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

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LLRF Workshop, Hamburg DESY
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- *What we need, to operate RF Gun in the PiP mode*
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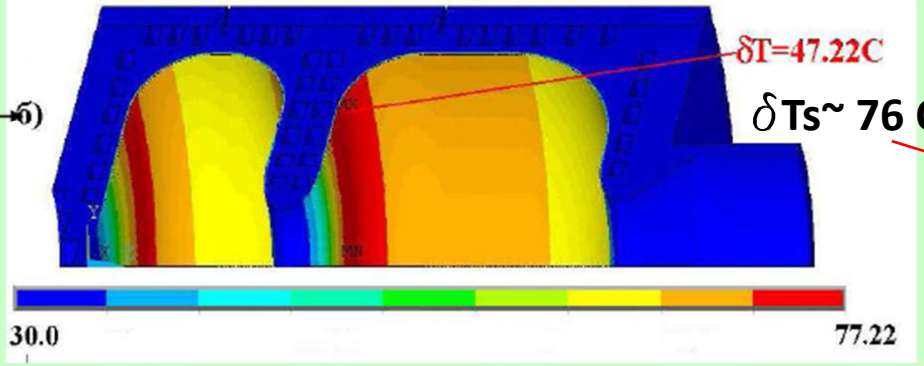
Why we need a PiP mode at RF GUN

Development of RF Gun cavity with improved parameters.

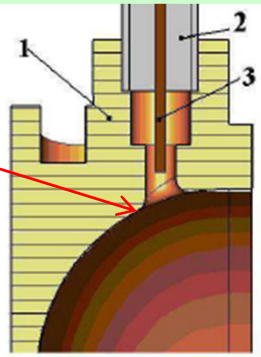
K. Floettmann, Yu. Kalinin**, M. Krasilnikov*, V. Paramonov**, A. Skasyrskaya**, F. Stephan**

Pi=6.18 MW
Q=25750

Gun 5 → 6)



δTs~ 76 C



The surface temperature rise after RF pulse τ=1 ms, Ec=60 MV/m.

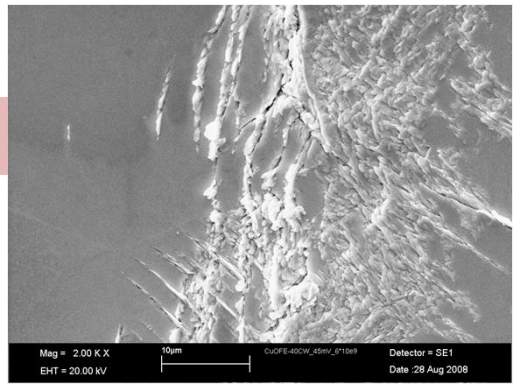
For PRR=10Hz, P loss=61.8 kW, T iris ~ 72° C
T pulse = 119°C (T pickup ~ 148° C)

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.



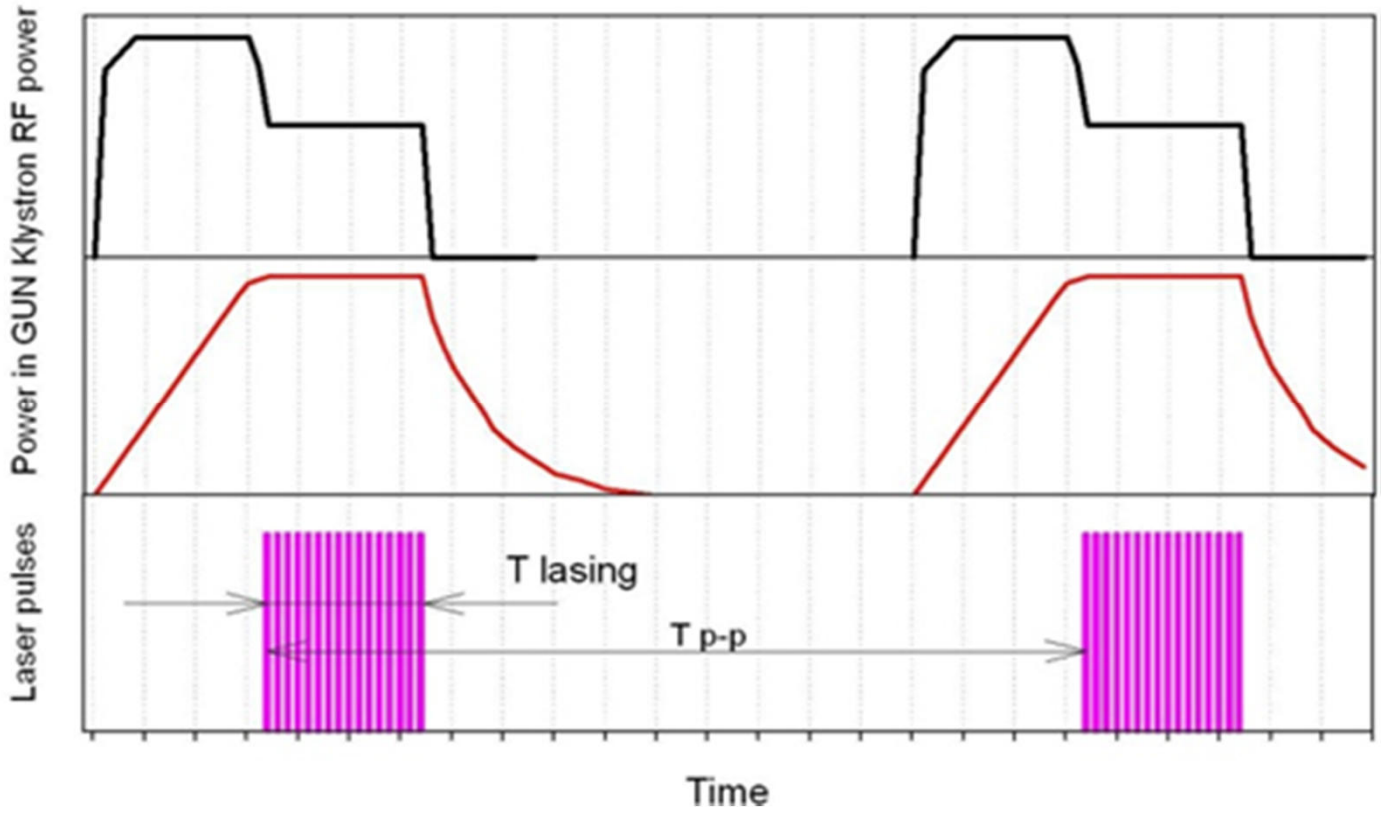
Breakdown & Pulsed Surface Heating Studies: Thermal Fatigue behavior versus Grain Orientation
by Markus AICHELER (Ruhr-Universitaet Bochum)

$$BDR \sim E^{30} * \tau^{5}$$

"Pulses inside the Pulse" mode

From A. Grudnev and al. Phys. Rev. ST Accel. Beams 12, 102001 (2009)

For RF gun BRD < (1/week)



Power losses reduction = T p-p / (T filling/2 + T lasing + T decay/2)

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

Qo = 25000, Ql = ~ 12000, > τ = 3 μS.

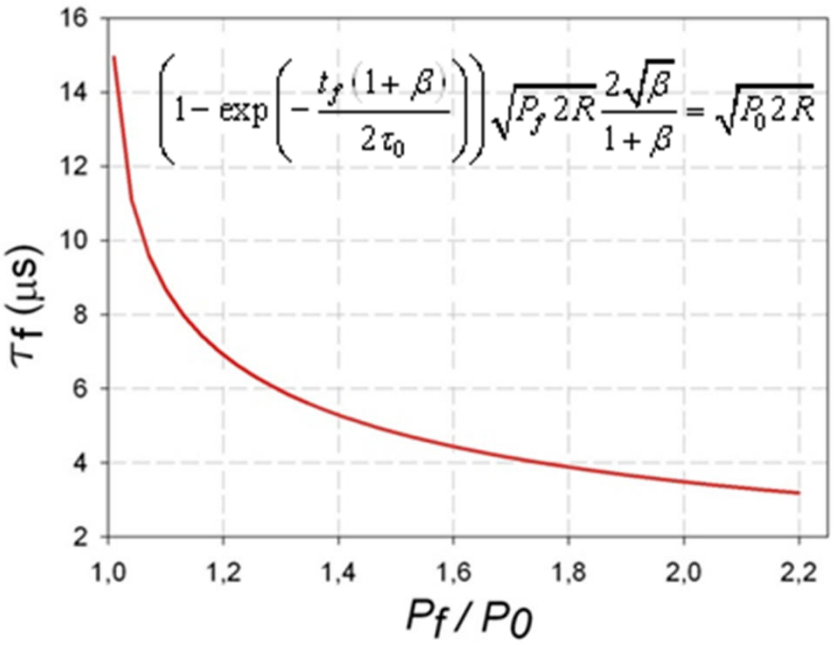
For 50 MV/m Po = 4.3 MW, T filling ~ 15 µS

GUN#5 in PIP mode, P klystron 10 MW

For 50 MV/m (Pf/Po = 2, T filling ~ 3 µS)

Design of new RF Gun

T filling ~ 1 µS, Pf ~ 20 MW



Total time to fill the gun cavity to the design gradient versus power ratios. β = 1.

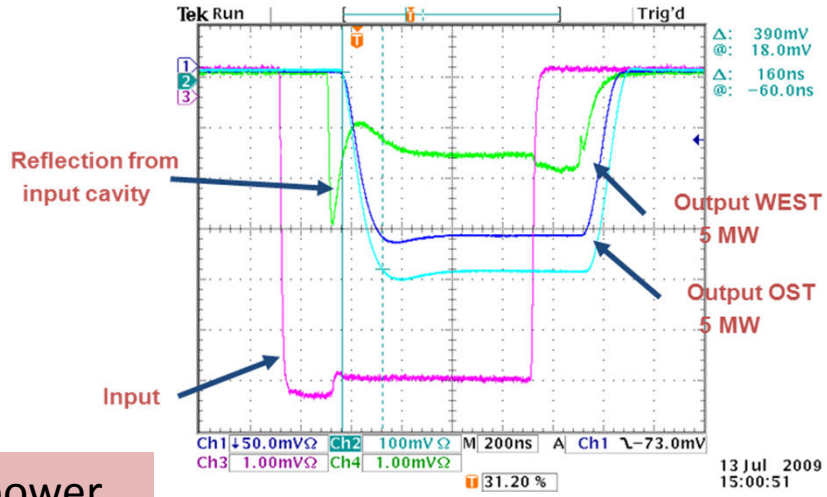
RF power sources

We have three types of MBK

117kV, 140 A, efficiency > 60%

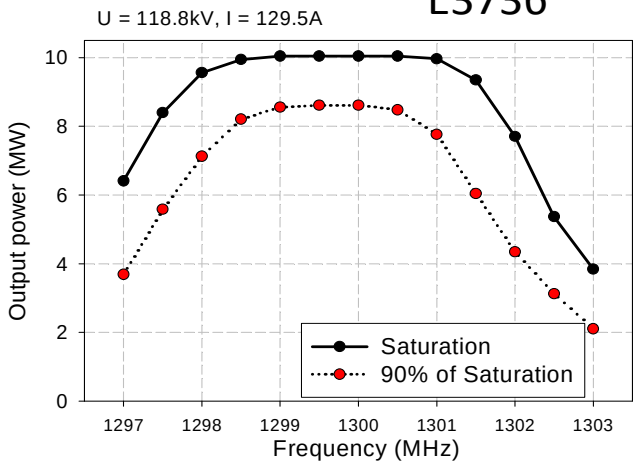
P impulse max	10.5 MW
P rf average	150 kW
P collector average	300 kW
P* body with RF	(2.8 - 4.5) kW
Bandwidth	> 3 MHz

Toshiba MBK, short RF pulse

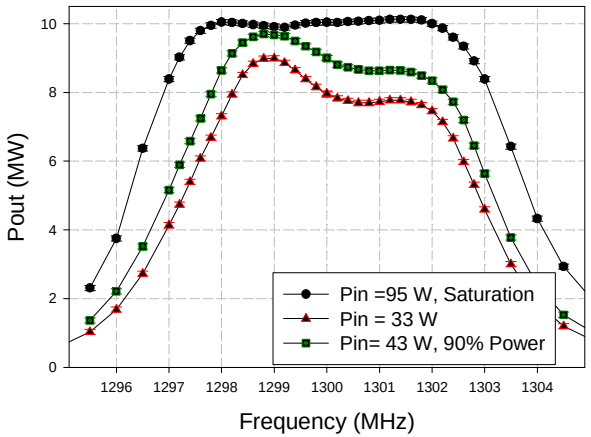


BRD ~ 1/(three weeks), 10 Hz, 1.5 mS, full power

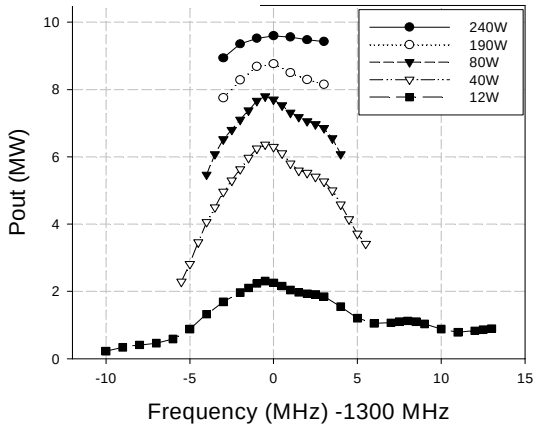
E3736



VKL 8301

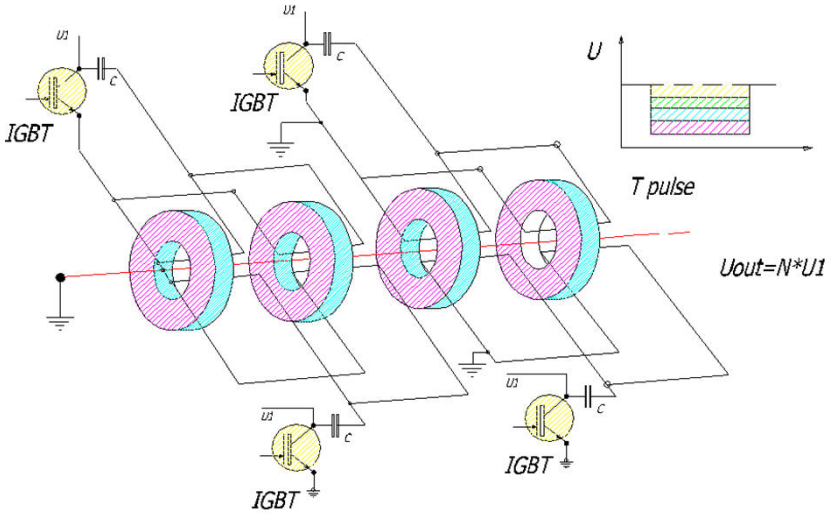


TH1802



Modulator

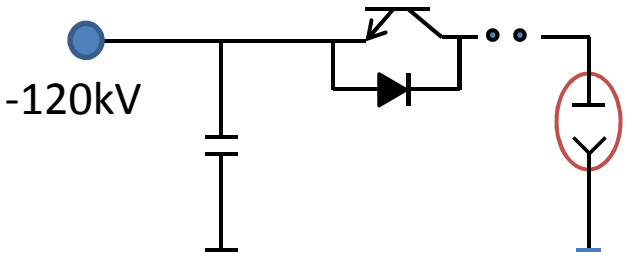
Linear type modulator



SLAC, KEK,..

Trise ~ 0.4 μS
T hv 1.6 – 4 μS
Imax ~ kA
PRR ~ kHz
Low voltage P/S

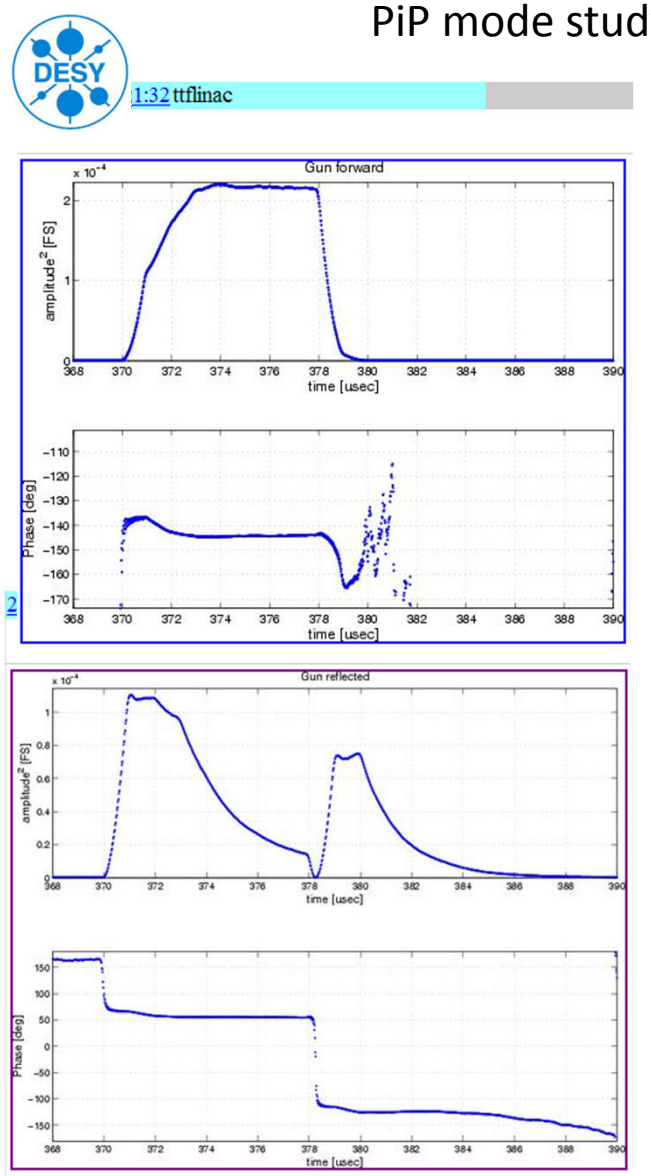
Direct hard-switch modulator



DESY, Diversified Technologies, Inc., Toshiba factory test stand,..

Trise ~ 0.6 μS
Thv 2.5 - 10000 μS
Imax ~ 100 - 200A
PRR ~ kHz
High voltage P/S

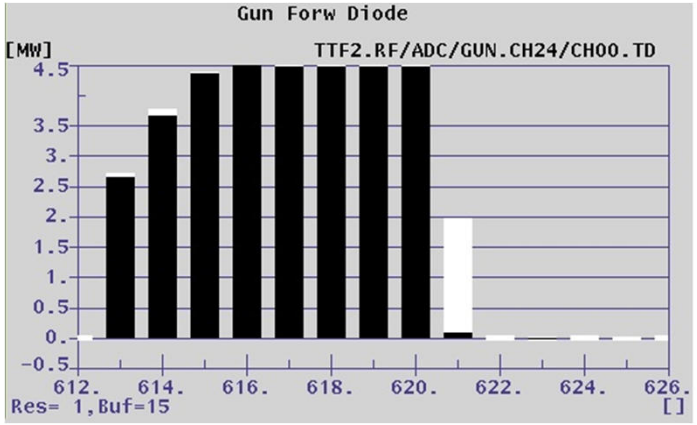
PiP mode study at FLASH with existing components

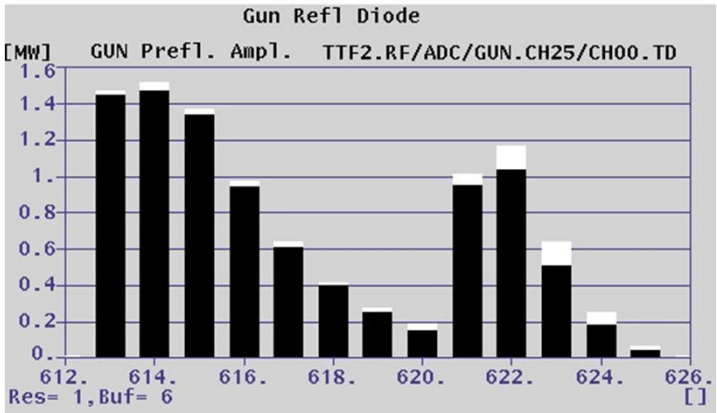


GOAL of first run:

Examination of the hardware and software.

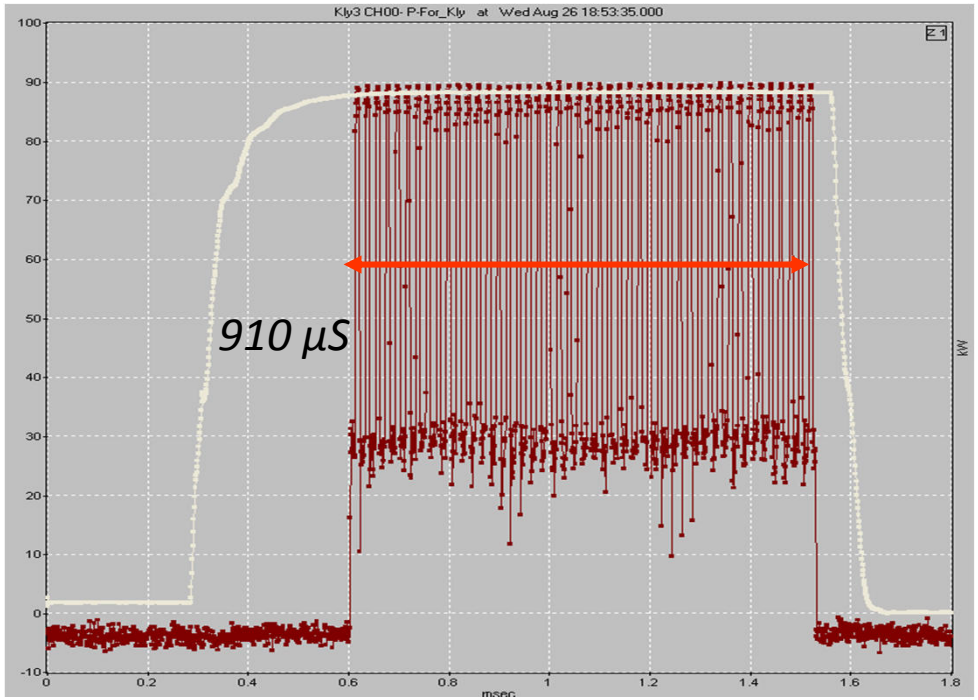
Optimization of the RF pulse shape.

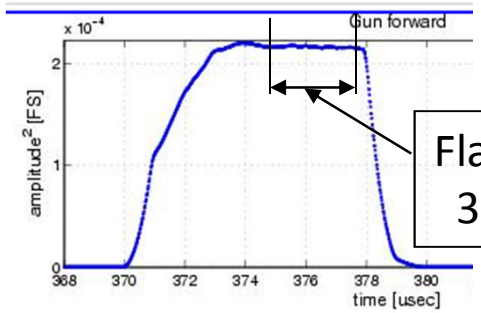


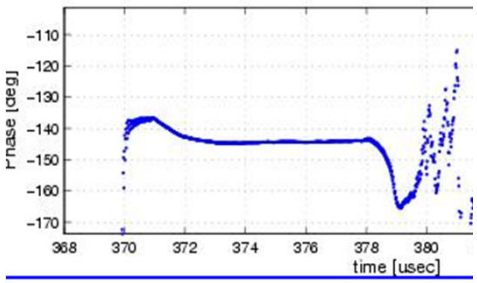


For pulse shape generation an user tables was used
In feed-forward mode of operation

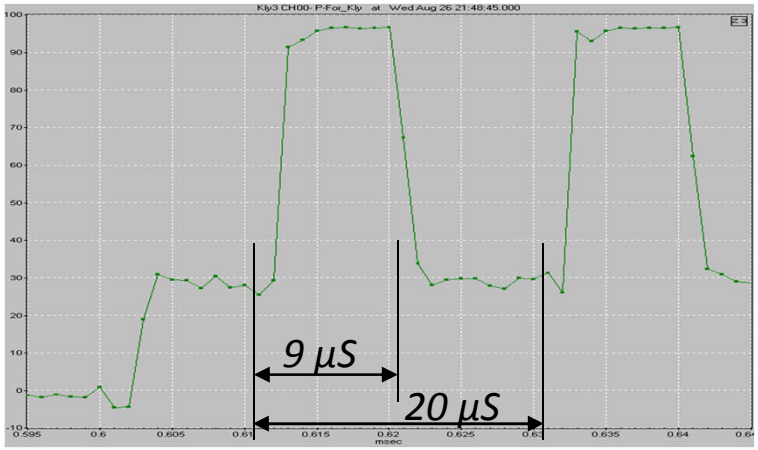
“pulses inside the pulse” mode first test at FLASH 27.08.2009





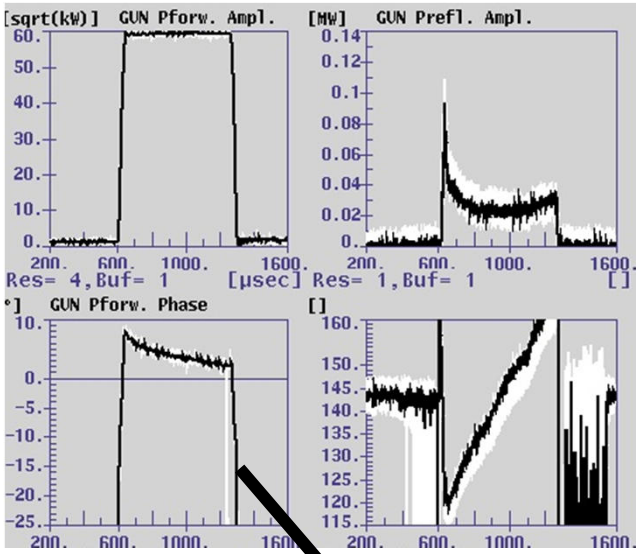


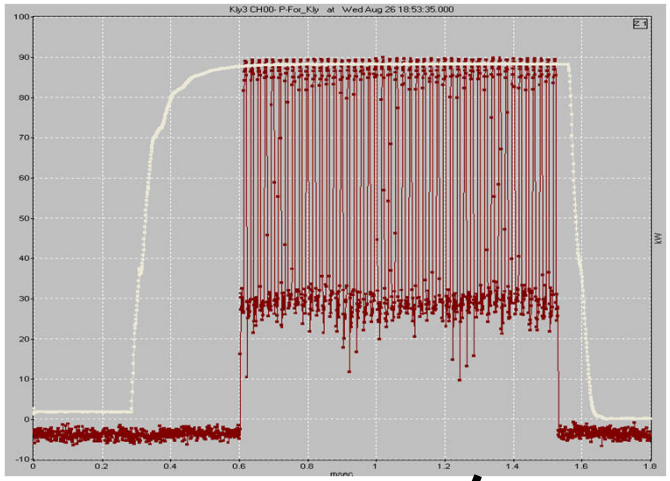
12.5 nS ADC



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

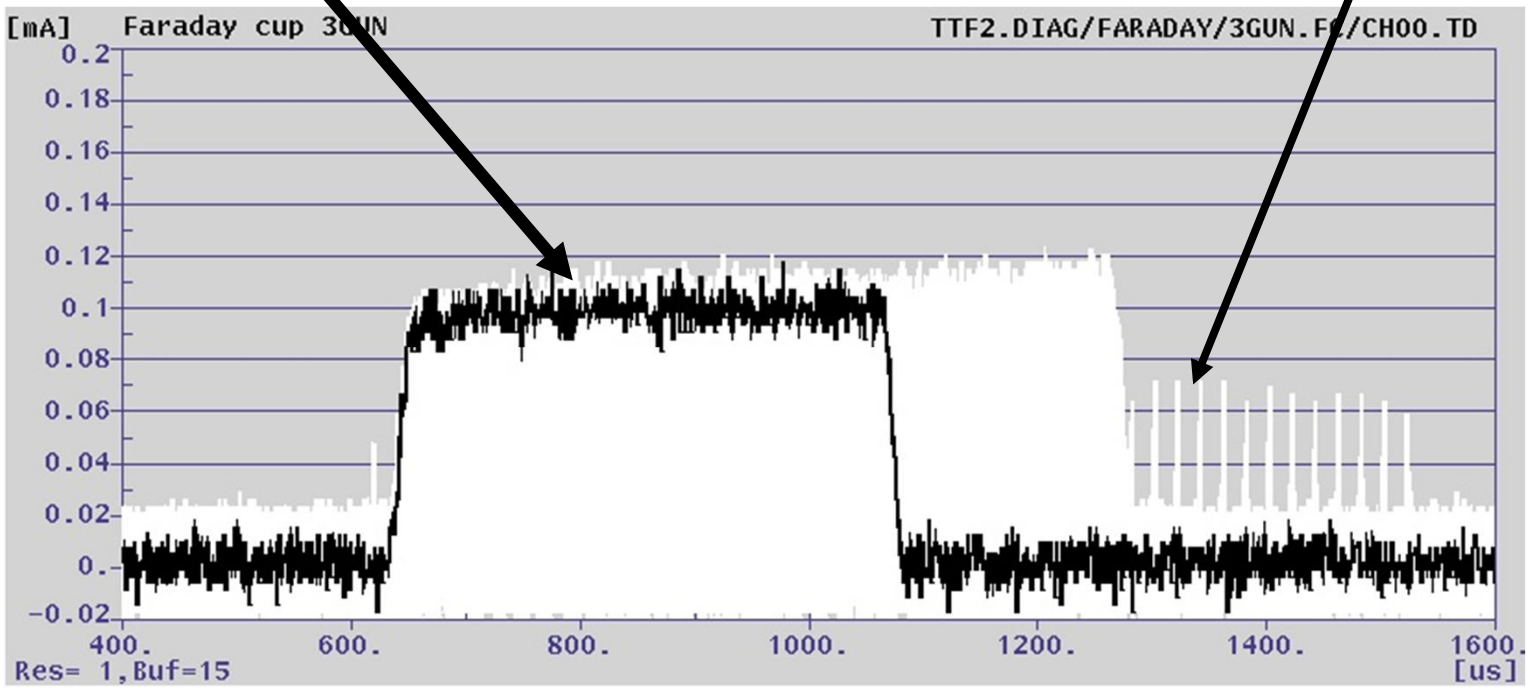
Dark current study

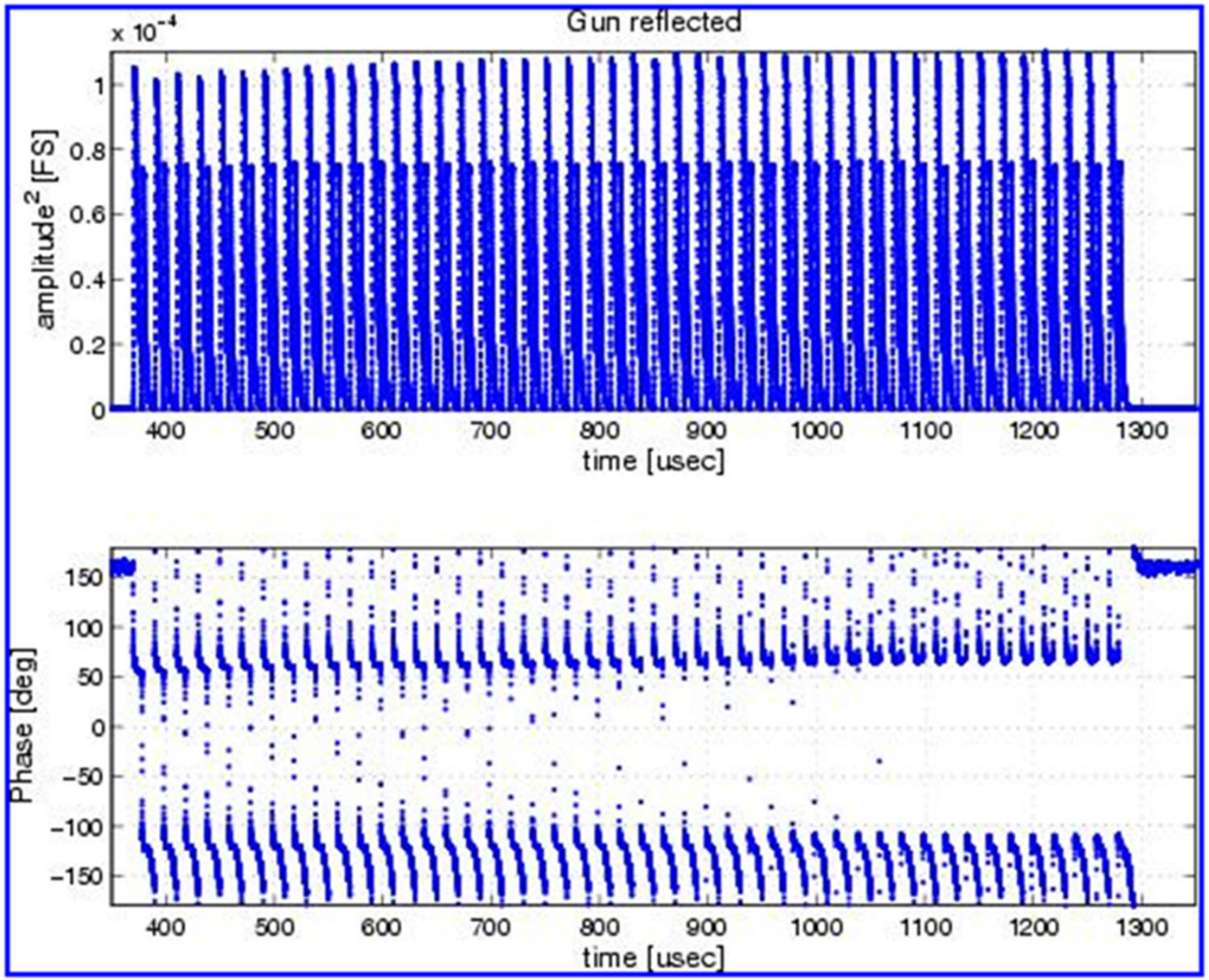




P klystron 3.7 MW

P klystron 4.0 MW

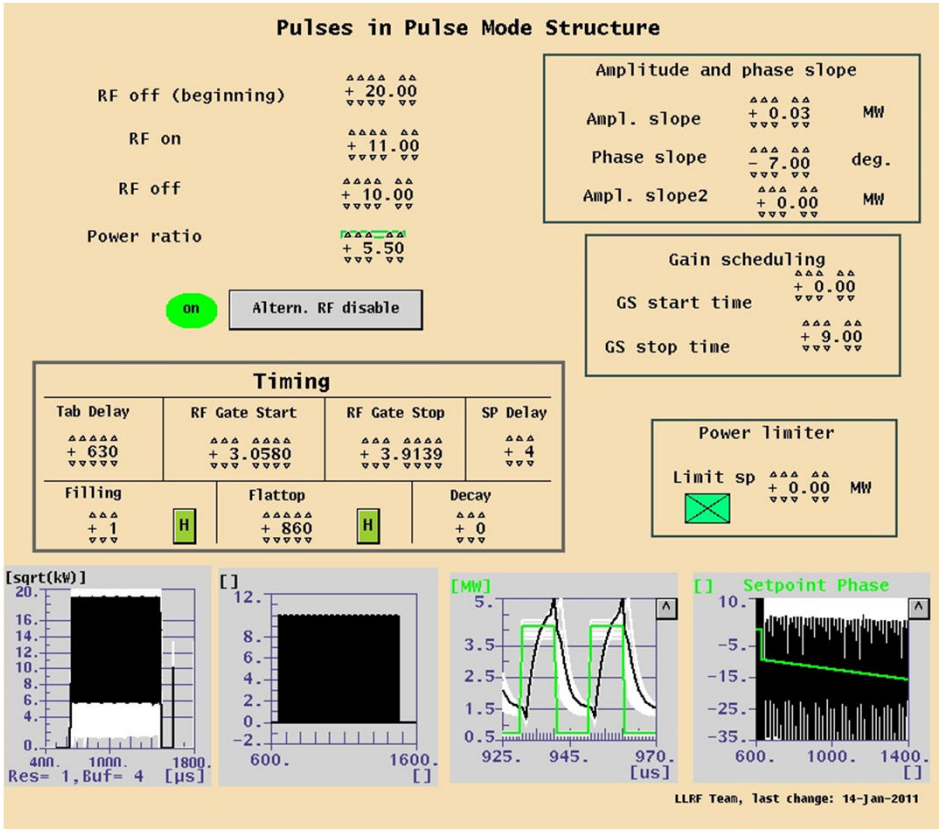




Wave shapes of reflected power and phase of RF gun , 900 µS pulse

Second run 16/01/2011

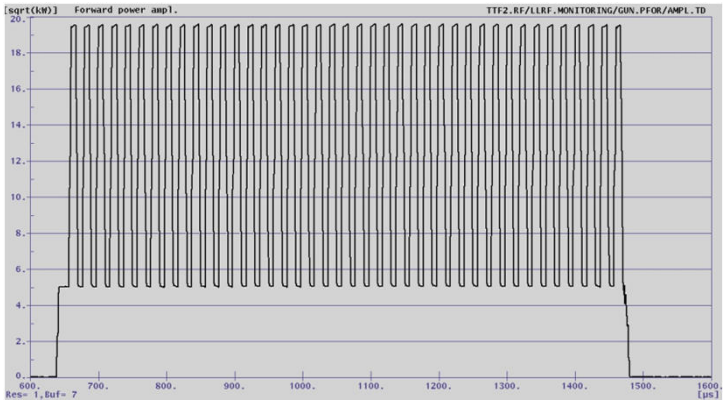
Normal mode, gun set points:
Pf = 3.70, Flattop = 350 µS,



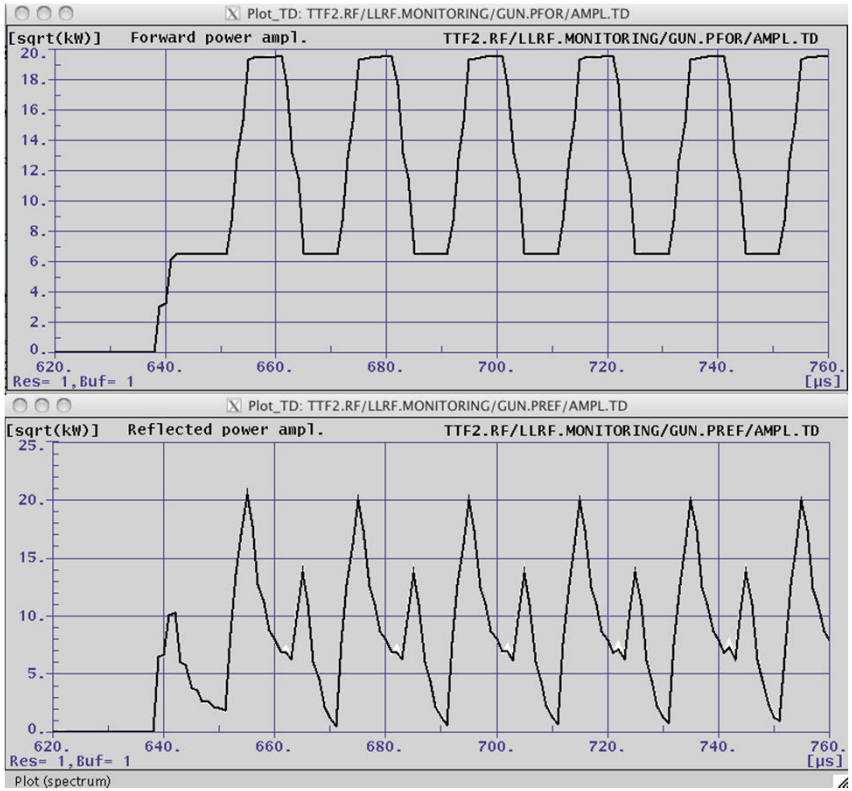
New DOOCS panel for PiP mode

Table generation (FF,SP, GT) was extended
Feedback loop can be closed

Gun mode



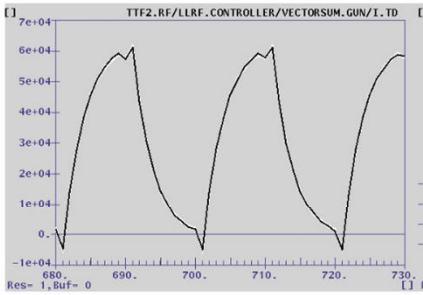
41 pulse, each 10μS, in total RF 800μS



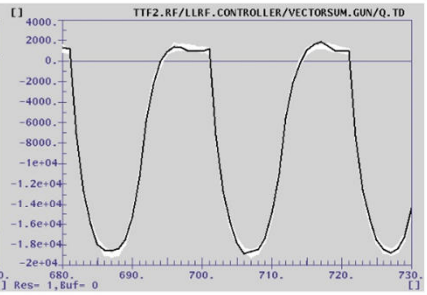
07.04.2011 11:19 Ayvazyan **RF Gun in PiP mode**

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.

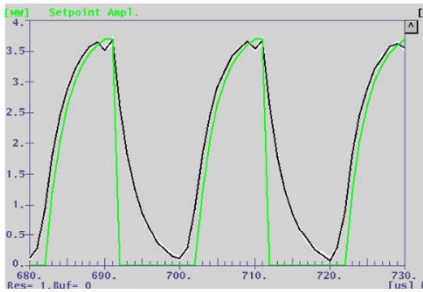
VECTOR SUM I



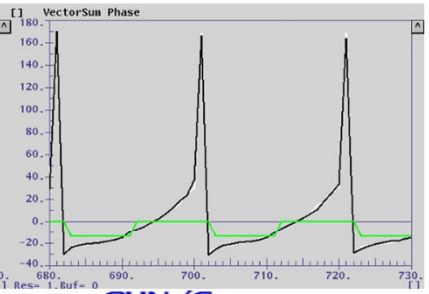
VECTOR SUM Q



VS & SP AMPLITUDE



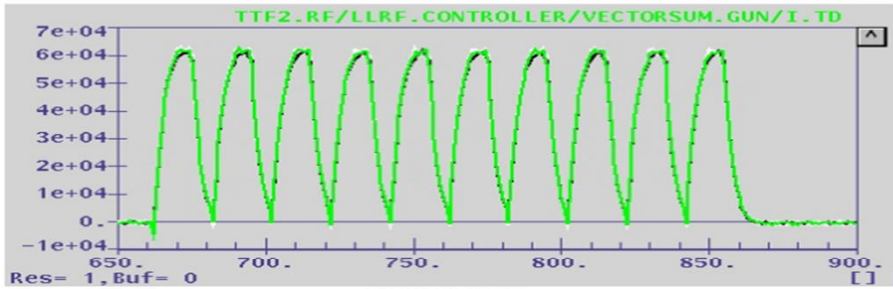
VS & SP PHASE

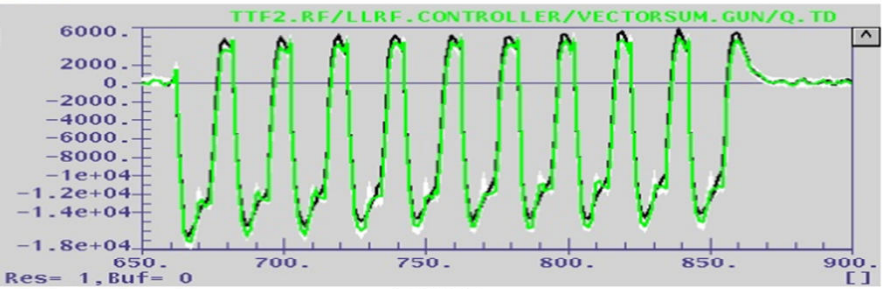


I

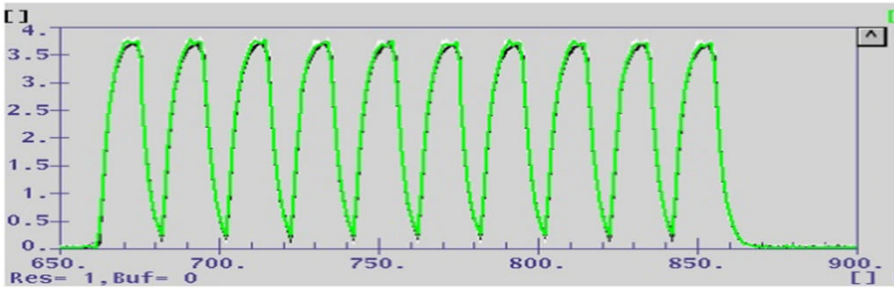
GUN/S

Q

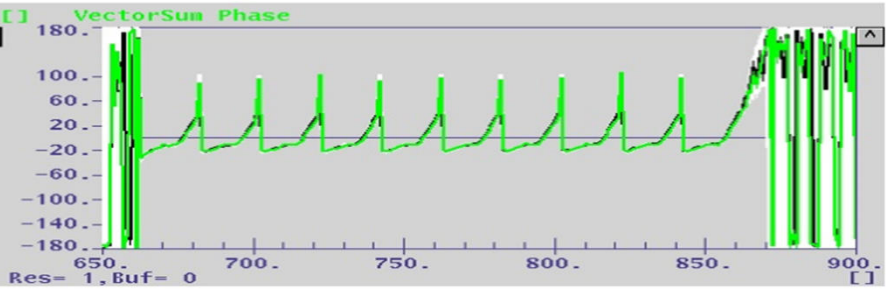




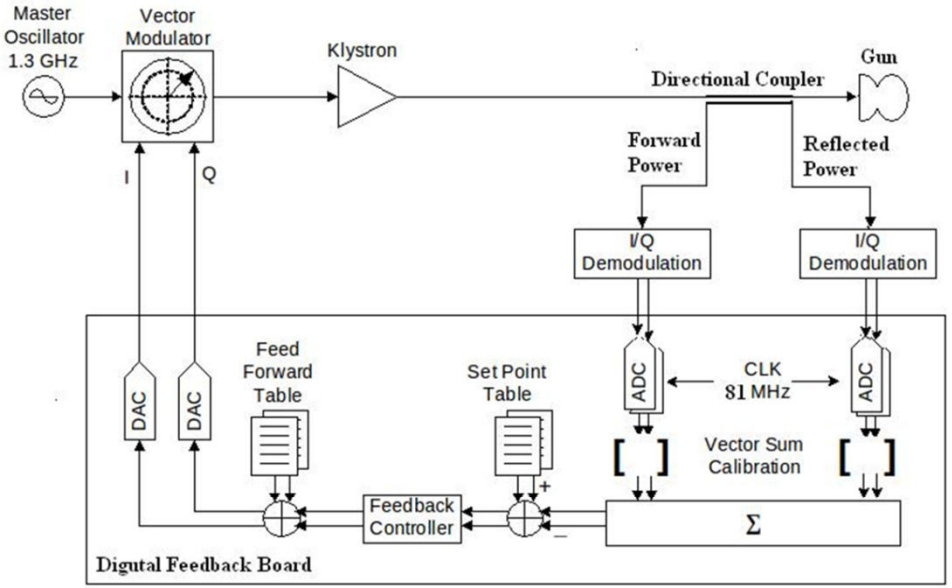
AMPLITUDE

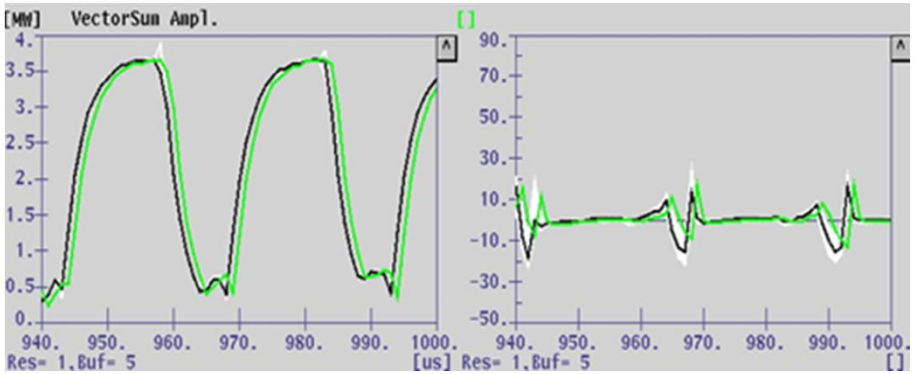


PHASE



RF Gun Control Algorithm Block Diagram

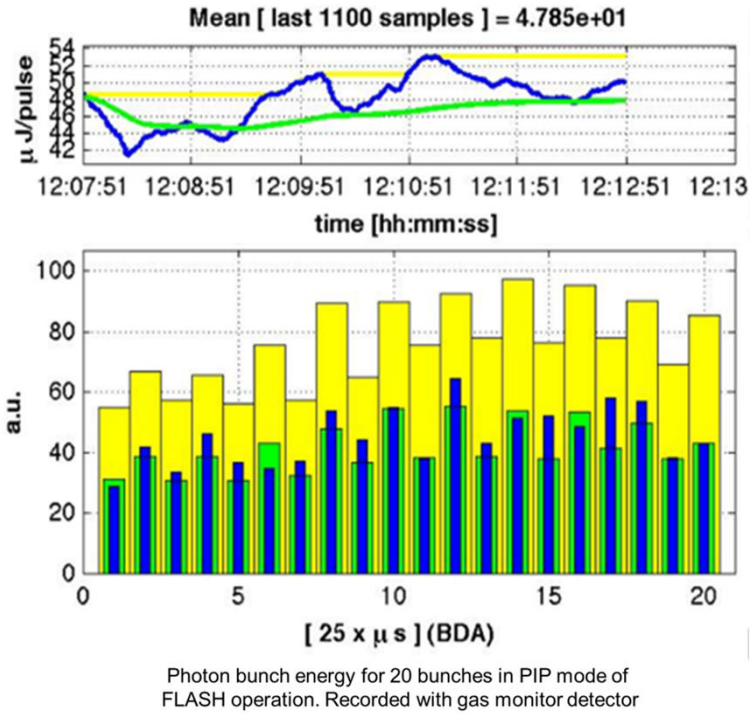




Set-point (green) and measured vector-sum (black) amplitude and phase signals

25.6.2011

The first SASE signal (µJ) in FLASH in PiP mode for a 20 pulse bunch train.



Photon bunch energy for 20 bunches in PIP mode of FLASH operation. Recorded with gas monitor detector

40 kHz, up to 60uJ, 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!