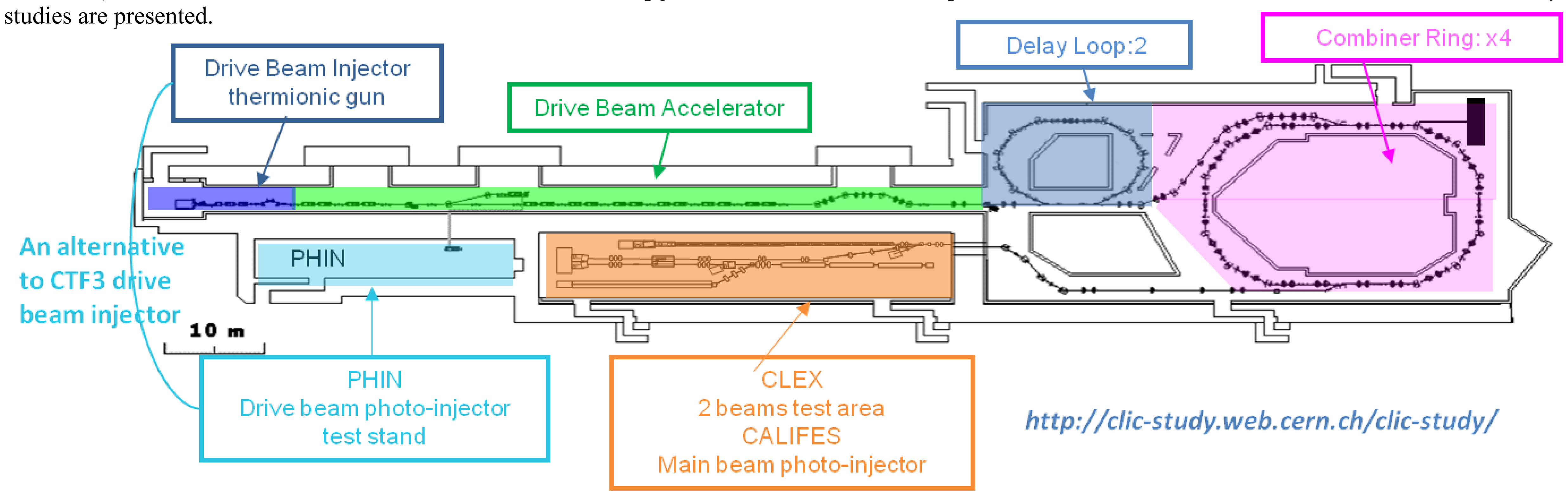
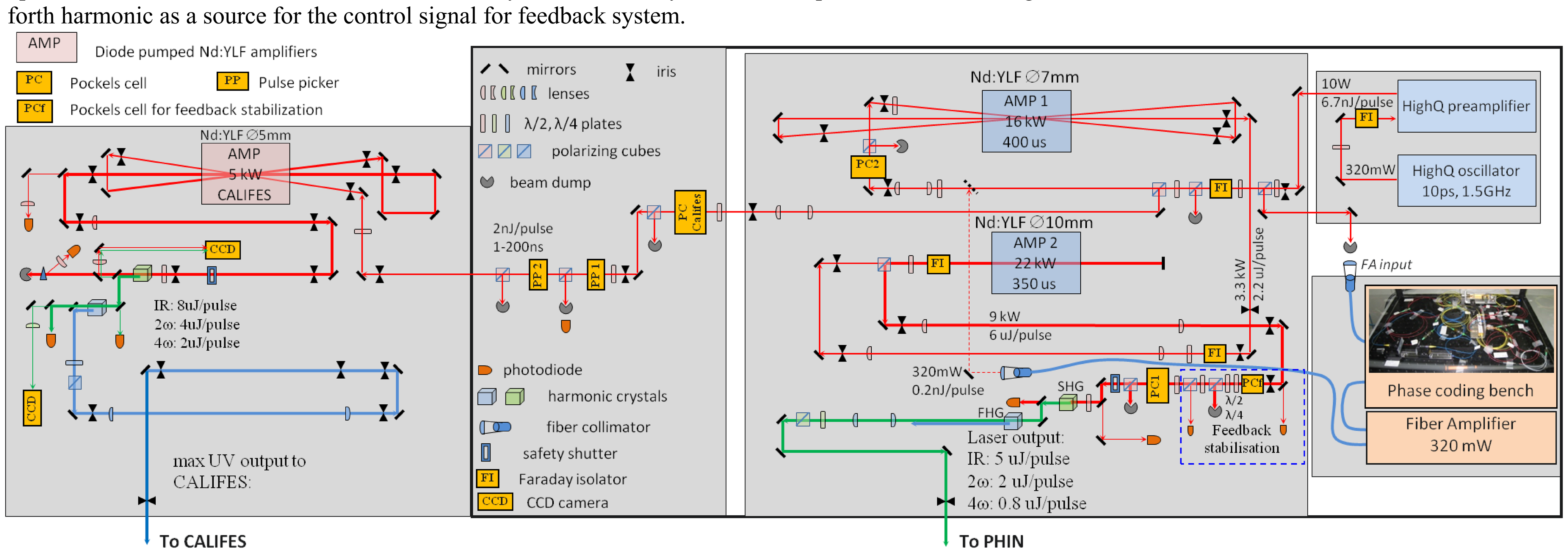


Table 1. CALIFES and PHIN photoinjector parameters

	CALIFES		PHIN		CLIC
	Design	Achieved	Design	Achieved	Design
Bunch rep.rate, GHz	1.5	1.5	1.5	1.5	0.5
Bunch duration, ps	8-10	8-10	8-10	8-10	8-10
Train duration max, us	0.14	0.2	1.2	1.2	140
Trains rep.rate, Hz	5	5	5	5	50
Charge/bunch, nC	0.6	0.6	2.3	8.1	8.4
Charge stability, % rms	<3	<3	<0.25	1-2	<0.1
Energy, MeV	5.5	5.5	5.5	5.5	5.5
Energy spread, % rms			<1	0.7	<1
Photocathode QE, %	0.3	0.3	3	3	1
Cathod lifetime, h			>50	>40	>150
UV laser energy on the table, uJ/pulse	**1**	**1.5**	**0.6**	**0.8**	**8**
UV mean power in the train, kW	**1.5**	**2.3**	**0.9**	**1.2**	**4**

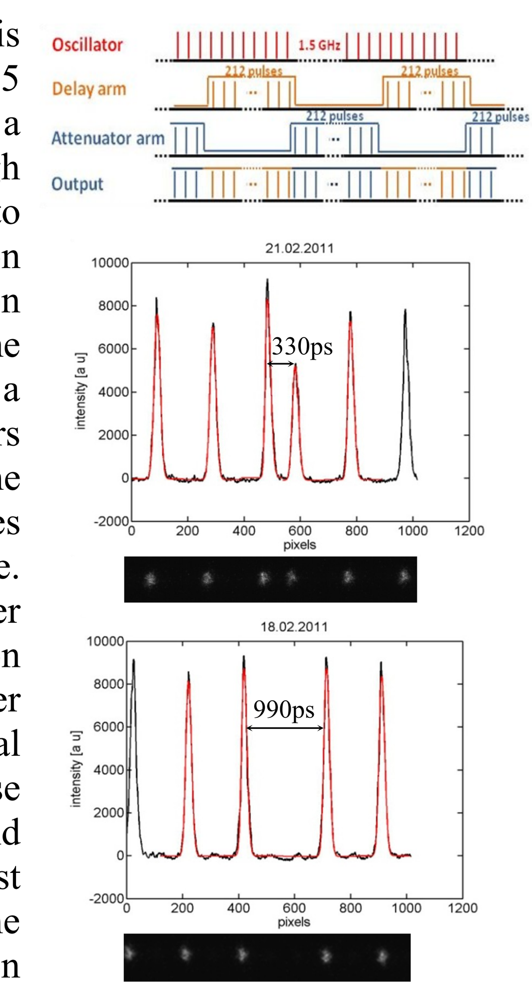
Laser layout

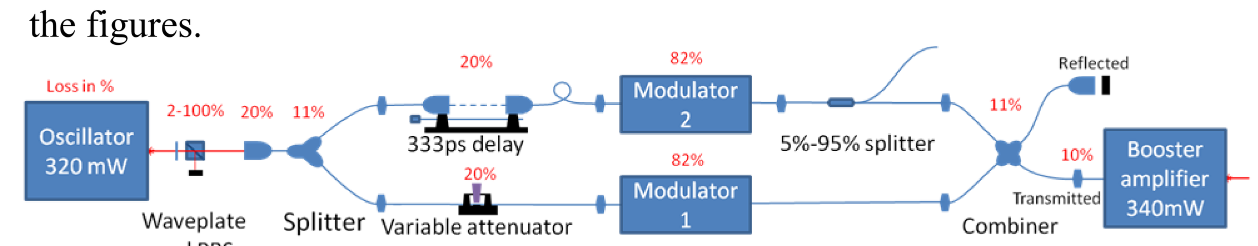
Passively mode-locked HighQ front-end delivers 10 Watts of 8ps pulses with the repetition rate of about 1.5GHz. One of the mirrors of the oscillator cavity is mounted on the piezo-actuator in order the reprate of the oscillator to be synchronized with external sync signal witch corresponds to the RF field in the gun cavity. The built-in controller routinely achieves synchronization with 250fs jitter. After HighQ front-end the beam is split into 2 beams: one beam goes through the diode pumped Nd:YLF ∅5mm CALIFES amplifier and finally after harmonics stages goes to the CALIFES RF-photogun; the second beam goes through two powerful diode pumped Nd:YLF amplifiers (∅7mm and ∅10mm) and after harmonics stages goes to PHIN photoinjector. In the PHIN line there is an option to launch approx. 300mW of the beam to the optical fiber for the Phase Coding Test Stand. After phase coding and additional amplification up to 320mW in Yb dopped fiber amplifier (Fianium) the beam launch back to the powerful amplifiers beam line. On the output of the AMP2 the 2MHz bandwidth feedback stabilization system was recently installed. The aim of this feedback stabilization is to provide the constant IR output power during 140us rejecting optical noise and instabilities of the laser. Currently the feedback system uses IR power as a control signal. In the future it is foreseen to test the second and forth harmonic as a source for the control signal for feedback stabilization.



Phase coding

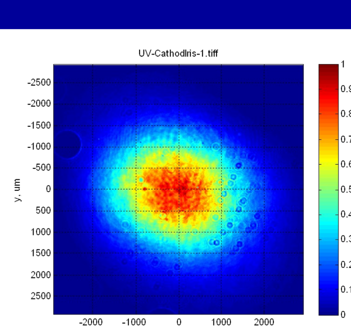
One of the main challenges on CTF3 is multiplying the electron bunch rate from 1.5 GHz to 12 GHz. This is carried out using a delay loop and a combiner ring, with high frequency input and output switches to separate and "interleave" the electron bunches. For this to work the initial electron bunch train must be „phase coded" i.e. some of the bunches must be delayed by half of a 1.5 GHz period with respect to the others [4]. With the laser based photo-injector the phase-coding can be done on the laser pulses before they are sent to the photocathode. The time structure produced by the laser directly correlates to the produced electron bunches. Phase-coding based on fiber technique with ultra-fast LN electrooptical switchers was recently done at CERN. Phase -coding timing was proven by optical and electron bunch measurements with the fast photodiode and streak camera [6]. The results of these measurements are shown on the figures.





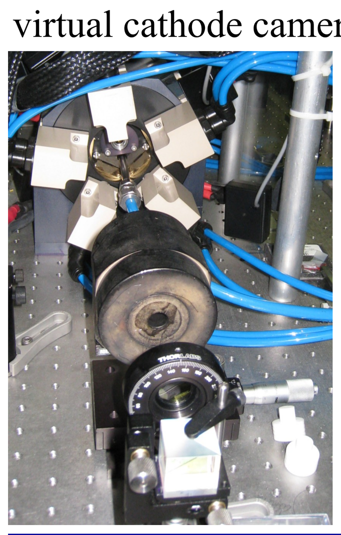
CALIFES laser operation

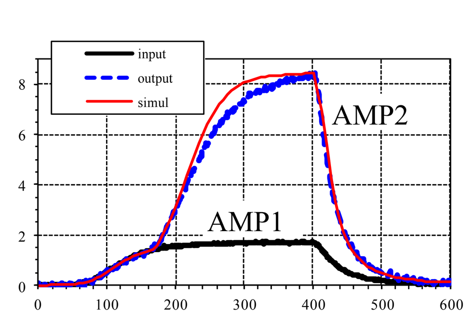
The CALIFES amplifier operates in a pulse mode, it amplifies the burst that is cut by Pockels cell (PC Califes) and fast pulse picker (PP1&PP2) with duration from 0.2-200 ps. The CALIFES amplifier operates in fully unsaturated mode and so the rectangular train shape is basically preserved. The UV beam shape on the virtual cathode iris is shown on the figure.

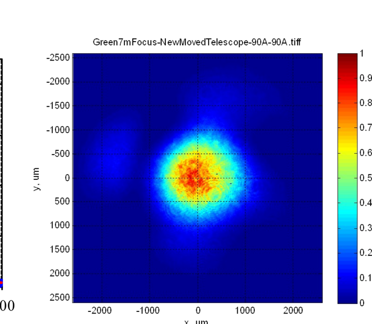


PHIN laser operation

The PHIN amplifiers operate in a steady-state mode, which is describe in details in [9]. The oscilogram of the output power from AMP1,2 is shown on the figure. Finally the plateau with a duration of 140us is used for CLIC dedicated studies. On the figure below it is shown the beam as it as seen by the virtual cathode camera.

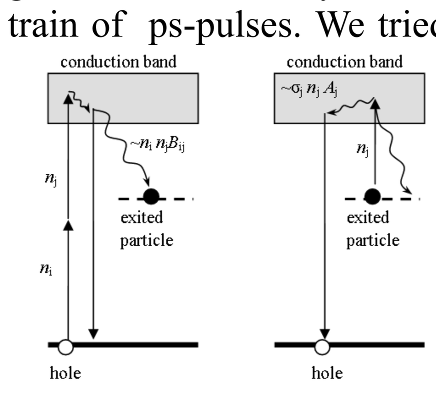


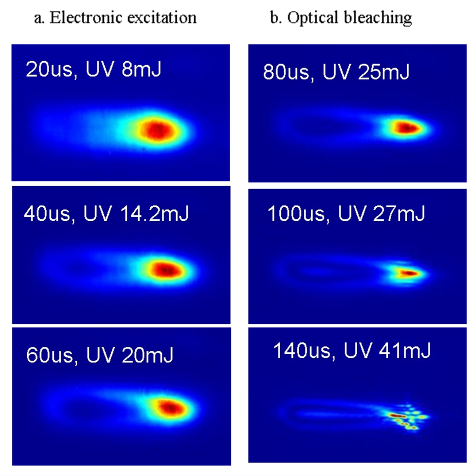


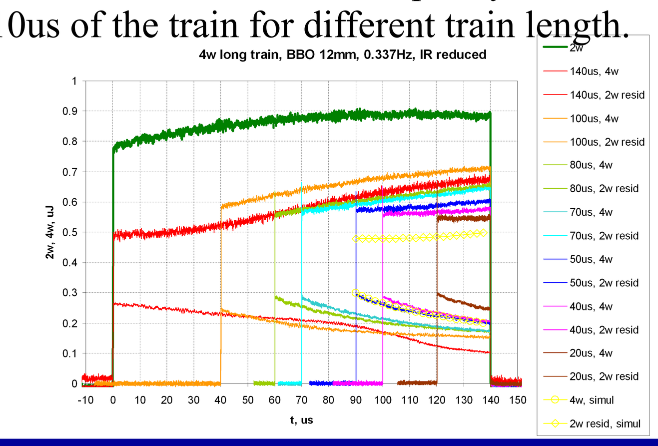


High-power harmonics for CLIC

CLIC parameters for the drive beam in case of RF-photoinjector electron source require UV optical pulse train a 140us duration with a mean power of 4kW within the train. It is well known that even for much lower power there is a crucial UV beam degradation due to two-photon absorption and thermal effects. Two-photon absorption causes the growth of excited "color" centres which can absorb the light linearly. With a state of the art crystal technology the BBO crystal is the only one good candidate for fourth harmonic generation. We carry on the experiments for UV beam generation with long train of ps-pulses. We tried three BBO crystals 4.2, 8.5 and 12mm length. It was not possible to achieve the nominal 140us train duration with maximum SHG power, so the incidentsecond harmonic power was reduced to decries the output UV power by a factor of 2. On the oscilograms one can easily see the decay of the UV power from the head to the tail of the train and the evolution of the decay with the train duration. On the figures it is shown the final beam quality for the last 10us of the train for different train length.

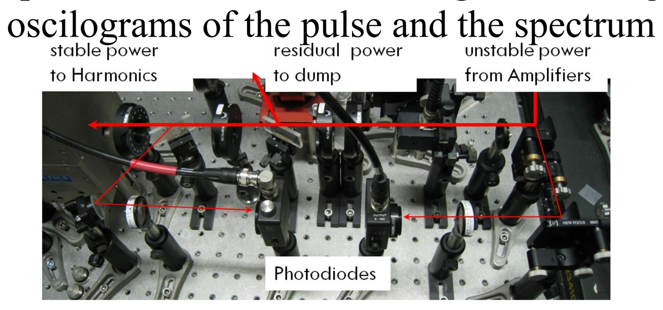


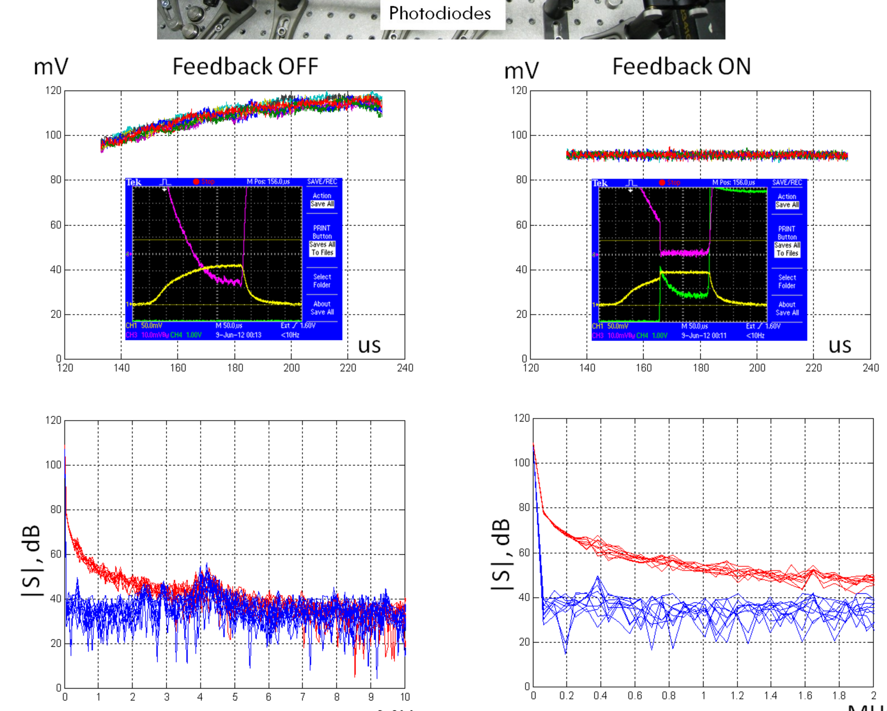




Feedback stabilization

The feedback stabilization system is formed of RTP Pockels cell with a 1700V half-wave voltage. It is also consists of PI-controller and 300V DC-amplifier. With the help of half– and quarter-wave plate it is possible to select a proper transmission working point with desirable modulation. On the figure below it is shown the example with 95% transmission @ zero voltage working point. It is also shown the oscilograms of the pulse and the spectrum for 10 shots.





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Collaboration

INFN Istituto Nazionale di Fisica Nucleare
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