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Studies of Alternate Timing Mode Bunch Patterns

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Introduction

- Bunch patterns tested in machine studies Jun-Dec 2007 (per suggestions at Apr 30, 2007 meeting with pre-USIG):

No.	Name	Current in super-bunch (es), mA	Timing gap, μs	No. bunch trains	Train current, mA	Train length, ns	Gap btwn trains, ns	Criteria**
1	1+3x7	16	1.59*	3	28.7	17.0	221.6	Bunch train current $>16\text{mA}$, $\leq 17\text{ns}$
2	3+2x18	16, 8, 4	0.796	2	37	48.3	400.6	Timing gap min $0.8 \mu\text{s}$ for choppers, variable mA (not using trains)
3	3+3x7	16, 8, 4	0.796	3	24.7	17.0	221.6	Satisfies both #1 & #2

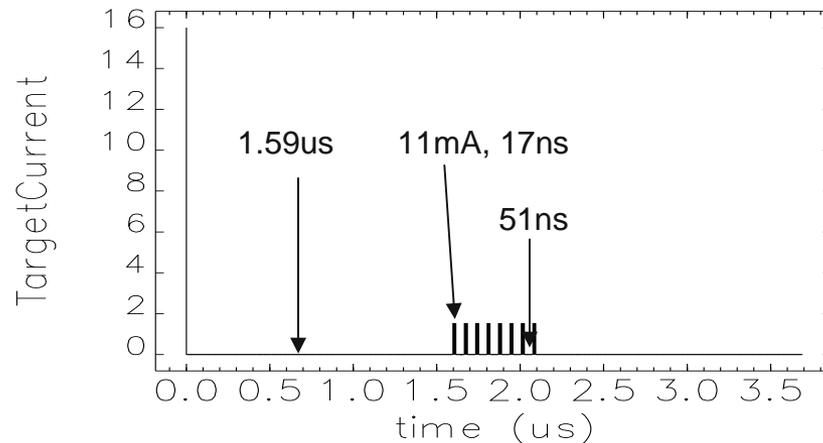
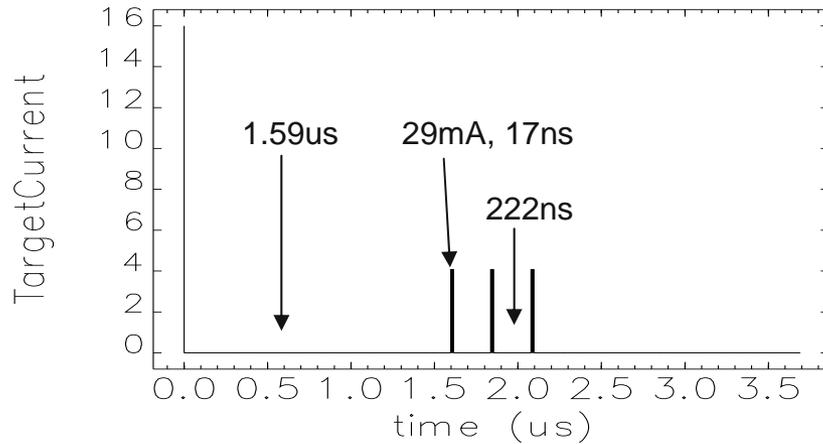
* Same as nominal 1+8x7 timing mode

** Thanks to J. Wang and L. Young

- Technical notes:

- L. Emery and K. Harkay, “Progress on Alternate Hybrid Bunch Pattern Study,” ASD/APG/2007-13 (October 29, 2007)
- V. Sajaev, “Sextupole optimization to reduce oscillation amplitude for non-injected bunches,” ASD/APG/2007-17 (December 13, 2007)

Status 1+3x7 and comparison with nominal timing mode



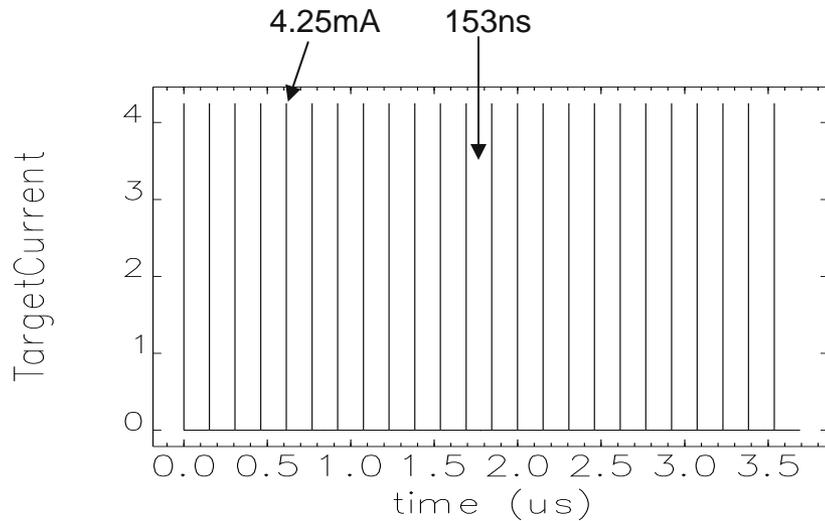
Test #1: 1+3x7

- High chromaticity
- Lifetime 150 min (22 bunches, 4.6 mA avg bunch current)
- Normal 60-s topup interval can't keep up 102 mA; 30-s topup okay
- Machine study with 32ID scheduled Sun, Jan 27, 2008

Nominal: 1+8x7

- High chromaticity
- Lifetime 300 min (57 bunches, 1.8 mA avg bunch current)
- Topup 60-s intervals

Comparison with standard 24 singlets



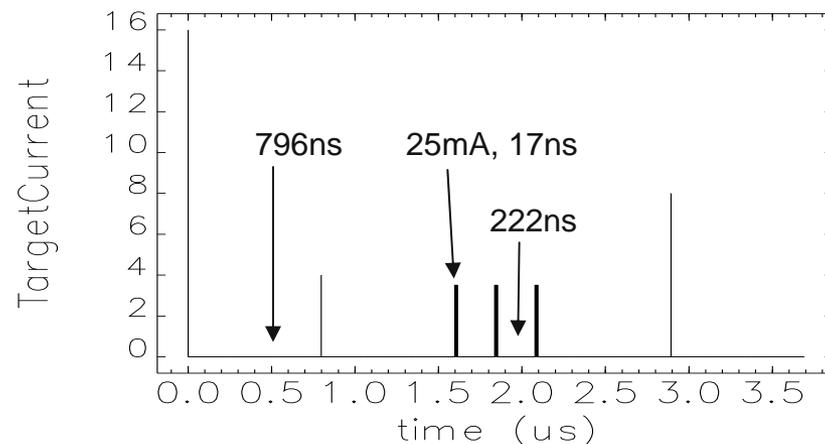
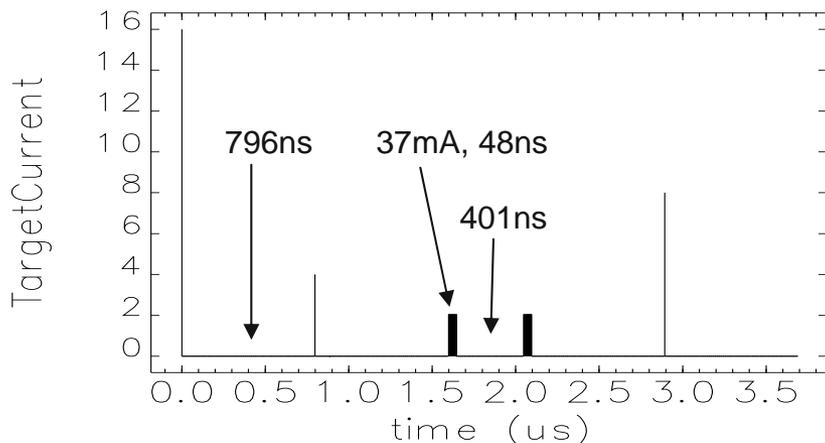
24x1

- Medium chromaticity
- Lifetime 390 min (24 bunches, 4.25 mA avg bunch current, lower than 1+3x7)
- Topup 120-s intervals

Lifetime vs. topup injection interval

- Lifetime is approximately inversely proportional to the bunch current
- 1+8x7 has more than twice as many bunches than 1+3x7, therefore the lifetime of 1+3x7 is almost half of that of the 1+8x7
- To maintain topup, injectors need to supply twice as much charge which can be done by either increasing the charge of the injecting bunch or by increasing frequency of the topup injections
 - Presently injectors deliver about 3 nC per shot (increase to 3.5 – 4 nC is possible and represents the safety margin required in case of injectors downtime)
 - PAR RF limits charge to 4.5 – 5 nC (limited power), booster injection efficiency start degrading quickly after 3 nC
 - The only reasonable way is to increase topup injection frequency by decreasing injection interval from 60 to 30 seconds or by making 2 injections every 60 seconds

Test patterns with 3 superbunches



Test #2: 3+2x18

- 37 mA bunch trains (filled one train up to 50 mA, but vacuum activity seen for two high-current bunch trains)

Test #3: 3+3x7

- We suggest this bunch pattern if it satisfies criteria for both #1 & #2

Both

- High chromaticity
- Problems injecting into three superbunches due to strong sextupoles in injection bump
- Potential lattice solution successfully tested, injection into test patterns TBD
- Lifetime/topup to be studied after injection issue solved

Conclusions

General question: Shall new timing mode replace old one or scheduled by request?
Replacement is preferable from machine operations point of view. Affected users should be polled, with final decision by Ops Directorate.

Test pattern #1: 1+3x7 (16 mA superbunch)

- Ready for studies with user; planned with 32ID for Jan 27 (startup period)
- Short lifetime requires Ops Directorate decision before it can be operational:
 - Reduce topup interval (30 s), or
 - Increase to 2 injection shots per topup, or
 - Study how to increase injection charge (would require time and funding),
 - Reduce superbunch current until lifetime sufficient to retain 60-s topup intervals (requires machine study and input from affected users)

Test pattern #2: 3+2x18 or #3: 3+3x7 (16, 8, 4 mA superbunches)

- Topup injection into three superbunches impeded by nonlinearity introduced by strong sextupoles. Potential lattice solution tested, actual topup injection into bunch patterns to be tested in machine studies.
- Test pattern #3 suggested as a compromise if meets criteria for users proposing both #1 and #2. Maintaining a single (alternate) timing mode preferred as it reduces operations bookkeeping.