Laser for polarized electron sources

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Overview

CLIC main beam at 3 TeV (polarized electron)

1st Techniques: SLAC baseline

2nd Techniques: 2GHz laser

Technology overview

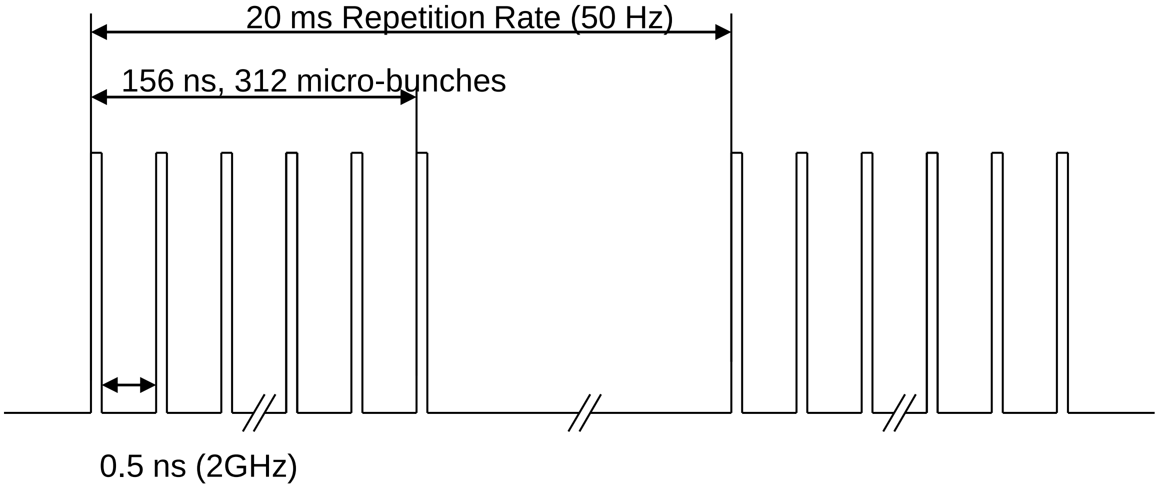
Activity at CERN: laser and photocathodes

CLIC main beam at 3TeV

Polarized electron beam requirements

CLIC injector parameters at 3TeV	
Charge / microbunch	~1 nC
Number of microbunches	312
Width of Microbunch	~ 0.1 ns
Time between microbunches	~0.5 ns
Width of Macropulse	156 ns

CLIC injector parameters at 3TeV	
Macropulse repetition rate	50 Hz
Charge per macropulse	312 nC
Average current from gun	15.6 μA
Average current in macropulse	2 A
Peak current of microbunch	10 A (100ps) 2.5 A (400ps)
Polarization	>80%



1^{st} technique: SLAC baseline

Base line under study at SLAC

Flash-lamp Ti:Sa → long laser pulse → long electron bunch. Time structure performed by bunching system.

Δt~150-350ns
λ0~800nm
120Hz

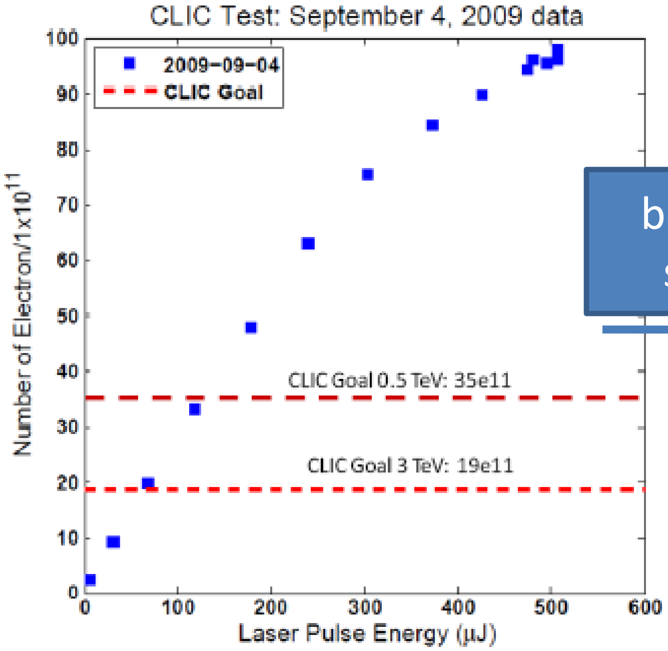
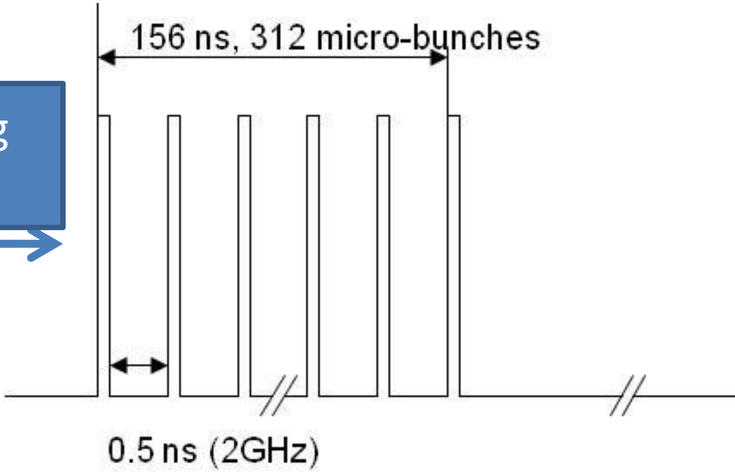


Figure 3: Production of polarized e⁻ at SLAC

bunching system



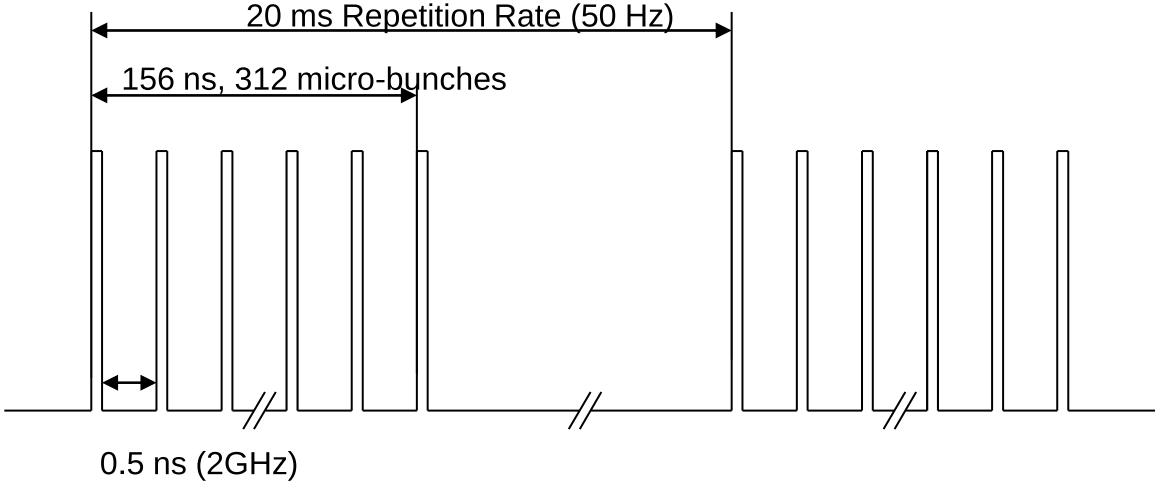
F. Zhou et al, SLAC-PUB13780; CLIC Note 813, 2009
A. Brachman et al, SLAC-PUB-11373

CONs: bunching system is required→ possible presence of satellites

PROs: charge production already demonstrated
only improvement of existing laser system; R&D for a new system is not required

2nd technique

Implementation of a laser with the required electron time structure



Advantages:

Electron bunching system not required→ Elimination of undesired satellites

Disadvantages

R&D on a new laser system is required but the technology is already available
Required cathode response time to be demonstrated

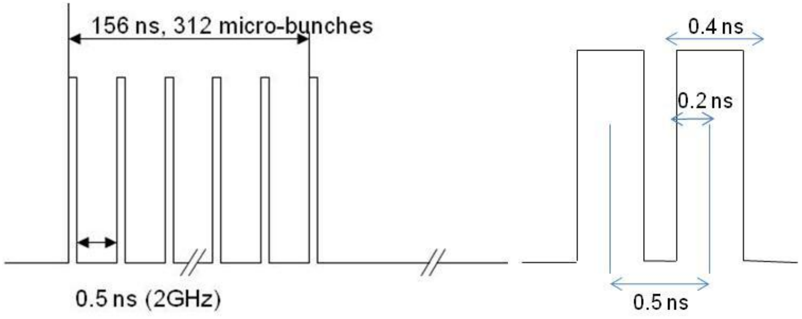
2^{nd} technique

Laser power & energy specification for QE=0.5% at 800nm:

$$E_L(\mu J) \sim 1.24 \frac{Q(nC)}{\lambda(nm) \times QE}$$

Laser power-energy specification at cathode QE=0.5% at 800nm	
Pulse laser energy	0.31µJ ; 1µJ (margin)
Pulse peak power	2.5 KW (400ps pulse width)
Pulse train energy	312 µJ
Beam average power	15.6 mW
Pulse train peak power	2KW

Laser time &bandwidth specification



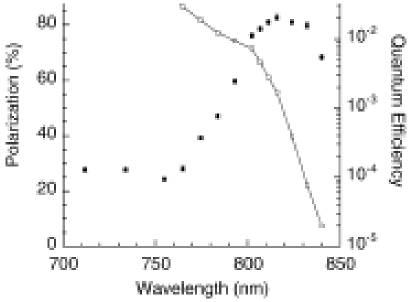


Fig. 2. Polarization (●) and quantum efficiency (□) obtained by a GaAs–GaAsP strained layer superlattice.

Laser power-energy specification at cathode QE=0.5% at 800nm	
Bandwidth	<10nm
Max pulse width (4σ)	400ps
Profile	Gaussian

Technology Overview

- Gain switched fiber coupled diode laser at ~1560nm + ErYb-doped fiber amplifier and harmonic conversion scheme to produce ~780nm.

PROs: telecommunication technology is used → cheap and easier support from industry

CONs: peak power reduction to avoid non linear effects is limited by the time structure ($\Delta t\_max \sim 400ps$)

A. Tunnermannet al. Ultrafast fiber laser Technology: status and prospect. Proc SPIE 2010, p1, San Francisco, CA (USA)

T. Eidam et al, Fiber based ultra short pulse laser system at ultrahigh average power, Proc SPIE 2010, p360 San Francisco, CA (USA)

~13μJ at 10MHz, 800ps stretched pulse.

Technique adopted at Jlab→ *J. Hansknecht, M. Poelker, Phys. Rev. Spec. Opt. Acc.* ***9,*** *2006*

200MHz-3GHz pulse repetition rate with Pavg=2W at 780nm

- SESAM mode-locked thin disk laser

PROs: output power can be scaled up by multiplying mode areas on gain medium and SESAM by same factor, low thermal effects

CONs: required wavelength to be demonstrated.
multi-pass configuration required

- Vertical External-cavity Surface emitting laser VECSEL:

PROs: lasing at different wavelengths including ~800 nm and ~1600nm
high repetition rate achieved, high power achieved (in case of optical pumping); power scaling as “SESAM mode locked think disk”

New emerging technology: work in progress

D. Lorenser et al, IEEE J. Quantum. Electronics, **42**, 8, p838, 2006
E. J. Saarinen et al, Optics Express, **15**,3, p955, 2007
J-M Hopkins, optics Letters, **33**,2, p201, 2008
P. Dupriez et al, Optics Express, **14**,21,p9611, 2006
…

- Solid state pumped Ti:Sa system:

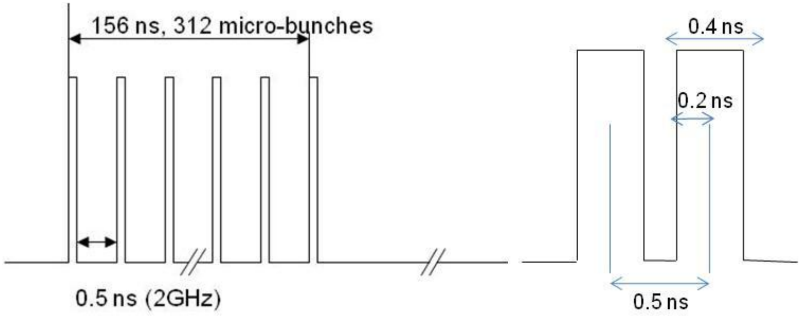
(pumping system would be a laser like the one used to drive PHIN and CALIFES photoinjector within CT3
M. Petrarca, M. Martyanov, M. Divall, G.Luchinin accepted to IEEE J. Quantum. Elec. 2010 and reference therein)

PROs: lasing directly in the required λ, large λ tunability around 800nm
CONs: pump λ in the green part of the spectrum
powerful pump system is required → expensive
large laser system

Summary:

Several laser technologies could provide the solution
Merging the different techniques would lead to the most suited solution
R&D is required for the optimization
The technology improves dramatically every year

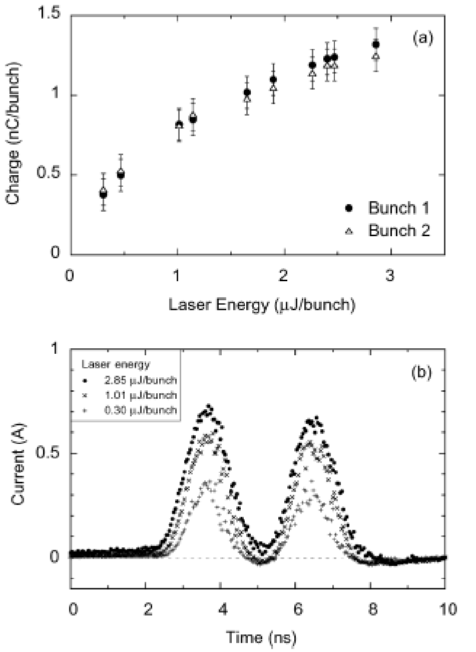
Photocathode



CLIC injector parameters at 3TeV	
Charge / microbunch	~1 nC
Time between microbunches	~0.5 ns
Peak current of microbunch	10 A (100ps) 2.5 A (400ps)

10 A peak current achieved:
T. Maruyama et al, NIM, A 492 (2002) 199-211

For example: K. Togawa et al, NIM, A 455 (2000) 118-122



InGaAs-AlGaAs
Superlattice Be-doped

Δt~1.4ns
Δpulse~2.8ns

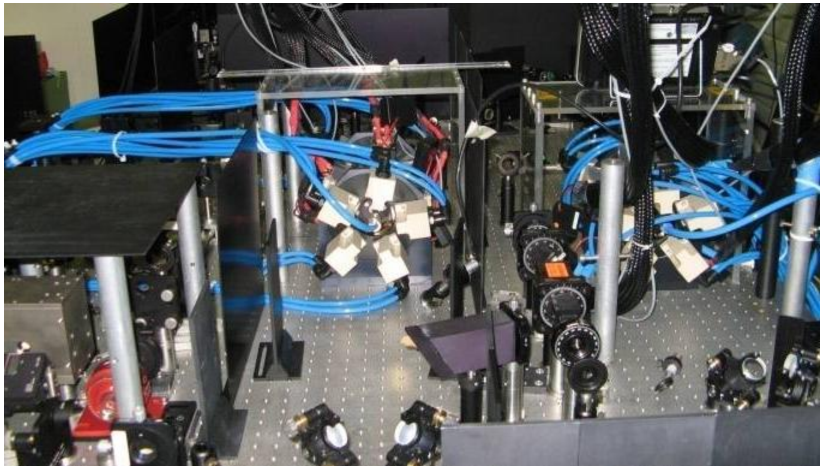
Fig. 5. Response of an InGaAs–AlGaAs strained-layer superlattice with a heavily doped surface: (a) laser energy versus extracted charge data for each bunch; (b) electron bunch shapes for several laser energies.

response time ?

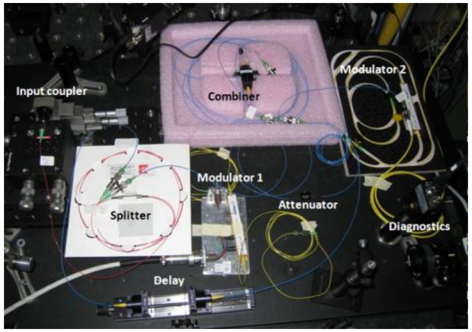
Response time: Δt_max=400ps and 2GHz rep rate
producing 1 nC
to be demonstrated

Activity at CERN

M. Petrarca, M. Martyanov, M. Divall, G.Luchinin
accepted to IEEE J. Quantum. Elec.



Fiber based system to perform phase coding.
Recently bought a fiber amplifier (300mW upgradable to 10W at 1.5 GHz r.r)



See M. Csatari talk in
Accelerator session: WG 6
(Drive beam complex CTF3)
14:40

Powerful Nd:Ylf laser to drive two rf photo-injector **PHIN**, CALIFES

See O. Mete talk in
Accelerator session: WG 6
(Drive beam complex CTF3) 15:00

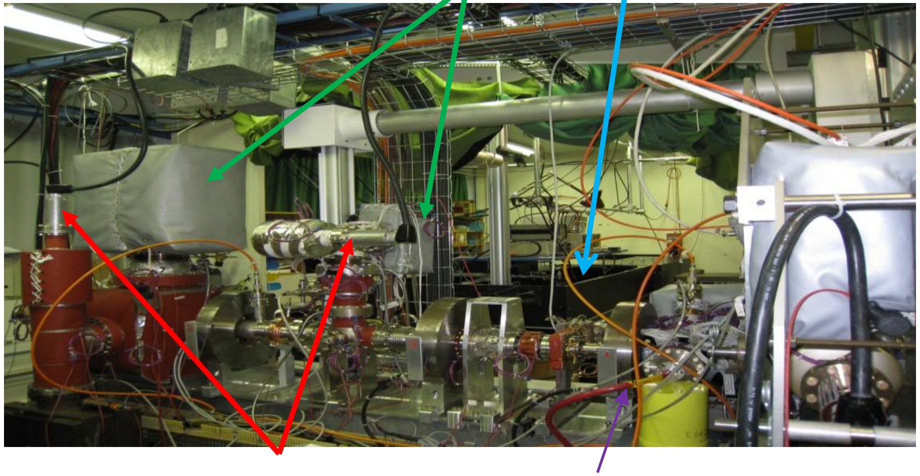
Activity at CERN

Photoemission laboratory produces and studies multi compound cathodes: Cs_2Te

other cathode structures will be investigated for longer wavelength response (Cs_3Sb etc.)

The lab can be adapted to use superlattice cathode and to study polarized electron generation…..

…..of course a dedicated lab would be better.



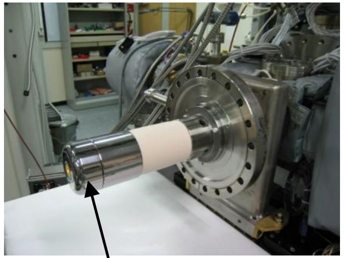
Ionic pump

Nd:Yag

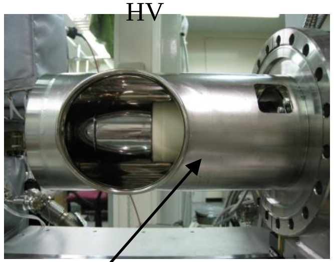
Sublimation pump

HV

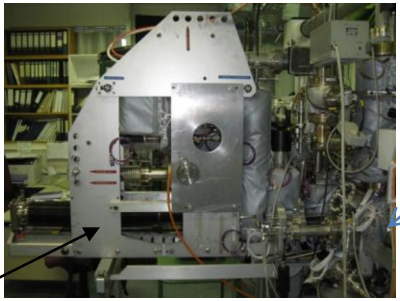
- DC gun (max 8MV/m)
- Fix electrode gap:1cm
- Electrode: Ti
- $1\times10^{-11}<p<7\times10^{-11}$ mbar
- Typical laser spot size 4mm



Electrode (Ti)



Anode (Stainless steel)



Cathode Preparation chamber

UHV (6×10^{-12}mbar) <u>transport carrier</u>
to transport good quality cathode to different facilities

OFHC: Oxigen free high conductivity copper

Summary

Several laser technologies could provide the solution
Merging the different techniques would lead to the most suited solution
R&D is required for the optimization
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Dedicated photocathode studies and R&D is required
To demonstrate the feasibility of producing the desired time structure