PS/PL/Note 93-50 (Min.)
20/07/93
J.H.B. Madsen

Summary Notes of the CLIC/PS Meeting on 16 July 1993

1. Brief status of the CTF laser — S. Schreiber

1.1 The two-pulse mode

Sending two pulses separated by 4 ns to the train pulse generator was tried out successfully during the last run. The way it works is indicated on App. 1 and 2.

1.2 Recent laser performance

Main points : 8 ± 2ps FWHH. 100 10^{-6} J with variations -28% and +9%, min/max., spatial energy distribution better. See App. 3, 4 and 5.
The pulse width can be increased to 25 ps but this is a major undertaking requiring a couple of days at least (during the coming run we shall stay at the 8ps)

2. High-charge RF gun assemblies

2.1 Limitations due to the self field of the e^- bunch next to the cathode — R. Bossart

See App. 6 and 7. Note that the latter concerns 144 MHz.
To extract high charges: large laser spot on the cathode, high ratio self field / E0 at cathode and solenoid for focusing.

2.2 MAFIA simulations — S. Lütgert

See CLIC Note 205.
The simulations show that with the present 1 1/2 cell gun, a solenoid and a 4 cells section a bunch charge of 50 nC can be produced if the field gradient in the gun is increased to 120 MV/m and the laser spot radius to 6.0 mm. See table 1 and 2. To get a single bunch with even higher charges a modified 1 1/2 cell gun is proposed.
The iris diameter is increased from 20 to 30 mm. To reinforce the focusing the wall surrounding the cathode is made conical (21°). The cathode surface stays flat; the laser spot radius becomes 20 mm . The bunch out of the 4 cells section has a larger energy spread and there is bunch lengthening. See table 3 and fig. 1..

We will look if the laser clearance is still enough for a 20mm Ø laser beam in the present layout.

Two points from the discussion :

- making a high charge RF gun is one of our objectives
- the transmission of a single bunch- high charge through TRS remains to be simulated

CTF 18.7.93

S. Schreiber
H. Braun

2-pulse amplification mode of the CTF-Synchro Laser

aim:

- to amplify similtaneously two consecutive LEC pulses
  $\Delta t = 4\,ns \;\hat{=}\; 12$ buckets
- to double the number of trains: 8 → 16 pulses in a more "natural" way

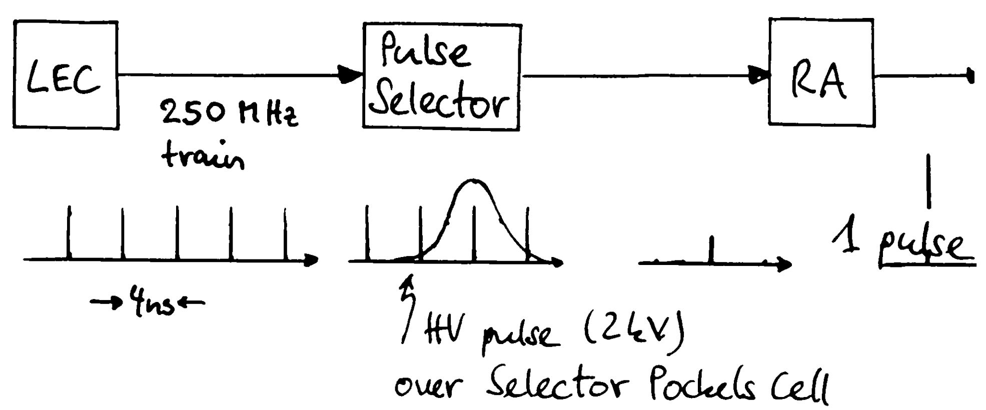
result in terms of 30 GHz rf power

☺ from 3 MW with 1 train / 8 pulses

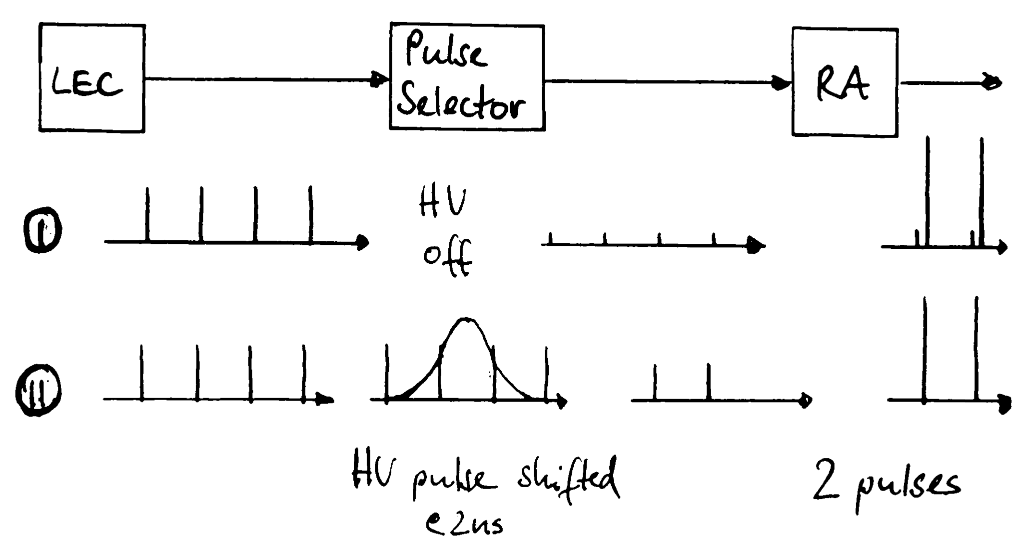
☺ → to **10 MW** with 2 trains / 16 pulses

How does it work?

normal scheme:

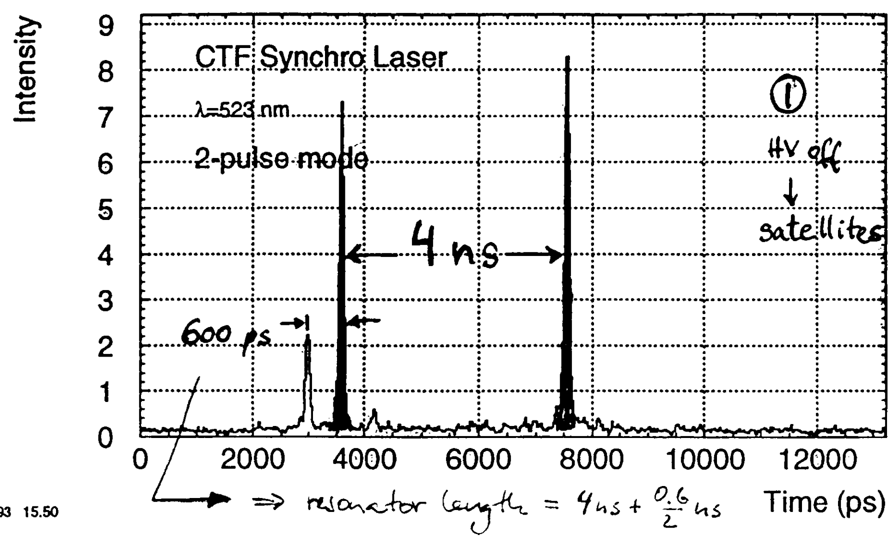


☺ new 2-pulse mode:

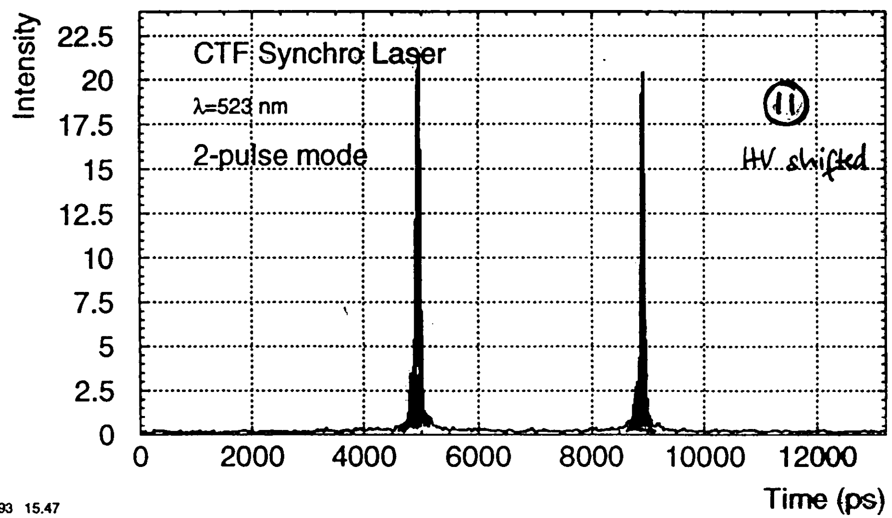


App. 1

➡ both pulses were amplified to about the same energy as in normal, single pulse mode.



30/06/93 15.50



30/06/93 15.47

Abb. 2

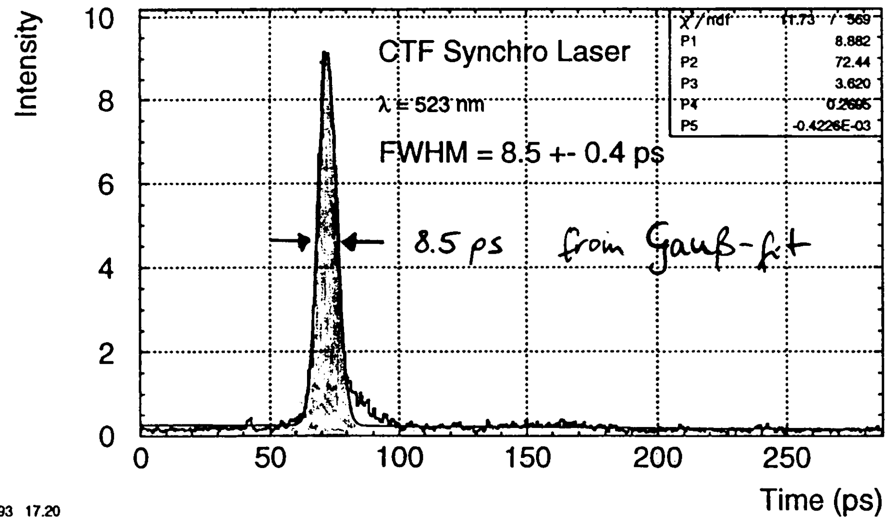
CTF ~~2.7.93~~ 16.7.93
S. Schreiber

Brief Status of the CTF Laser

- compressor is installed and working

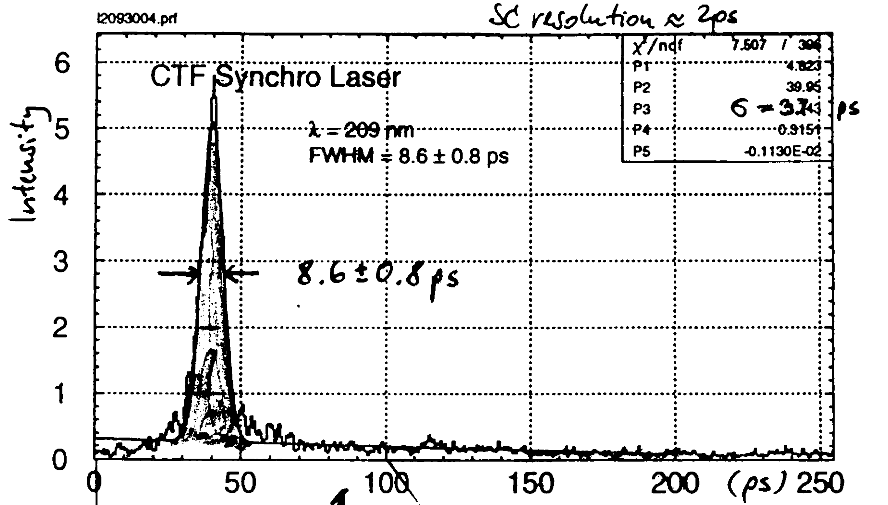
pulse width measured @ 523 nm
not amplified

SC resolution unfolded $\Delta t = 7.7 \pm 0.4\,ps$ FWHM



⇨ the FWHM is less than **10** ps now

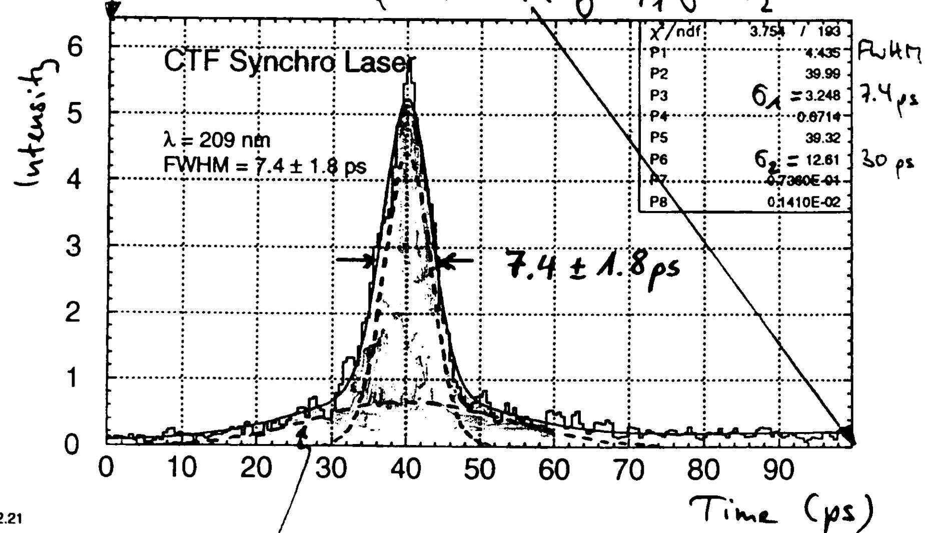
after amplification @ 209 nm



↑ fitted with Gauß + straight line

same pulse

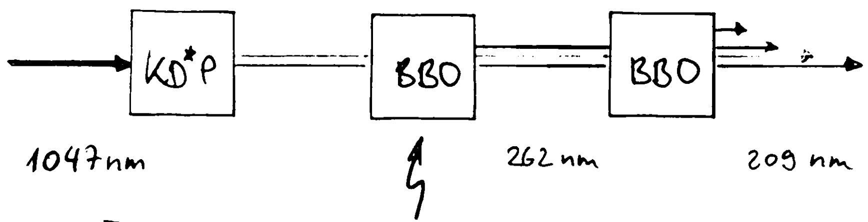
↓ fitted with Gauß₁ + Gauß₂ + line



* the wide Gaussian is also visible in the slit image → it is background

Abb. 3

harmonic generators



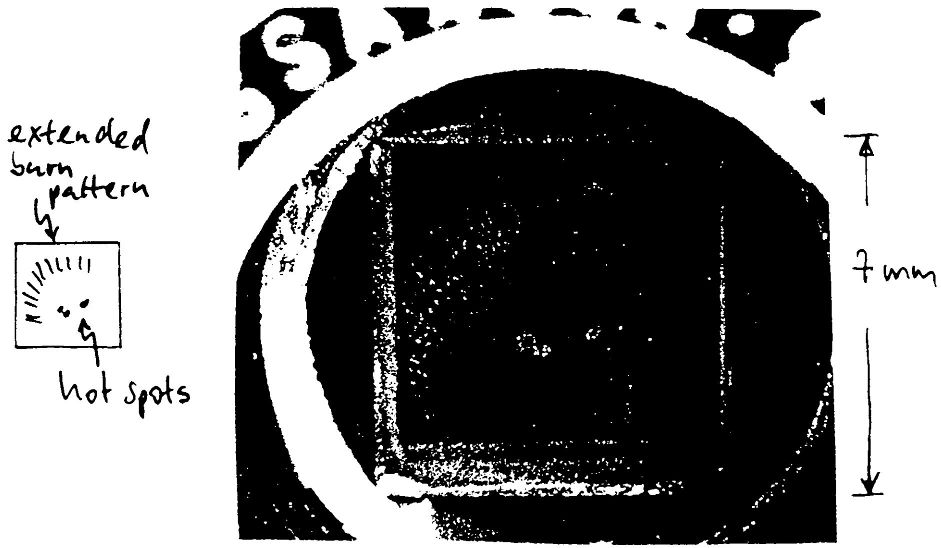
⇒ Considerable damage of the 4th harmonic BBO surface

⇒ this explains the poor energy output

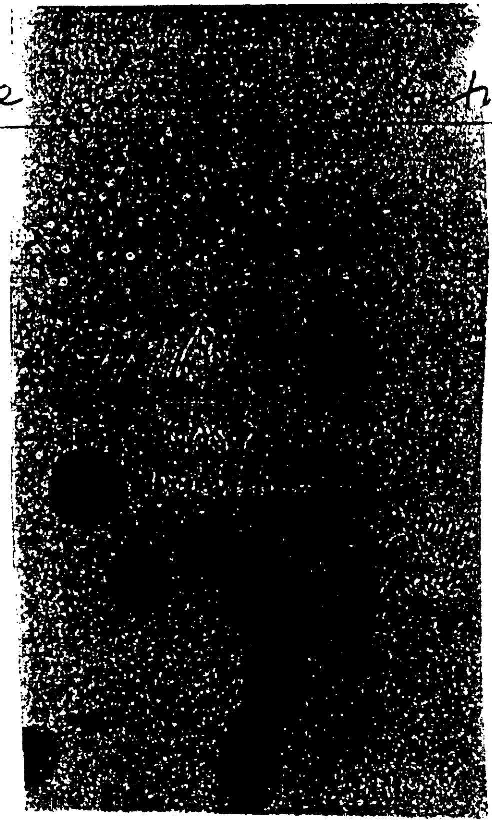
a new BBO is already available (~6000 SF)

* damage threshold ≈ 10 GW/cm²

we have ⟨E⟩ = 3.5 GW/cm²



transverse ...tion



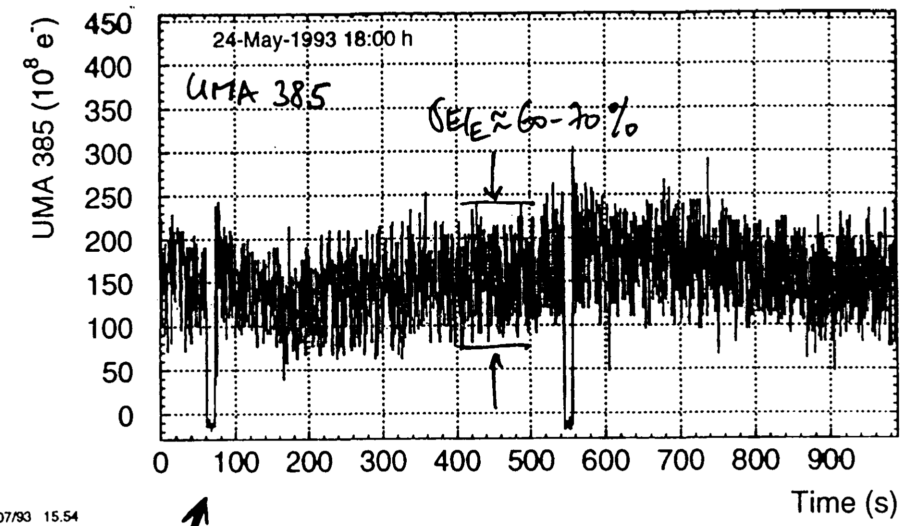
⇒ @ IR the spatial beam profile looks good, no hot spots seen

⇒ @ 209 nm shape is determind by the doubling crystals

shape is more like this

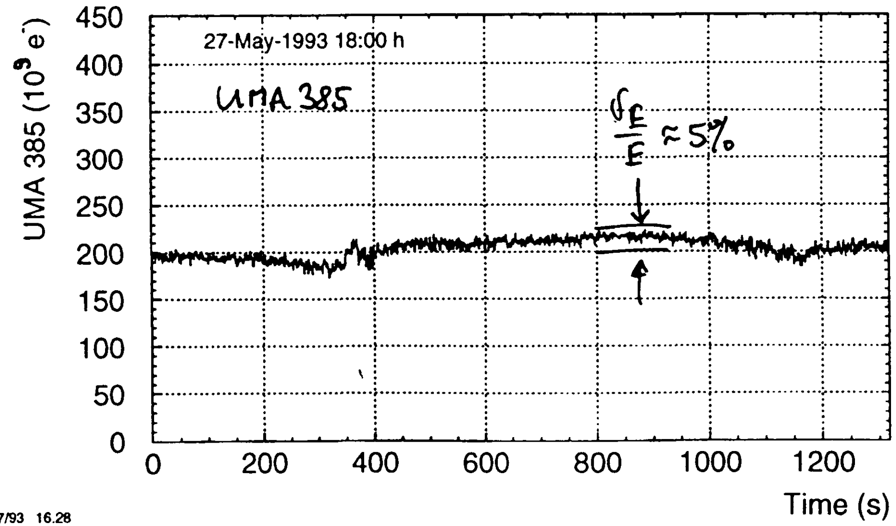
Abb. 4

Energy stabilitation ← Lasing near the fluoreszens lifetime



01/07/93 15.54

before stabilization after



01/07/93 16.28

Abb. 5

Energy/jitter (this week)

- $E_{1047\,nm} \approx 10$ mJ → OK.
- $E_{262\,nm} \approx 1$ mJ → OK

  ↑ with new BBO ↓

- $E_{209\,nm} \approx 100\ \mu J$ → OK

  (how long ?)

- Energy-jitter a bit worse than before (due to compressor)

[b] $\Delta E_{1047\,nm} = -9\% + 7\%$ (min/max) → OK

[a] $\Delta E_{523\,nm}$ not amplified $= -28\% + 7\%$ (min/max) ↳ to be improved

[a] $\Delta E_{209\,nm} = -28\% + 9\%$ (min/max)

[a] measured with a Molectron Joulemeter + HP scope over ~1000 shots

[b] measured with the build in Photodiode + HP scope

Self Field of Electron Bunch on Photocathode

Gauss Law : $E_z = \sigma / \varepsilon_0$

Surface charge density : $\sigma = Q / \pi r^2$

Bunch charge : Q

Bunch radius : r

1. Case CTF : $Q = 14\,nC$, $r = 4\,mm$, $\sigma = 28\,nC/cm^2$
   $f = 3\,GHz$, $E_z = \sigma/\varepsilon_0 = 31\,MV/m$, $E_0 = 75 \ldots 100\,MV/m$
   Ratio $E_z / E_0 =$ 0.35 ± 0.05 demonstrated by CTF

2. Case MAFIA : $Q = 50\,nC$, $r = 6\,mm$, $\sigma = 44\,nC/cm^2$
   $f = 3\,GHz$, $E_z = \sigma/\varepsilon_0 = 50\,MV/m$, $E_0 = 85 \ldots 120\,MV/m$
   Ratio $E_z / E_0 = 0.60$

3. Case MAFIA : $Q = 150\,nC$, $r = 10\,mm$, $\sigma = 48\,nC/cm^2$
   $f = 3\,GHz$, $E_z = \sigma/\varepsilon_0 = 54\,MV/m$, $E_0 = 60 \ldots 120\,MV/m$
   Ratio $E_z / E_0 = 0.90$

4. Case 1 GHz Gun

Scaling Laws:
3 GHz → 1 GHz

$$E_0 = 100\,MV/m \sqrt{\frac{1\,GHz}{3\,GHz}} = 58\,MV/m$$

$$r = 10\,mm \times 3 = 30\,mm$$

$$Q = 14\,nC \times \left(\frac{30\,mm}{4\,mm}\right)^2 \frac{58\,MV/m}{100\,MV/m} = 450\,nC$$

$E_z / E_0 = 0.31$, $\sigma = Q / \pi r^2 = 16\,nC/cm^2$

Large bunch radius r must be compressed by solenoid magnet.

For smallest τ, J_{max}(RCL) is slightly greater than J_{max}(LW) ; for greatest τ, it is smaller. These discrepancies have quite different origins.

For smallest τ, it may be explained by the limited transverse extension of the studied photoemited beam (for τ=20 ps, and E_0=30 MV/m, the pulse length is $L(\tau)$=1 mm, while the beam radius, for S=1 cm^2, is 5.6 mm), which contrasts with the theoretically unlimited extension of the planar diode. J_{max}(LW)/J_{max}(RCL)$\rightarrow$1 when $\tau\rightarrow0$ (and $L(\tau)/R\rightarrow0$).

For the greatest τ, the discrepancy is due to the retardation effects : the last emitted photoelectrons no longer experience the electromagnetic influence of the electrons located in front of the beam pulse. Beyond some pulse duration τ, the maximum current density no longer decreases at all.

At the end, Figure 4 shows the maximum field-photoemitted charge Q_{max}, for various E_0, compared to J_{max}(RCL).$S.\tau$.

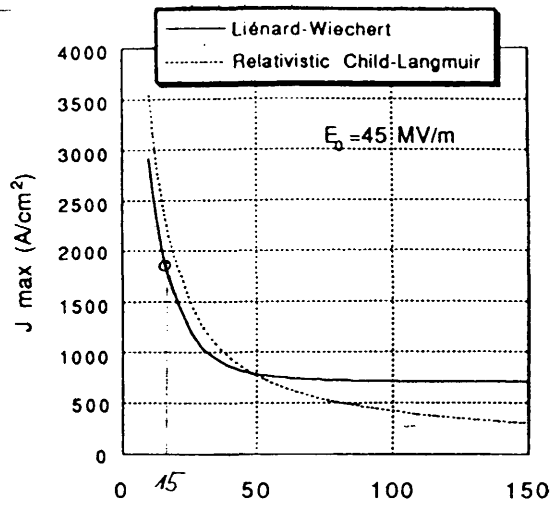


Figure 3

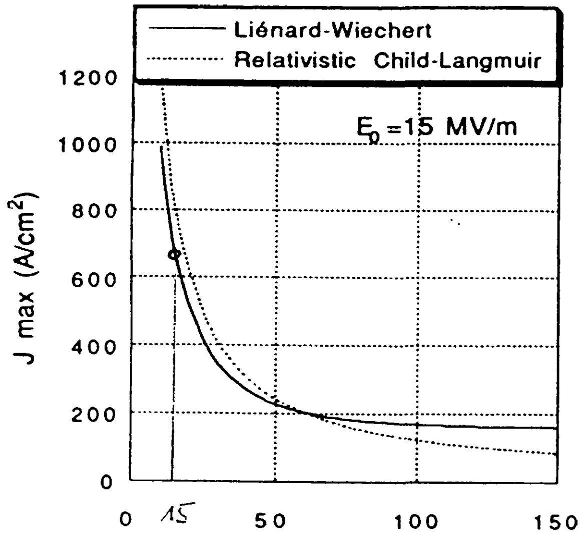


Figure 1

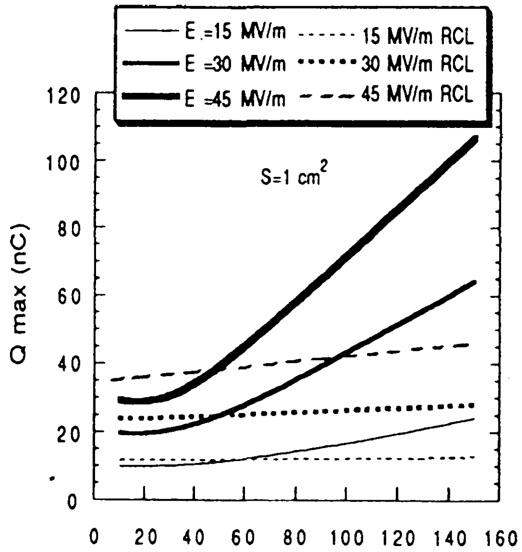


Figure 4

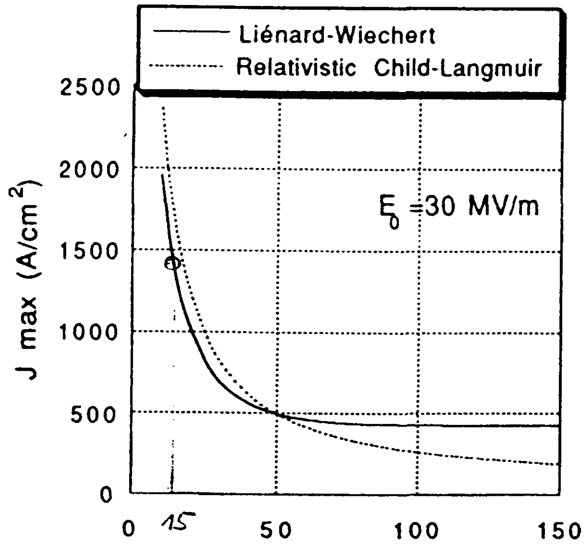


Figure 2

5. REFERENCES

[1] J.-M. Dolique and J.C. Coacolo, "Relativistic Acceleration and Retardation Effects on Photoemission of Intense Electron Short Pulses", in 1991 IEEE Particle Accelerator Conference Proceedings, San Francisco, USA, May 1991, pp.233-235

[2] R. Dei-Cas, S. Joly and the FEL group, "Overview of the FEL activities at Bruyères-le-Châtel", in 1990 Int. Conf. on Free Electron Lasers, Paris, France, September 1990

E_0 [MV/m]	σ [nC/cm^2]	σ/ε_0 [MV/m]
15	10	11
30	20	23
45	30	34

$\sigma_{max} \leq 0.75\, \varepsilon_0 E_0$ for $\tau < 25$ps

$\underline{Q = 10\,nC}$, $r_0 = 3\,mm$, $\sigma_t = 6.38\,ps$, $E_1 = 100\,MV/m$, $E_2 = 70\,MV/m$,

$\varphi_1 = 30°$, $\varphi_2 = -60°$, $B_0 = 0.30\,T$.

z / mm	26.5	77.5	153.5	203.1	252.9	302.7	352.7	402.6
l_b / mm ($2\sigma_b$)	3.0	3.1	3.1	3.1	3.2	3.2	3.2	3.2
r_b / mm	2.9	3.9	5.9	6.1	5.2	4.4	3.8	3.2
$r_{b\,max}$ / mm	4.1	5.8	8.8	9.1	7.8	6.6	5.7	4.9
ε_N / mrad·mm	38.4	49.5	61.7	61.3	61.1	72.6	74.2	74.4
γ	4.0	9.1	9.1	9.0	12.3	15.6	19.1	22.5
$\frac{\Delta\gamma}{\gamma}$ / %	2.8	0.6	0.6	0.5	0.4	0.4	0.4	0.4
Divergence / mrad	68.5	30.0	11.1	2.4	- 3.1	- 4.6	- 5.3	- 5.8
	gun		drift / sol.		booster			

Table 1

$\underline{Q = 50\ nC}$, $r_0 = 6\ mm$, $\sigma_t = 6.38\ ps$, $E_1 = 120\ MV/m$, $E_2 = 70\ MV/m$

$\varphi_1 = 20°$, $\varphi_2 = -70°$, $B_0 = 0.35\ T$.

z / mm	26.4	77.5	153.4	203.1	252.9	302.7	352.6	402.5
l_b / mm ($2\sigma_b$)	3.2	3.3	3.3	3.4	3.4	3.4	3.4	3.4
r_b / mm	4.9	6.3	9.2	9.1	7.6	6.3	5.3	4.4
$r_{b\,max}$ / mm	7.3	9.6	14.2	14.0	11.8	9.9	8.4	7.1
ε_N / mrad·mm	100.9	160.8	192.4	113.6	126.3	147.2	161.9	179.4
γ	4.2	10.1	10.1	10.0	13.0	16.2	19.4	22.6
$\frac{\Delta\gamma}{\gamma}$ / %	4.4	0.9	1.2	1.4	1.0	0.9	1.0	0.9
Divergence / mrad	105.1	42.0	48.6	− 3.5	− 9.4	− 10.6	− 11.1	− 11.9

gun | drift / sol. | booster

Table 2

$\underline{Q = 150\ nC}$, $r_0 = 10\ mm$, $\sigma_t = 6.38\ ps$, $E_1 = 120\ MV/m$, $E_2 = 70\ MV/m$

$\varphi_1 = 10°$, $\varphi_2 = -80°$, $B_0 = 0.35\ T$.

z / mm	31.7	83.6	159.0	208.7	258.5	308.4	358.3	408.2
l_b / mm ($2\sigma_b$)	3.9	4.2	4.4	4.5	4.5	4.6	4.6	4.6
r_b / mm	6.0	6.3	8.8	8.6	7.2	6.1	5.1	4.4
$r_{b\,max}$ / mm	8.9	10.1	14.1	14.1	12.3	11.0	9.8	8.8
ε_N / mrad·mm	256.8	236.1	288.0	461.7	484.2	567.9	598.5	613.6
γ	4.8	10.5	10.5	10.5	13.3	16.3	19.3	22.3
$\frac{\Delta\gamma}{\gamma}$ / %	10.6	6.6	5.7	5.9	6.6	6.7	6.5	6.4
Divergence / mrad	89.6	41.0	6.8	− 9.1	− 8.2	− 9.5	− 10.0	− 10.15

gun   drift/sol.   booster

Table 3

MAFIA

FRAME: 5 15.07.93 - 09:21:48 VERSION(VRS31I)

150 uC

GUN2D6CHCTS2.DRC

CTF 5 1/2 CELL GUN
FIELD: GUN - 120 MV/M, SEC2 - 70 MV/M, BUNCH CHARGE - 150 NC,
PHASE1 - 10 DEG, PHASE2 - -80 DEG, PULSE LENGTH - 15 PSEC (FWH

NO UNIT DEFINED FOR THIS FIELD

P--:3.10

#ARROW

COORDINATES/M
FULL RANGE / WINDOW
R(.0000, .045000)
(.0000, .045000)
Z(.0000, .47200)
(.0000, .47200)

SYMBOL - UNDEF/1/*

MAX ARROW - .00000E+00

-MESHLINE: 1

CUT AT /M: .0000E+00

INTERPOLATE - 0
TIME STEP - 2
ITIME - 1038

R

Z

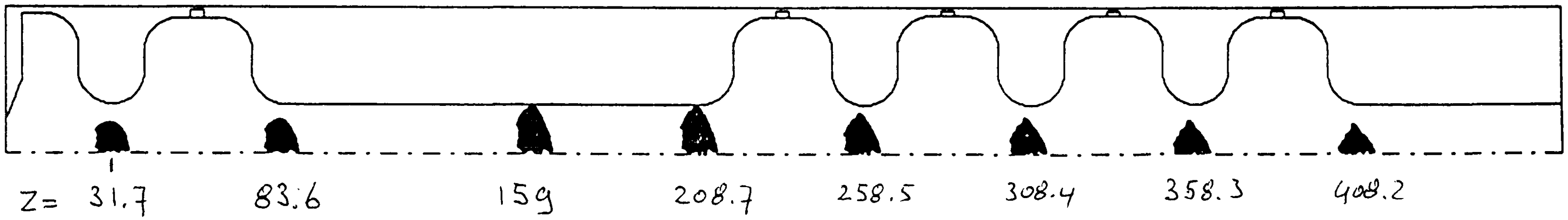


Fig 1