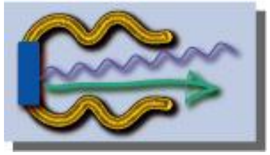


Laser driver for CTF3 photo-injectors

M.Martyanov, M. Divall, V. Fedosseev, C.Hessler

CERN

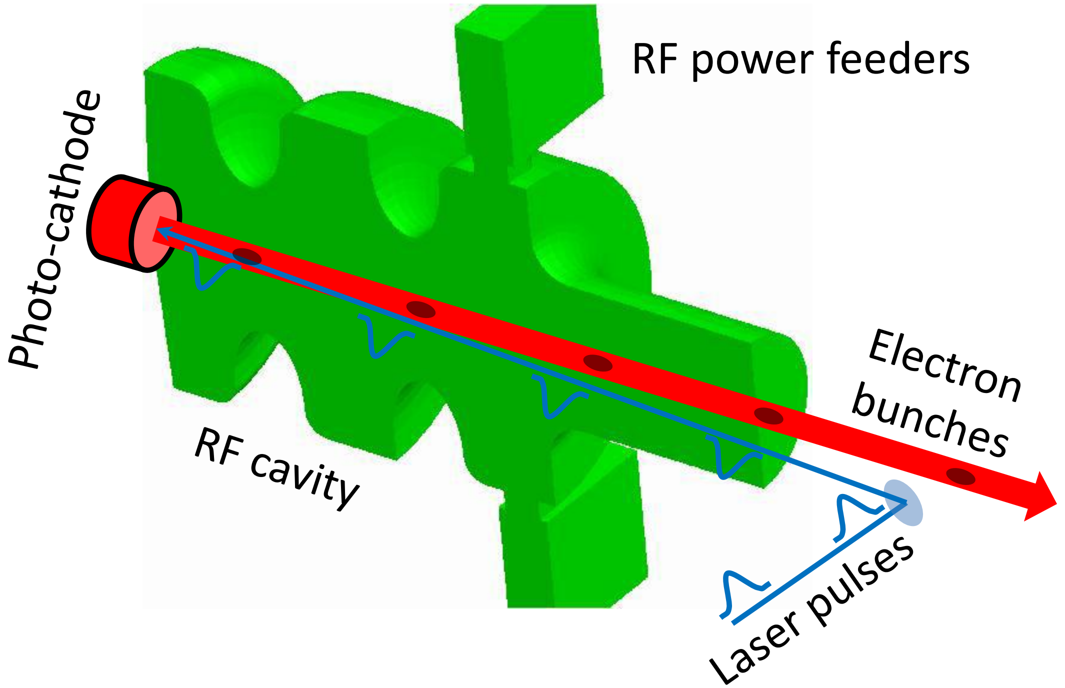
21.02.2013

Photoemission and photo-injectors (photo-guns)

Photoemission:

Energy of a photon > Work function

External electric field (DC or RF) helps electrons to become a bunch (beam) after they are extracted from the cathode surface

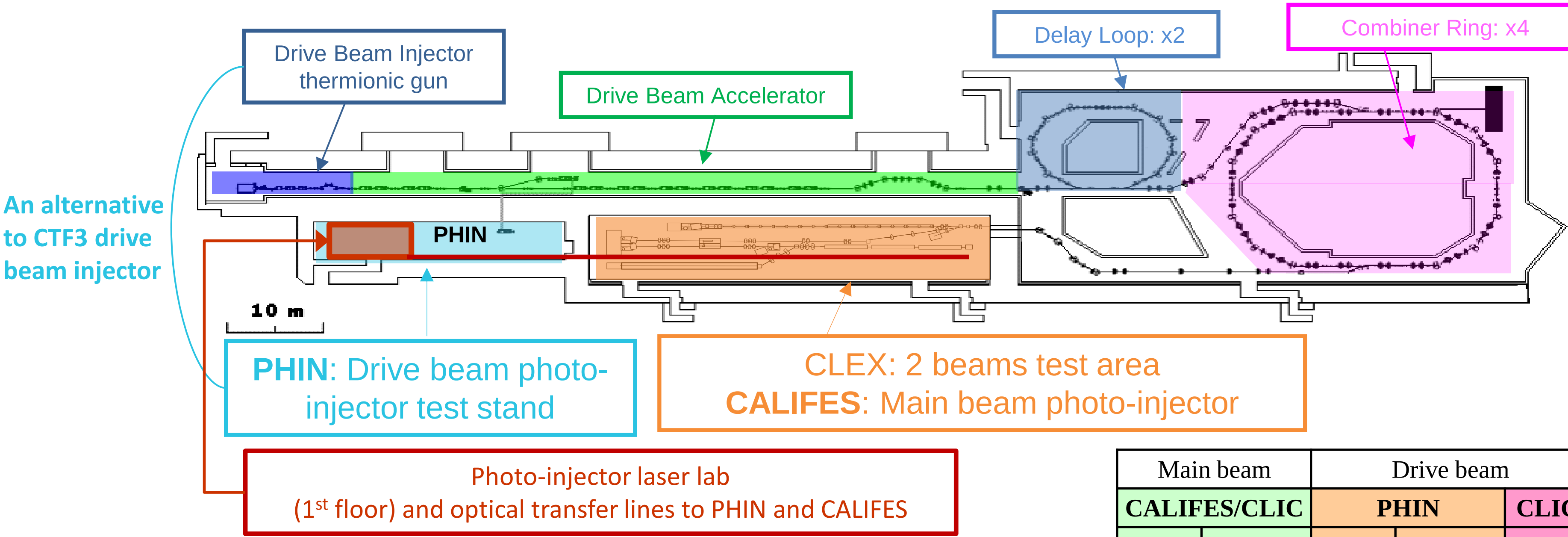


RF photo-gun

What is not shown here:

- Magnetic coils around the cavity
- Vacuum pumping system
- Water cooling system
- Cathode load-lock system
- Diagnostics etc.

Photo-injectors at CTF3: CALIFES and PHIN

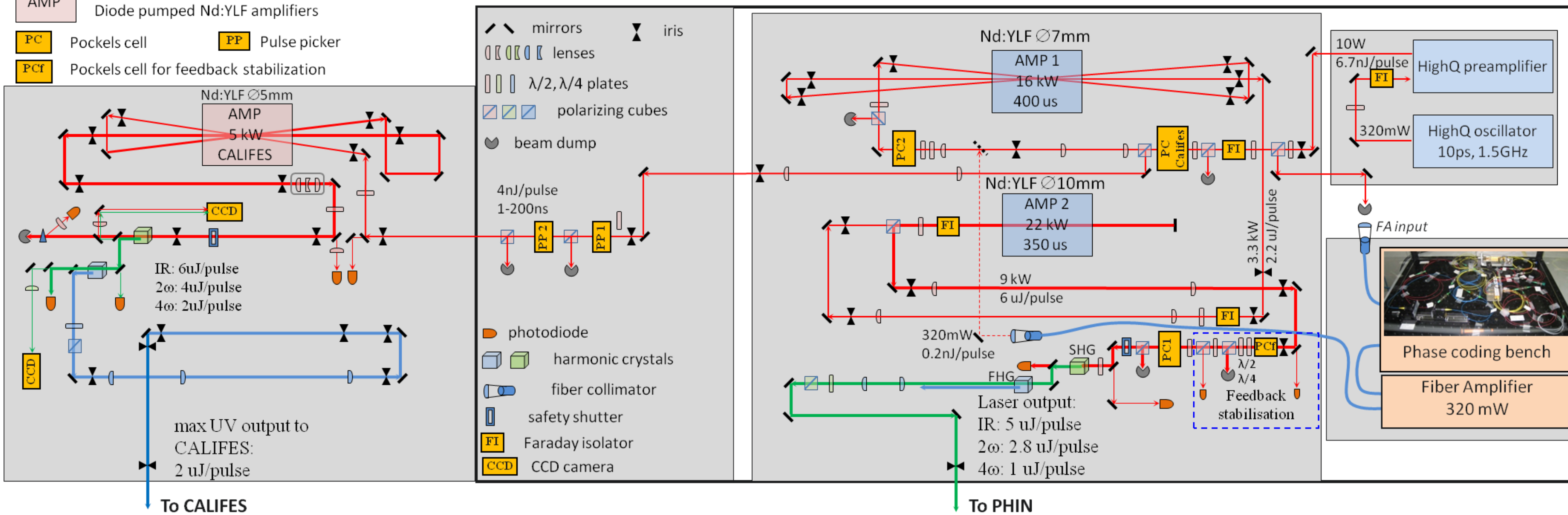


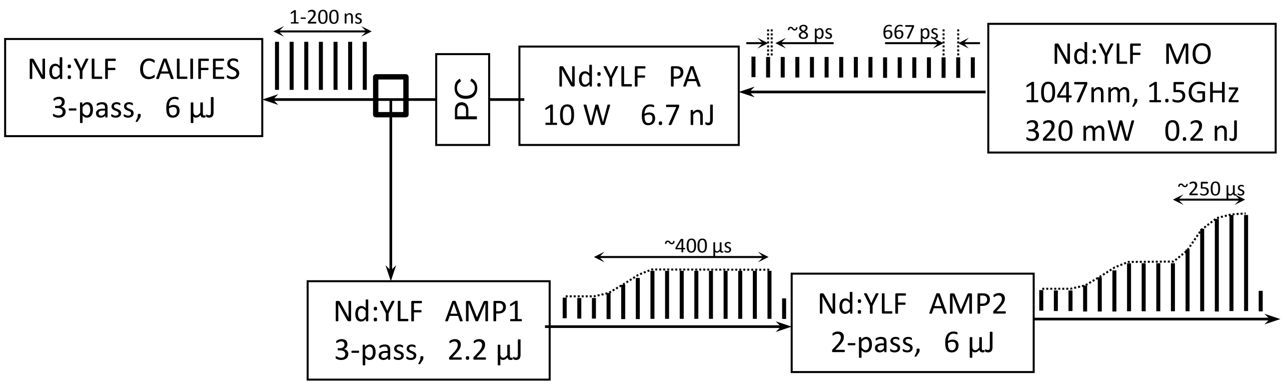
	Main beam		Drive beam		
	CALIFES/CLIC		PHIN		CLIC
	Design	Achieved	Design	Achieved	Design
Bunch rep.rate, GHz	1.5	1.5	1.5	1.5	0.5
Bunch duration, ps	8-10	8-10	8-10	8-10	8-10
Burst duration max, us	0.14	0.2	1.27	1.27	**140**
Burst rep.rate, Hz	5	5	5	5	**50**
Charge/bunch, nC	0.6	0.6	2.3	9.2	8.4
Charge stability, % rms	<3	<3	<0.25	1-2	<0.1
Photocathode QE, %	0.3	0.3	3	3	1
Cathode lifetime, h			>50	>100	**>150**
E_{UV}, uJ/pulse	1	2	0.6	1	8
W_{UV}, kW	1.5	3	0.9	1.5	4

CTF3 Photo-injector laser specifics:

- Burst mode operation
- Burst rep.rate 1-50Hz
- Intra-burst rep.rate 1.5GHz
  (phase-locked to klystron sub-harmonic)
- Pulses in the burst should be equal (stability)

Laser setup layout





High-Q front end

Nd:YLF passively mode-locked oscillator and preamplifier

1047 nm, 10W

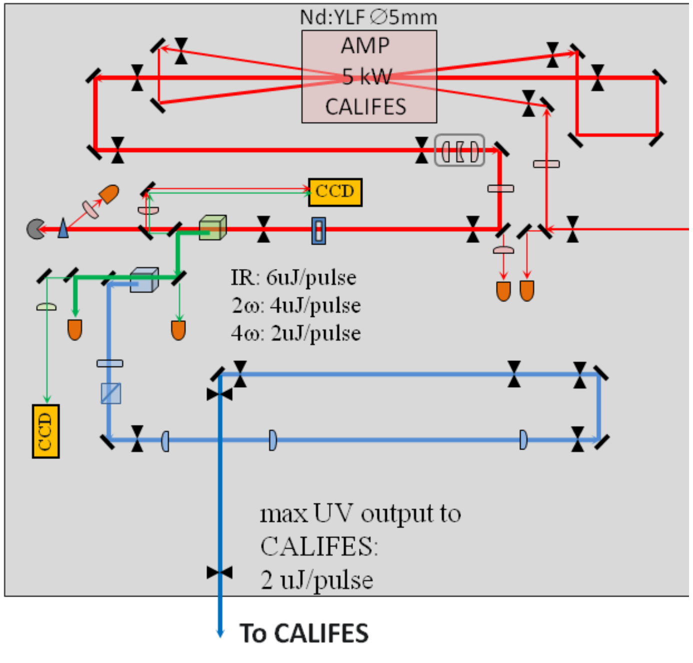
1.5 GHz, phase-locked to the external signal (3GHz klystron sub-harmonic)

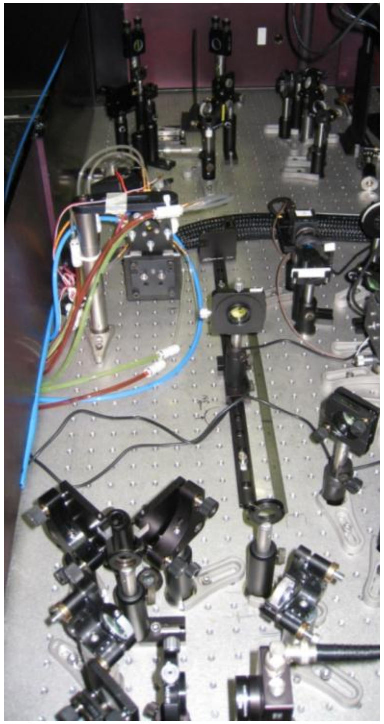
CALIFES amplifier and harmonics

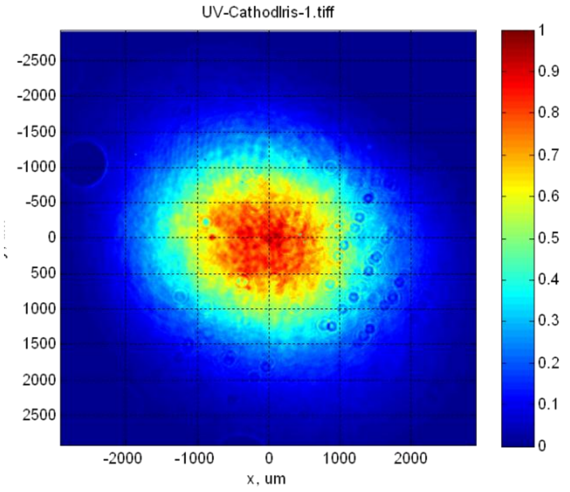
Pulsed mode operation

Nd:YLF rod, 5mm diam, 70 mm long
SHG: KTP II-type (oe-e) 11mm
FHG: BBO I-type (oo-e) 4.2mm

5 pumping diodes (Dilas Gmbh.)
Max 5.5 kW pumping power
Pump pulse duration 500us
1-pass gain 12 (3-pass 1700)
IR input: 4nJ/pulse
IR output: 6uJ/pulse
Peak intensity: ~ 100MW/cm2
SHG efficiency: 67%, 4uJ/pulse
FHG efficiency: 53%, 2uJ/pulse



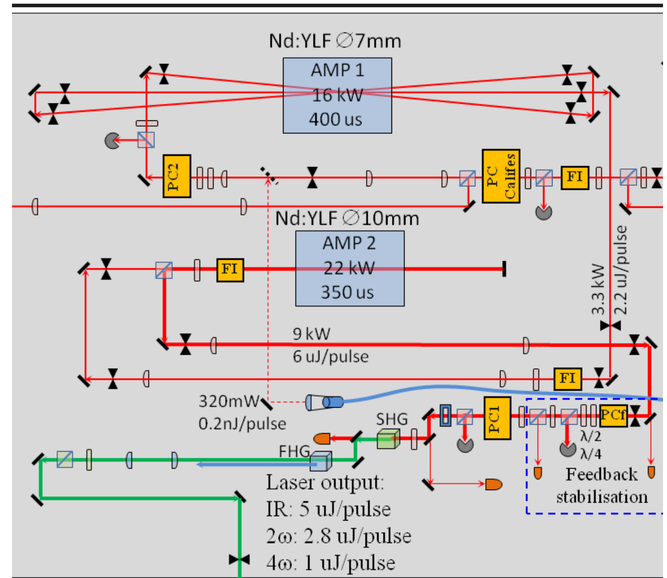


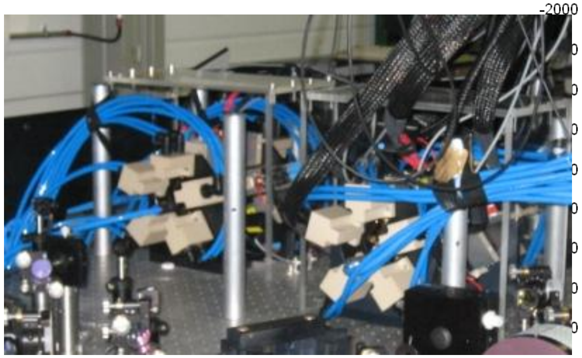


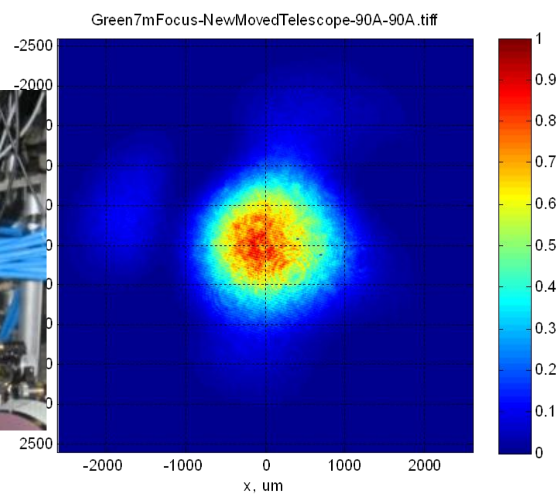
PHIN amplifiers and harmonics

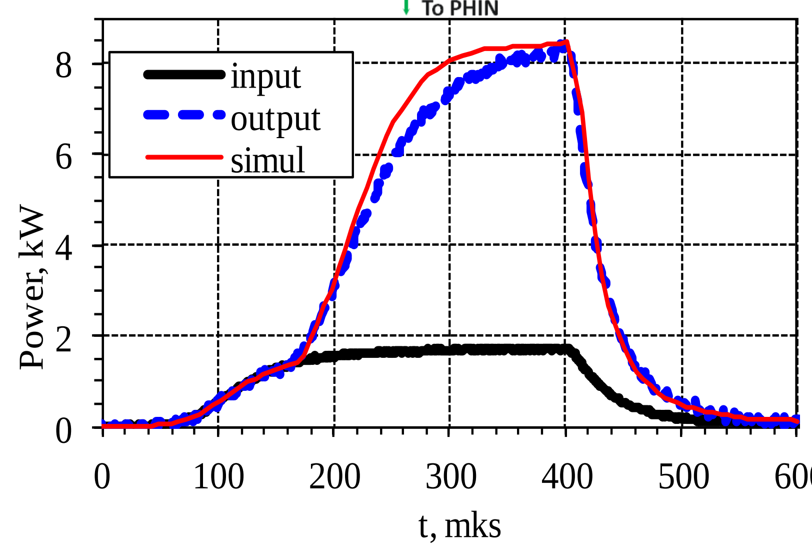
Steady-state operation

AMP1 - Nd:YLF 7mm diam, 90mm long
AMP2 – Nd:YLF 10mm diam, 120mm long
Max diode pump power 16kW (AMP1) and 22kW (AMP2), 500us
IR input: 7.6W, 5nJ/pulse
IR output AMP1: 3.5kW, 2.3 uJ/pulse (gain 1/3-pass 7.7 / 460)
IR output AMP2: 9kW, 6uJ/pulse (gain 1/2-pass 2.2 / 5)
Peak intensity: ~ 100MW/cm2
SHG: KTP II-type (oe-e), eff. 56%, 2.8uJ/pulse
FHG: BBO I-type (oo-e), eff. 35%, 1uJ/pulse

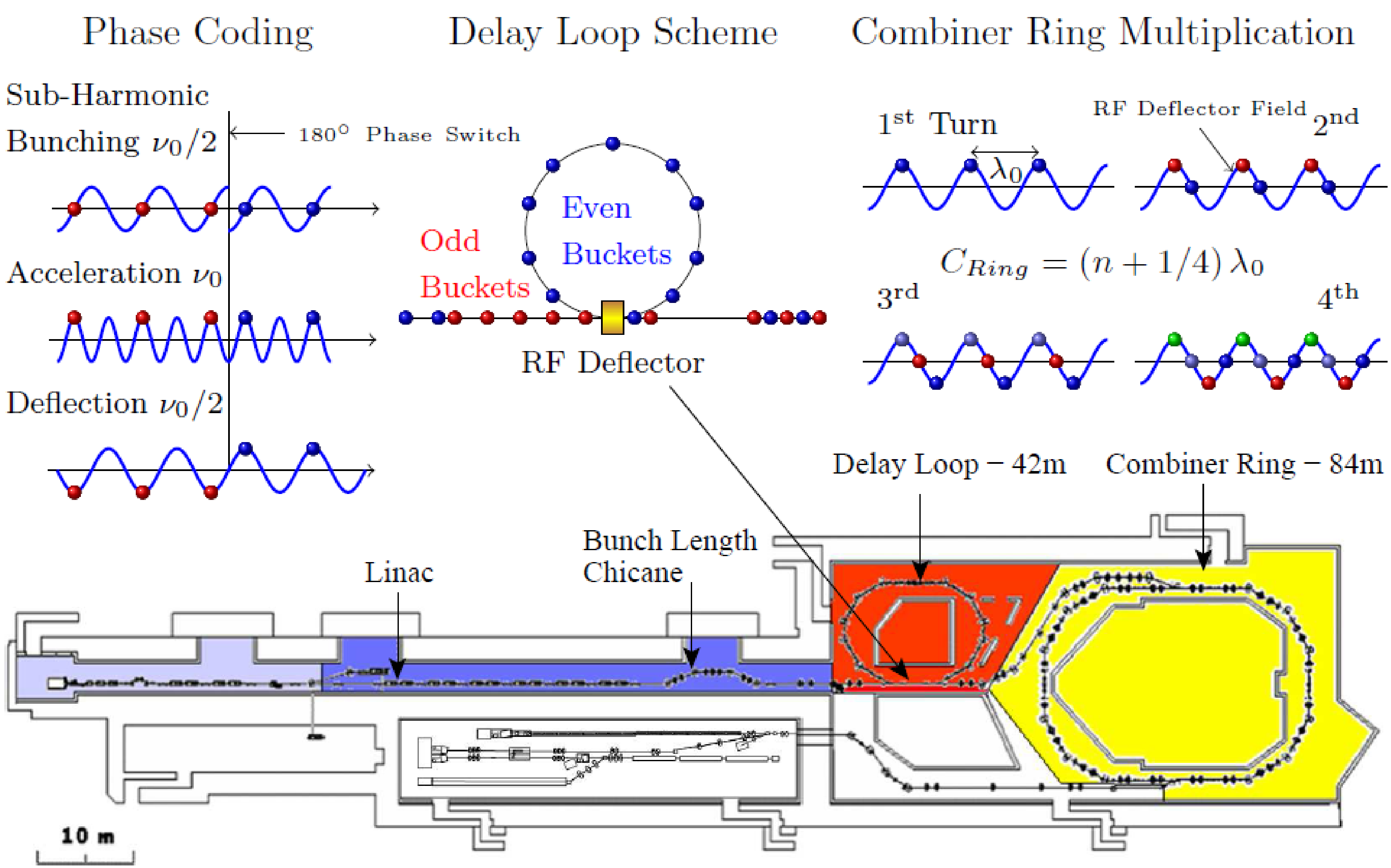




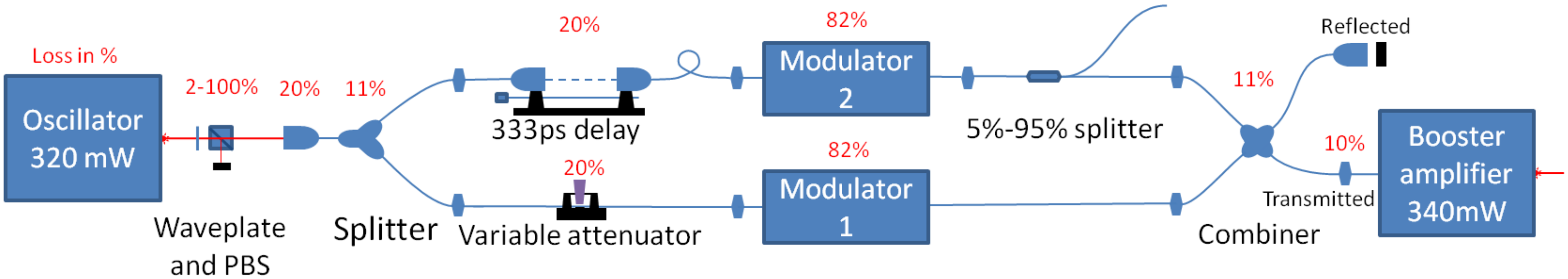


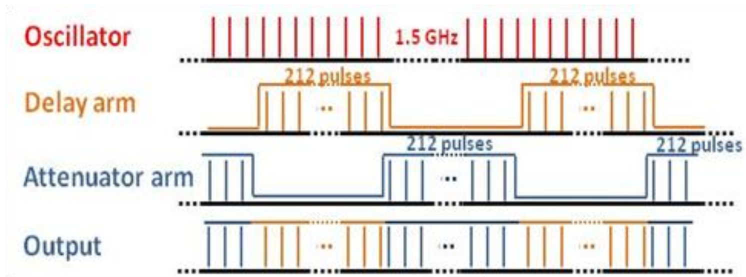


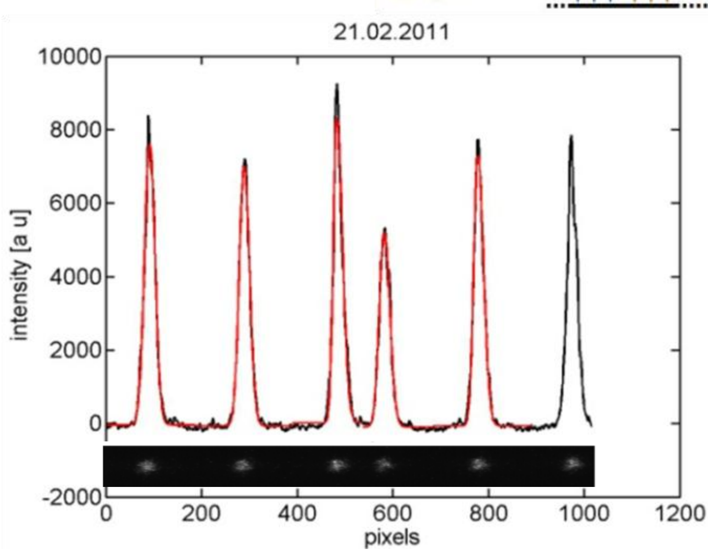
CLIC Phase-coding

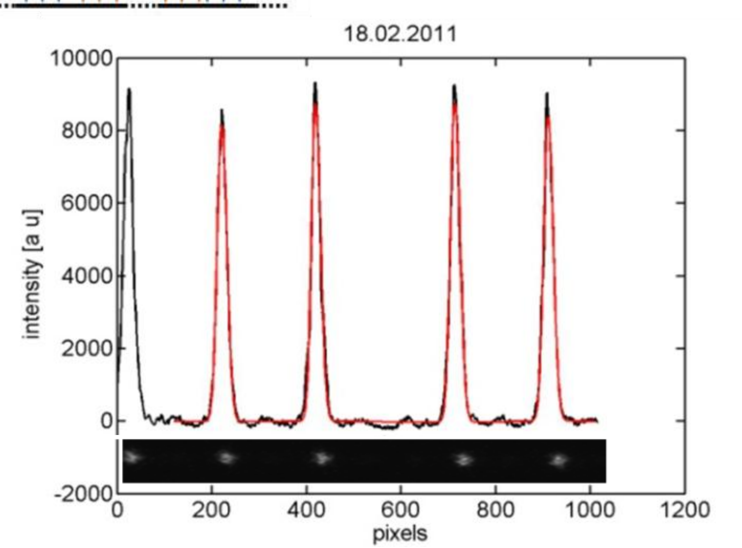


CLIC Phase-coding tested at PHIN





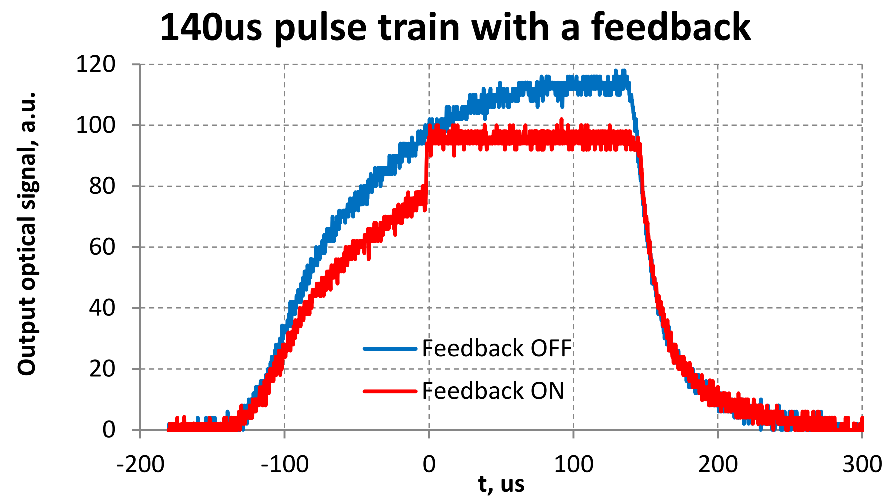


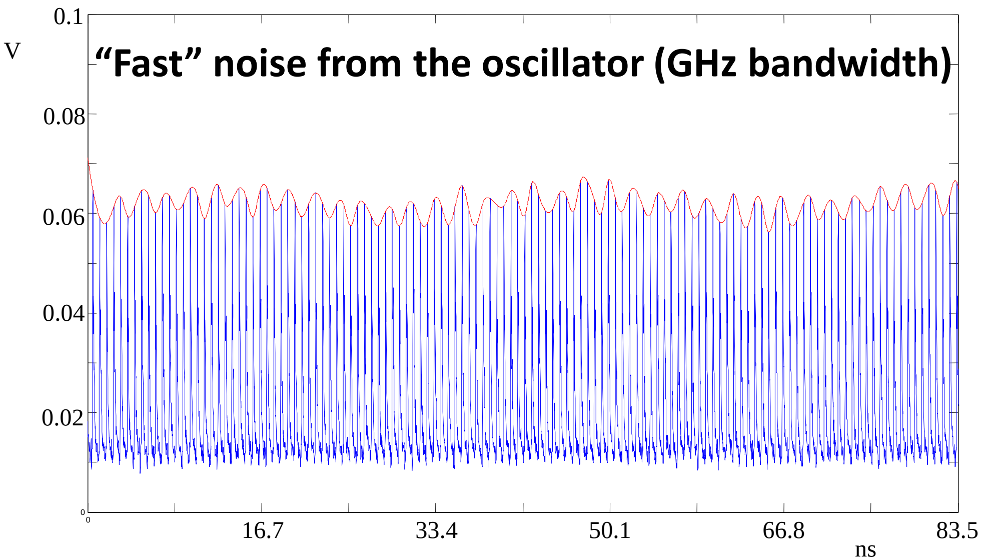


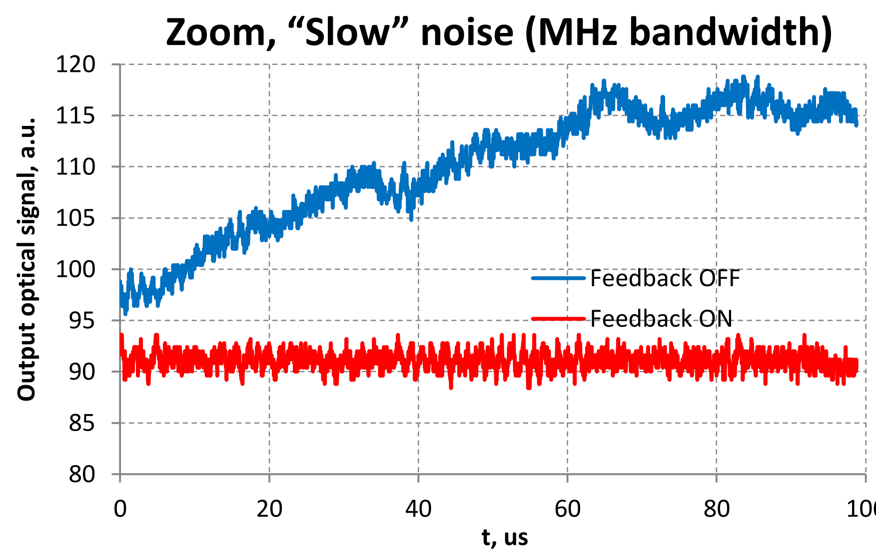
Feed-back stabilization

Optical noise:
"Fast" – from the oscillator
"Slow" – from the oscillator and amplifiers

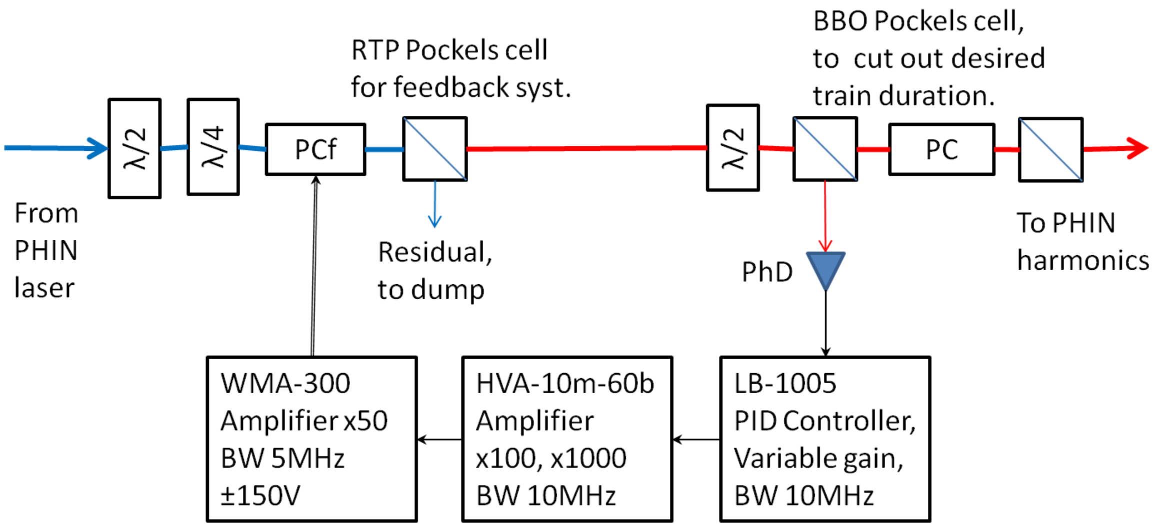
Stabilization is needed to suppress the noise

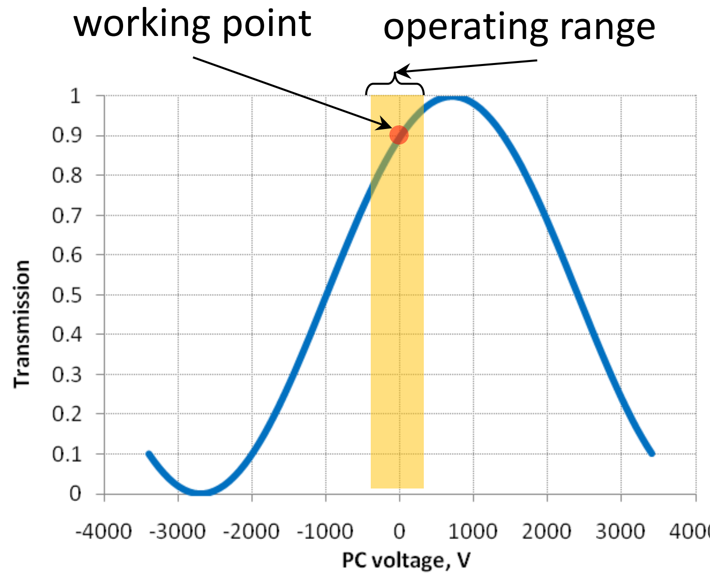




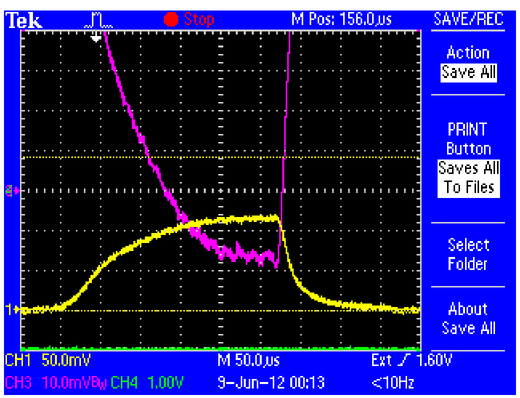


Feed-back stabilization (MHz bandwidth)

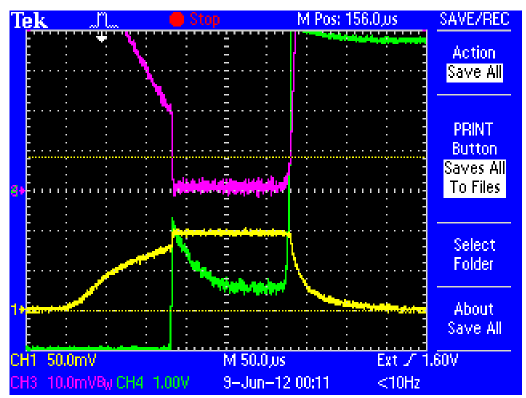




feed-back off



feed-back on

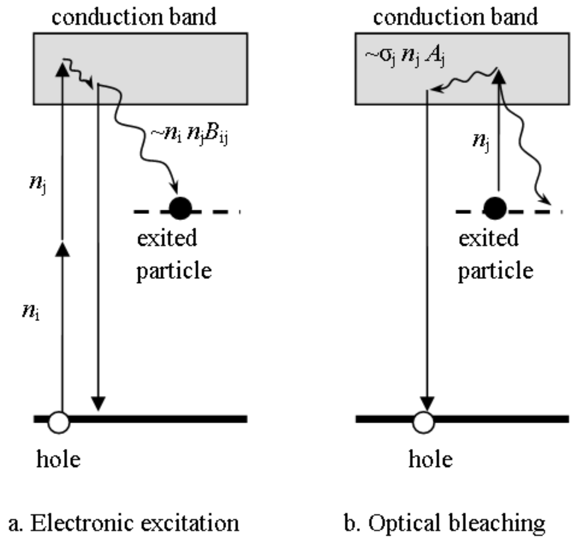


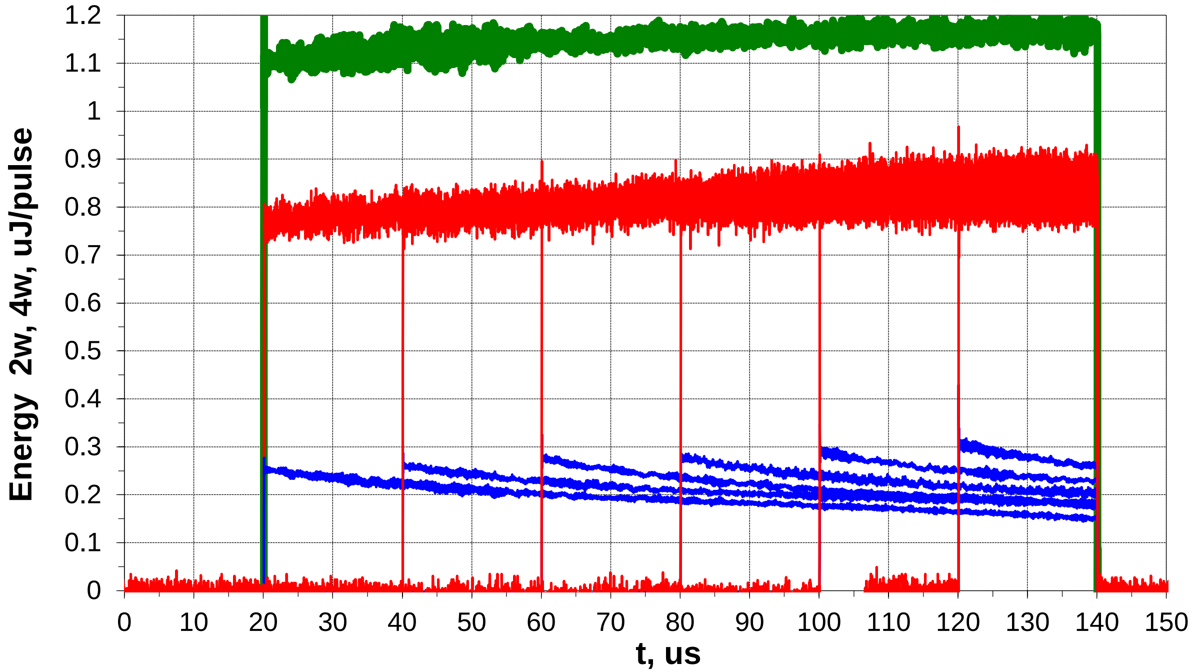
Yellow – optical pulse
Red – error signal
Green – driving voltage

High-power 4th harmonics for CLIC

FHG, BBO 4.2 mm
UV and Green bursts oscillograms

Model of induced linear absorption, caused by weak 2-photon absorption

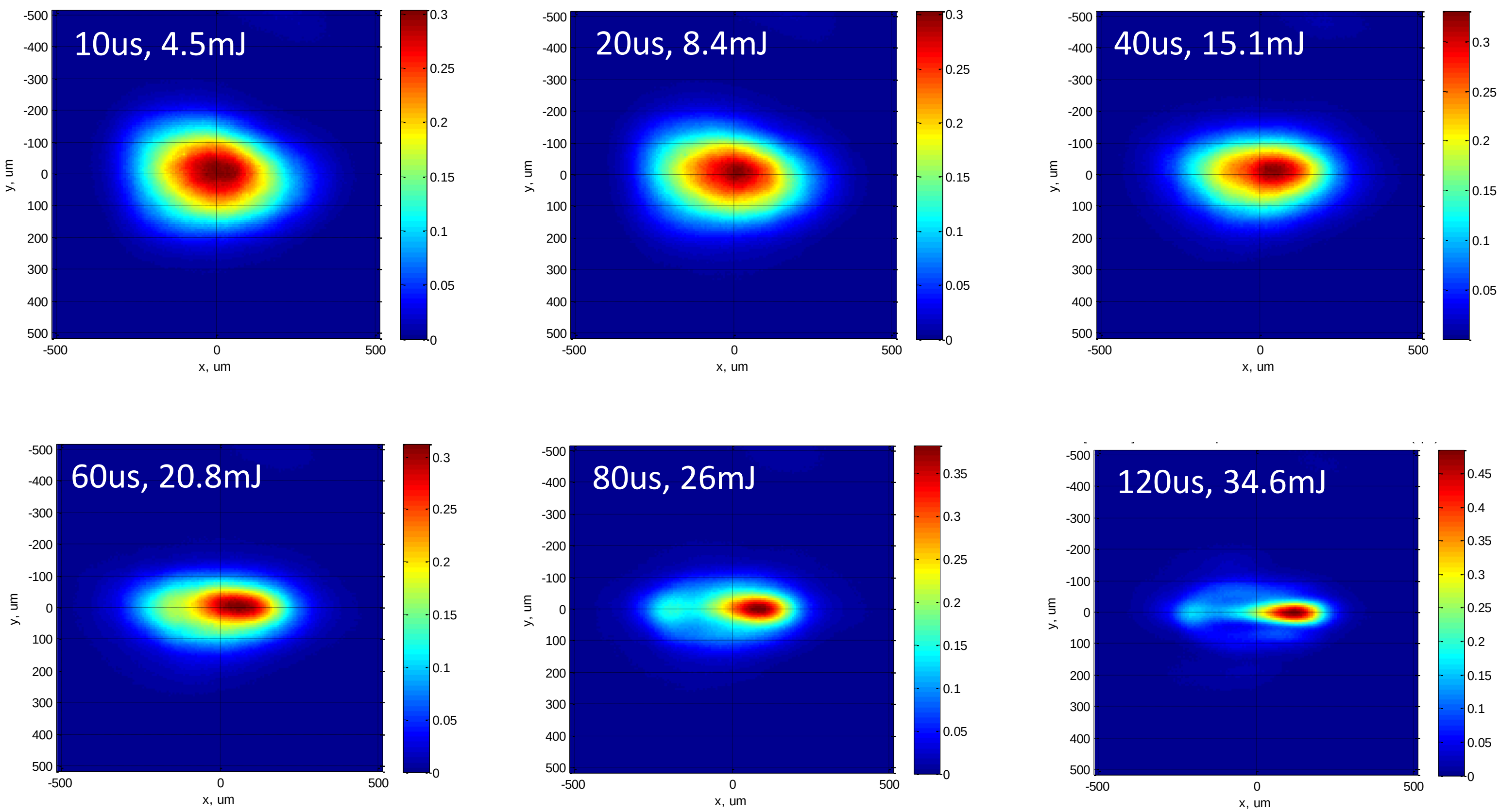




High-power 4th harmonics for CLIC

FHG, BBO 4.2 mm

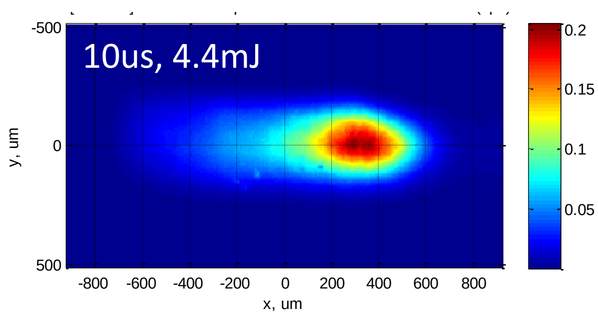
UV beam shape for different burst duration

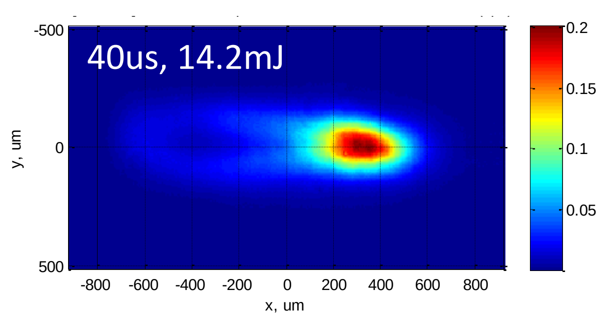


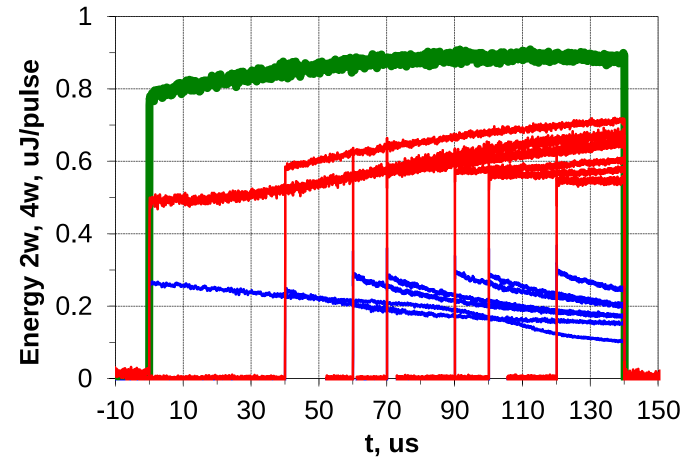
High-power 4th harmonics for CLIC

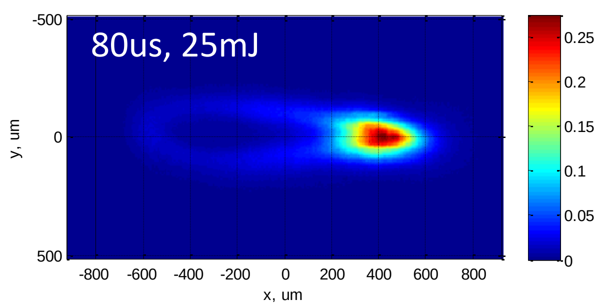
FHG, BBO 12 mm

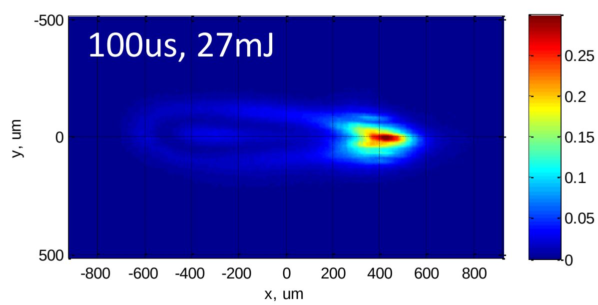
Just for curiosity or fun

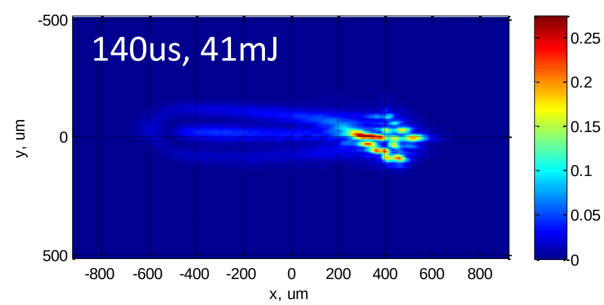












Future plans

- ❑ More of feedback (fast feed-forward, GHz bandwidth)
- ❑ Powerful UV generation (towards CLIC)
- ❑ 50Hz PHIN amplifiers operation (towards CLIC)
- ❑ Test Green cathodes Cs_3Sb (avoid powerful UV light generation)

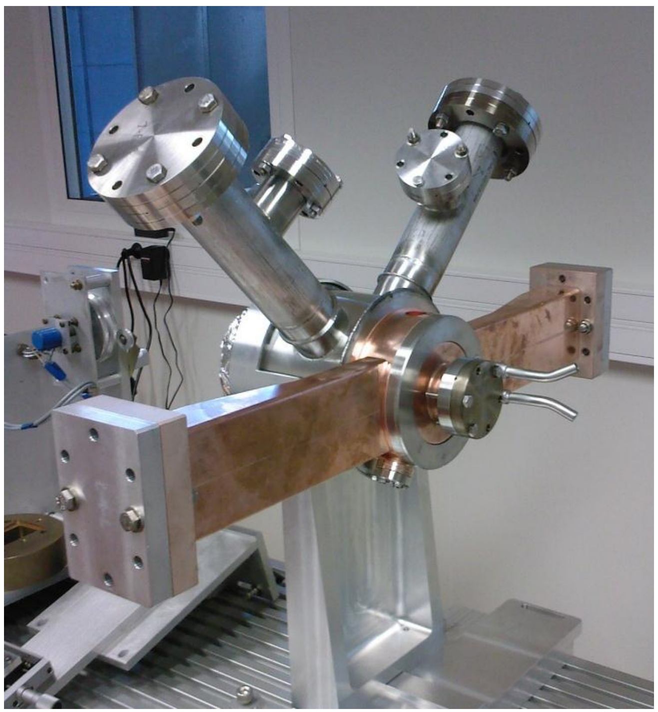
Thank you for your attention !

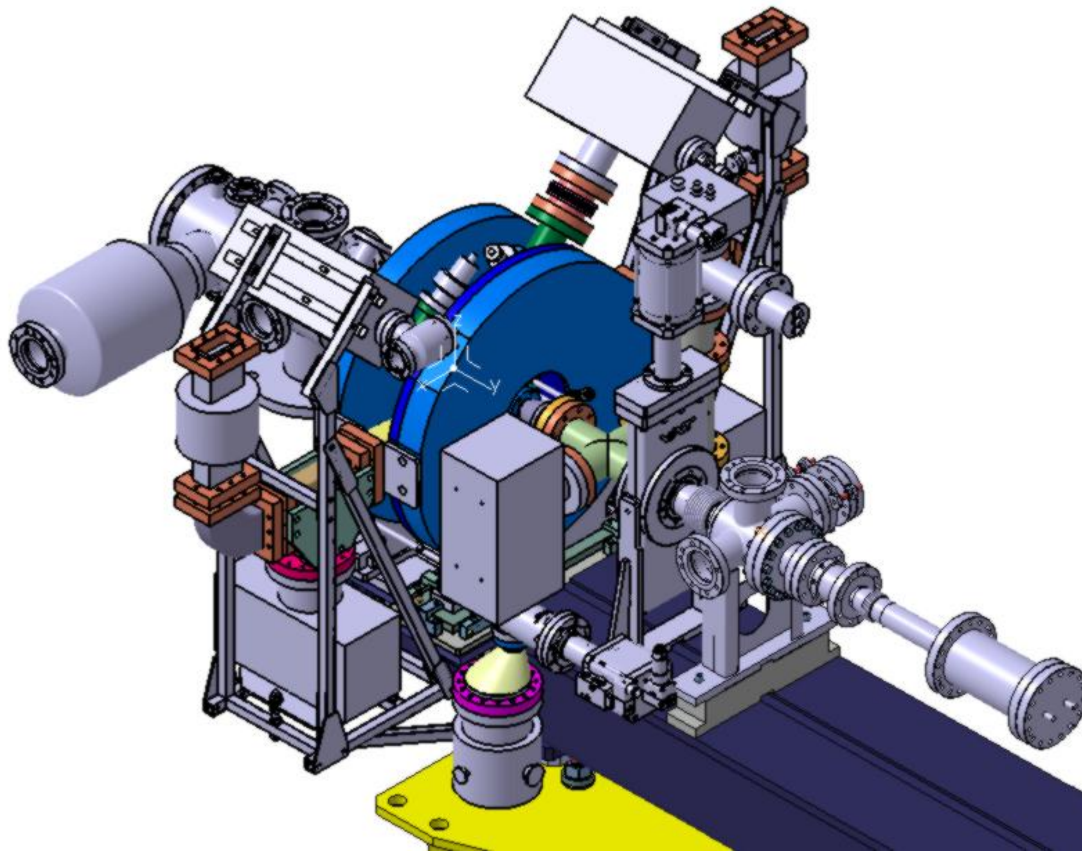
Acknowledgments and References:

1. I.Ross, "**Feasibility Study for the CERN "CLIC" Photo-Injector Laser System**", CERN-OPEN-2000-301 ; CLIC-Note-462, (https://cdsweb.cern.ch/record/467721)
2. G. Kurdi, I. O. Musgrave, M. Divall, E. Springate, W. Martin, G. J. Hirst and I. N. Ross, "**Development of the CTF3 photo-injector laser system**", Central Laser Facility Annual Report 2006/2007
3. M. Divall, G. Kurdi, I. Musgrave, E. Springate, W. Martin, G.J. Hirst, I.N. Ross, "**Design and testing of amplifiers for the CTF3 Photo-Injector Laser**", CARE-Report-2006-021-PHIN, (https://cdsweb.cern.ch/record/1089233)
4. M. Petrarca, M. Martyanov, G. Luchinin, M. Divall, "**Study of the Powerful Nd:YLF Laser Amplifiers for the CTF3 Photo-injectors**", IEEE J. Quantum Electron. 47 (2011) 306-313
5. M. Divall et. al. "**Fast phase switching within the bunch train of the PHIN photo-injector at CERN using fiber-optic modulators on the drive laser**", Nucl. Instr.&Meth. A, 659 (2011) 1–8

Photoemission and photo-injectors (photo-guns)

RF photo-gun: Evolution from a simple idea to a setup





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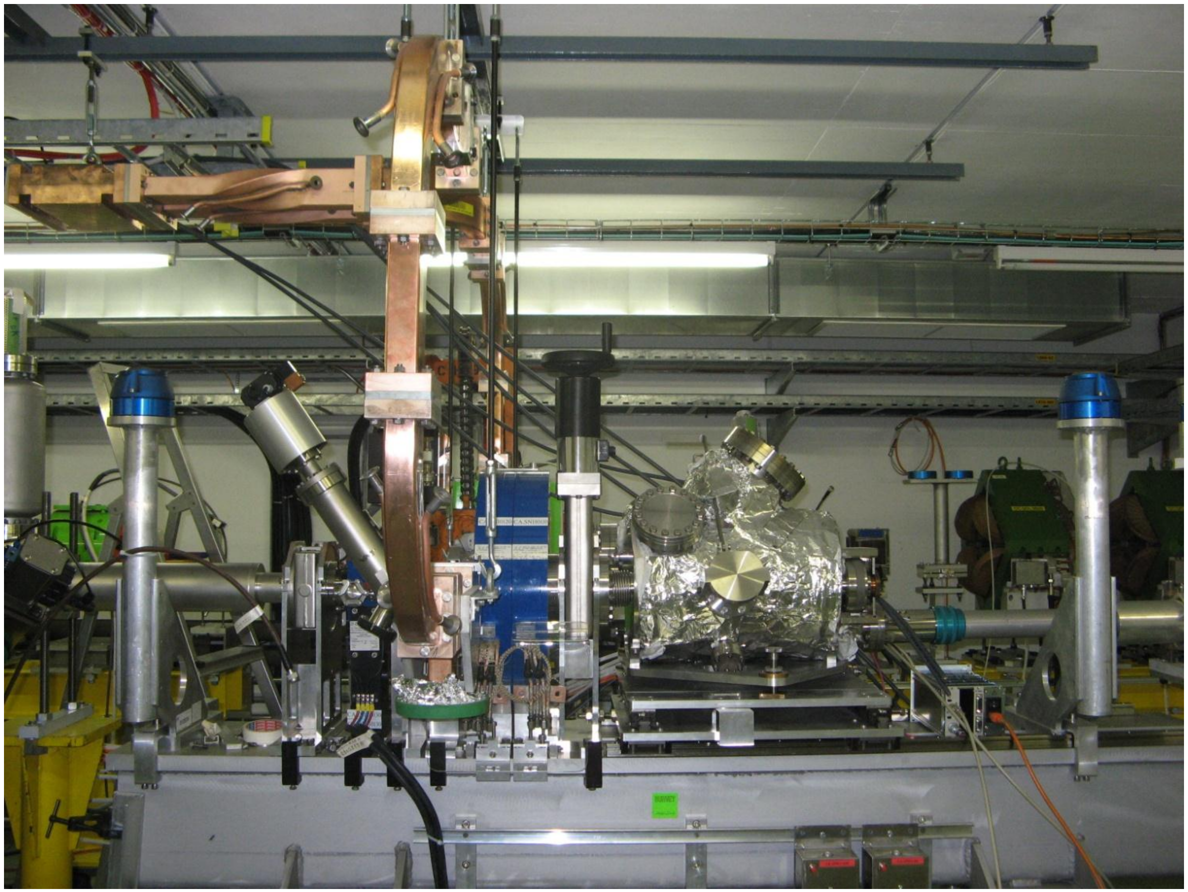
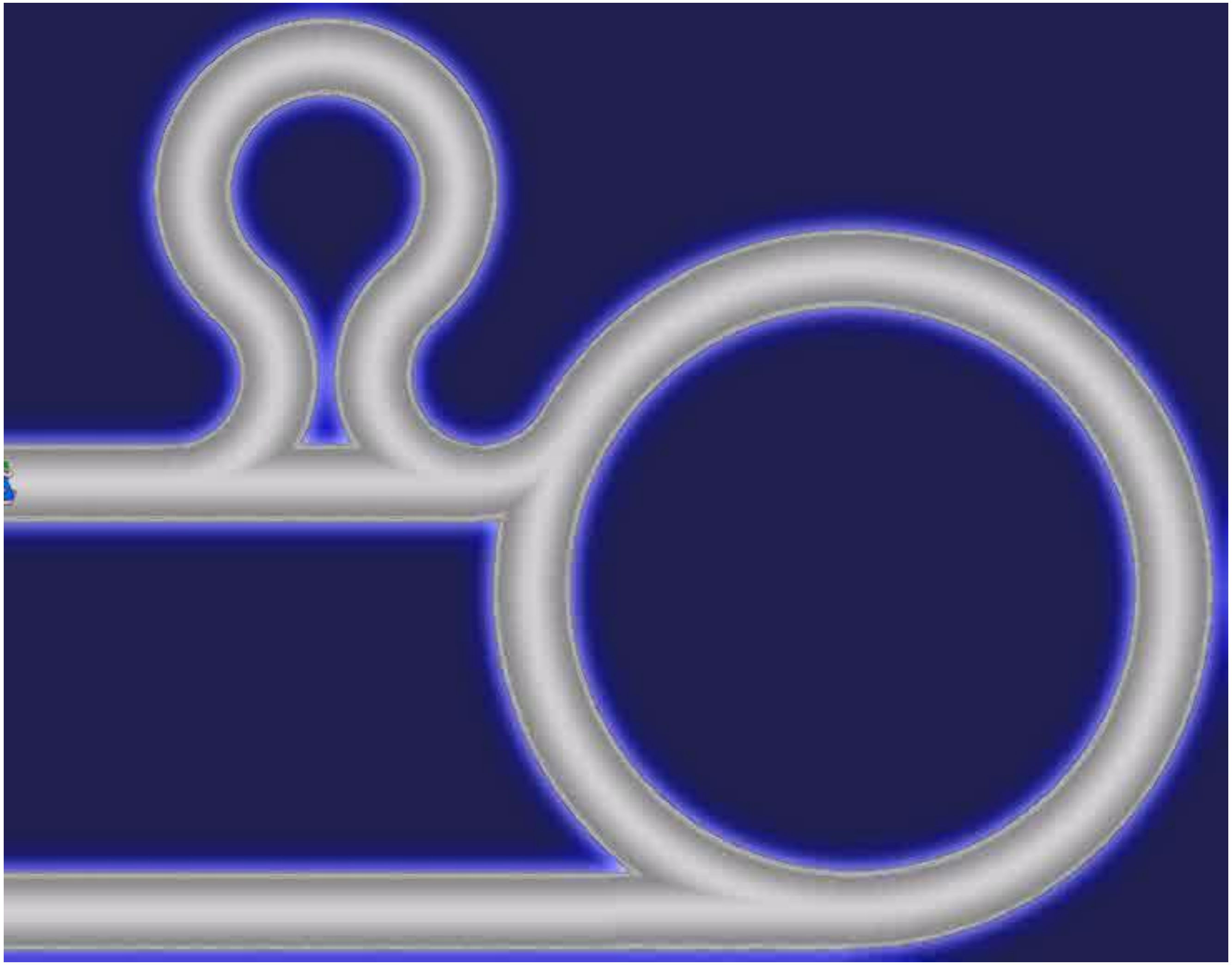


CLIC Phase-coding



by the courtesy of Alexandra Andersson, CERN BE-RF-FB