Pulses inside the pulse: a mode of operation of RF photo gun


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For PRR=10Hz,  P loss=61.8 kW, T iris ~ 72°C
T pulse = 119°C (T pickup ~ 148°C)

No way to increase pulse length, no way for quasi CW operation

Alternative:
SC GUN, DC GUN, 20 K cold GUN, Multi harmonics GUN or GUN in PiP mode

For acceleration of one electron bunch in the GUN, we need 60 M/m only for time at most of 1.5 nS.
$BDR \sim E^{30} \times \tau^5$

"Pulses inside the Pulse" mode

For RF gun $BRD < (1/\text{week})$


Power losses reduction $= \frac{T_{p-p}}{\left(\frac{T\text{ filling}}{2} + T\text{ lasing} + \frac{T\text{ decay}}{2}\right)}$
What we need, to operate GUN in the PiP mode

Klystron
~10 MW pulse power, ~ 150 KW average power, bandwidth about 3 MHz

Modulator
Pulse repetition rate ~ few kHz

Laser
Average repetition rate during 1 mS ~ 1 MHz, Max 5 MHz during one RF pulse ~ 4 µS, RF pulses repetition rate ~ 50 kHz during 1 mS, 10Hz

Modification of software and electronics
GUN#5 in normal mode, P klystron 5 MW
\(Q_0 = 25000, Q_I = \sim 12000, \quad \tau = 3 \ \mu S\).
For 50 MV/m \(P_0 = 4.3\ \text{MW}, \ T\ \text{filling} \sim 15 \ \mu S\)

GUN#5 in PIP mode, P klystron 10 MW
For 50 MV/m (\(P_f/P_0 = 2, \ T\ \text{filling} \sim 3 \ \mu S\))

**Design of new RF Gun**

\(T\ \text{filling} \sim 1 \ \mu S, \ P_f \sim 20 \ \text{MW}\)
We have three types of MBK

- 117kV, 140 A, efficiency > 60%
- P impulse max = 10.5 MW
- P rf average = 150 kW
- P collector average = 300 kW
- P* body with RF = (2.8 - 4.5) kW
- Bandwidth > 3 MHz

BRD ~ 1/(three weeks), 10 Hz, 1.5 mS, full power
Modulator

Linear type modulator

- SLAC, KEK, ...
- $T_{rise} \approx 0.4 \ \mu S$
- $T_{hv} \ 1.6 - 4 \ \mu S$
- $I_{max} \approx kA$
- $PRR \approx kHz$
- Low voltage P/S

Direct hard-switch modulator

- DESY, Diversified Technologies, Inc., Toshiba factory test stand, ...
- $T_{rise} \approx 0.6 \ \mu S$
- $T_{hv} \ 2.5 - 10000 \ \mu S$
- $I_{max} \approx 100 - 200 A$
- $PRR \approx kHz$
- High voltage P/S
PiP mode study at FLASH with existing components

GOAL of first run:
*Examination of the hardware and software.*
*Optimization of the RF pulse shape.*

For pulse shape generation an user tables was used
In feed-forward mode of operation
“pulses inside the pulse” mode first test at FLASH

27.08.2009

46 bunches, (50kHz), P forward = 4.0MW about 1 hour of operation without any interlock!
Dark current study

P klystron 3.7 MW

P klystron 4.0 MW
Wave shapes of reflected power and phase of RF gun, 900 µS pulse
Second run 16/01/2011

Normal mode, gun set points:
Pf = 3.70, Flattop = 350 µS,

New DOOCS panel for PiP mode

Table generation (FF,SP, GT) was extended
Feedback loop can be closed
RF Gun in PIP mode

RF Gun in pulses inside the pulse mode: 40 pulses with 10us RF on and 10us RF off time. Feedback is on with gain of 5.

Graphs showing amplitude and phase over time.
25.6.2011
The first SASE signal (µJ) in FLASH in PiP mode for a 20 pulse bunch train.

40 kHz, up to 60µJ, GMBD-B, 0.7nC, beam energy: ~ 960MeV, wavelength: ~ 7.01nm. SASE intensity distribution is flat.
Summary and Plans

In June 2011 we have successfully run RF Gun in PiP mode with SASE conditions and feedback loop closed. RF pulse structure in the gun: full pulse length – 820 µs with 33 RF pulses with 16 µs RF on and 9 µs RF off time. Up to 23 bunches with SASE, number of bunches are limited by RF pulse length at ACC2/3.

With PiP mode in the FLASH on the existing RF GUN we can expect to have:
- Single beam pulse
- Two beam pulses, separated up to 1000 µS
- Three beam pulses, separated on 500 µS
- .......
- Forty beam pulses, separated on 25 µS

In the next FLASH study run, we would like to continue the PiP mode study:
- new software and hardware for feedback regulation
- optimization of RF pulse shape
- up to now we don’t have a problem with a breakdown in the GUN in PiP mode, we have a possibility to reduce a filling time by using a new 10 MW klystron at GUN RF station.
- long time test
- lasing in PiP mode
Thank you for attention!