On DR beam loading change during extraction in alternating pulse operation (For low energy operation of ILC)

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Kiyoshi Kubo (KEK)

# Introduction (what is problem?)

- For low energy experiment of ILC, alternate pulse operation is proposed.
  - one pulse of e- beam is used for e+ production only
  - next pulse is for collision only
- e+ ring will be empty after extraction.
  - Large (and fast) change of beam loading during extraction and injection
  - Extracted beam should be stable.
    - Beam loading change should be compensated by RF control
    - Need too much power (?)

Study was done for 6 km ring. Results will be similar for 3 km ring with half bunches.

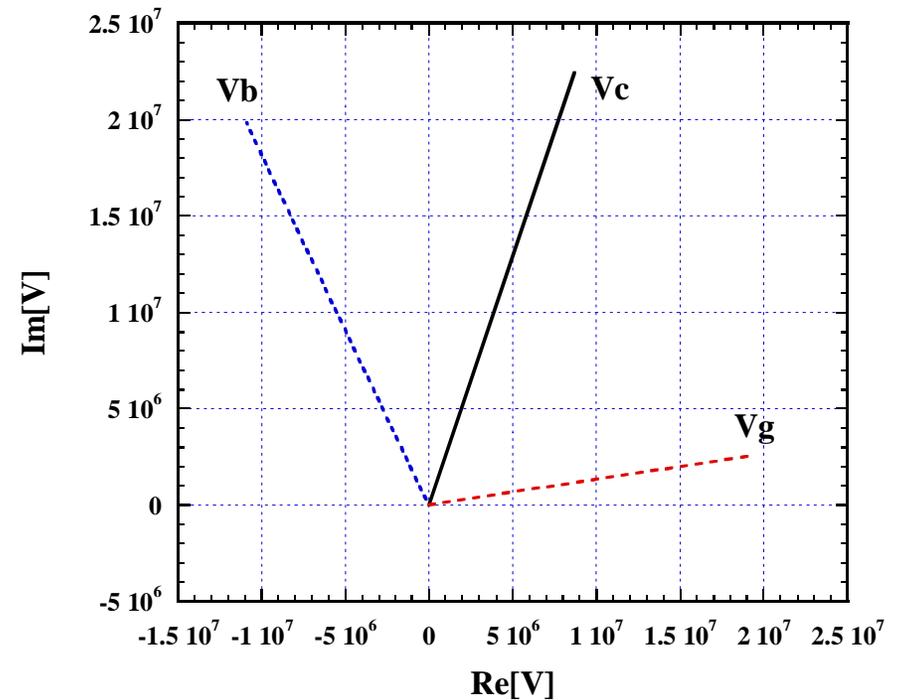# Normal mode (RDR parameter)

Choosing loaded Q

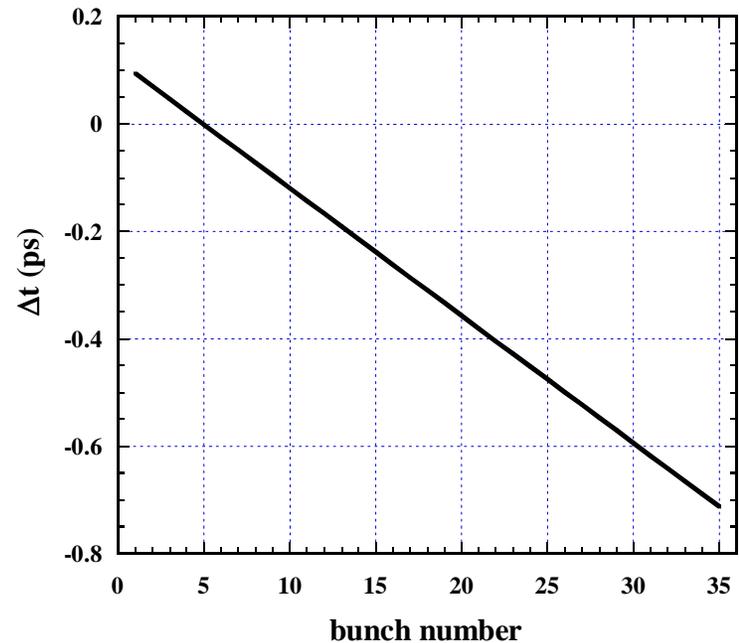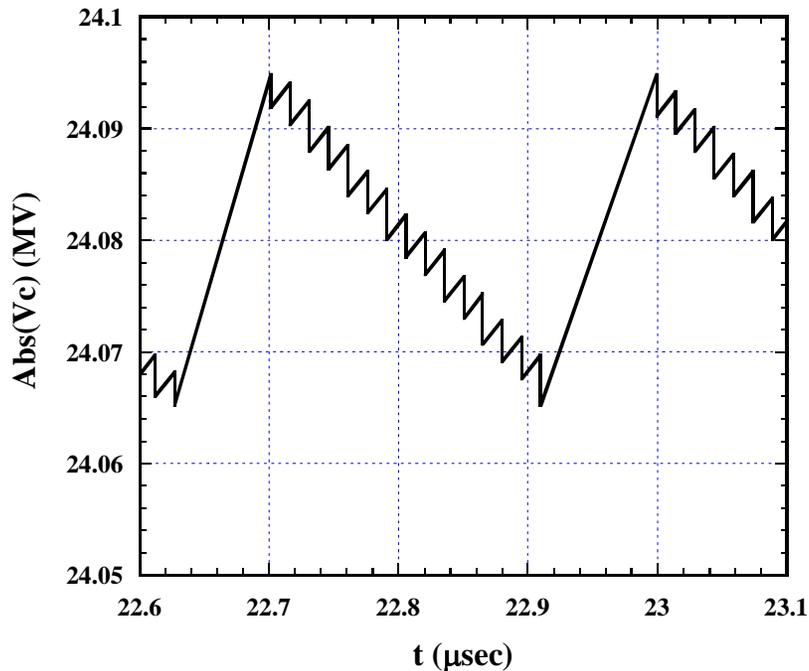Pg vs. QL
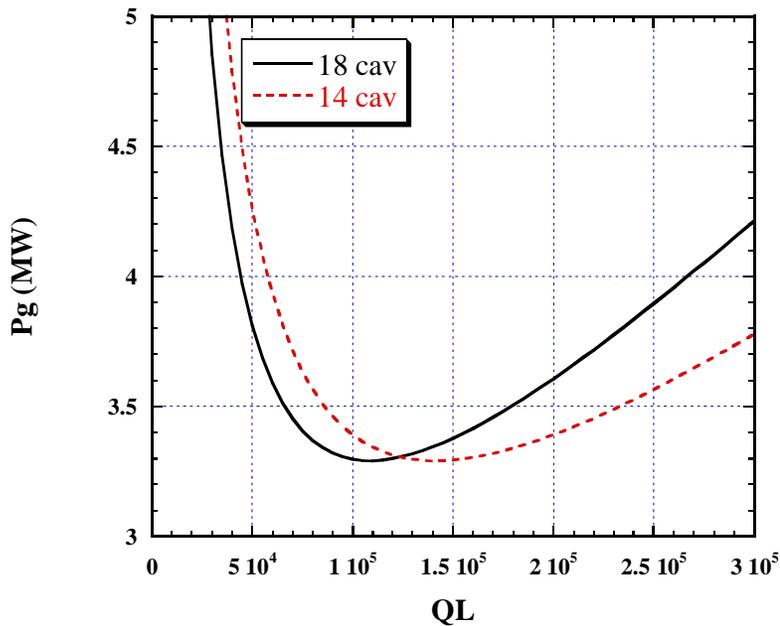
Set QL=1E5
For optimum condition (Ncav=18)
  f_RF - f_res = 5932 Hz
  detuning angle = -1.07 rad

Transient beam loading
in nominal operation condition

(76 trains/ring, 35 bunches/train)

Timing difference between head and tail of a train is about 0.8 ps.
Probably acceptable.

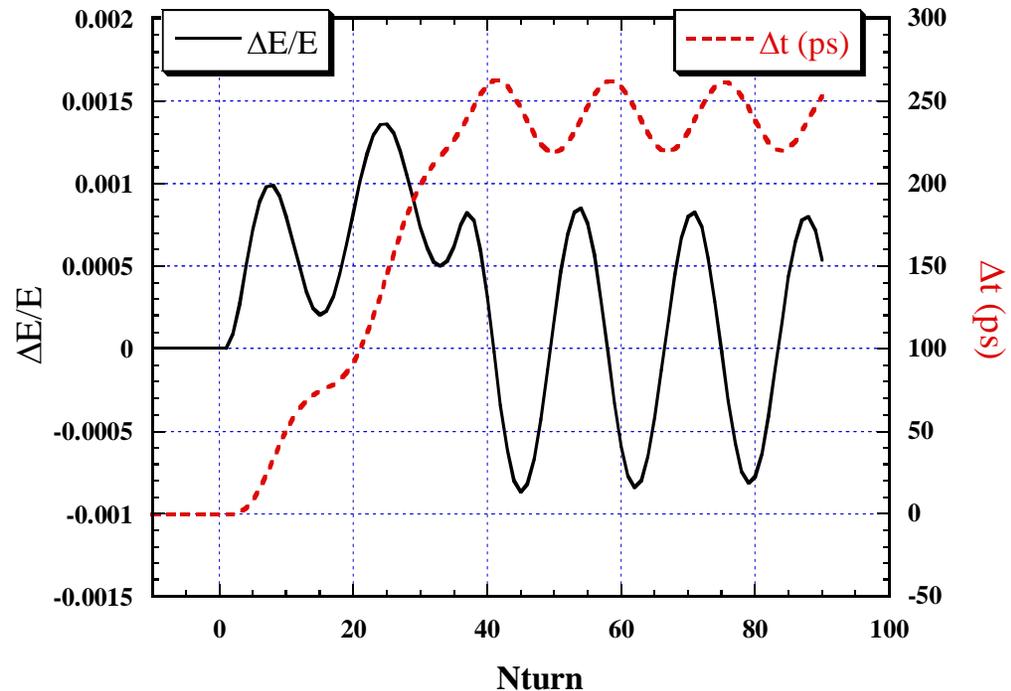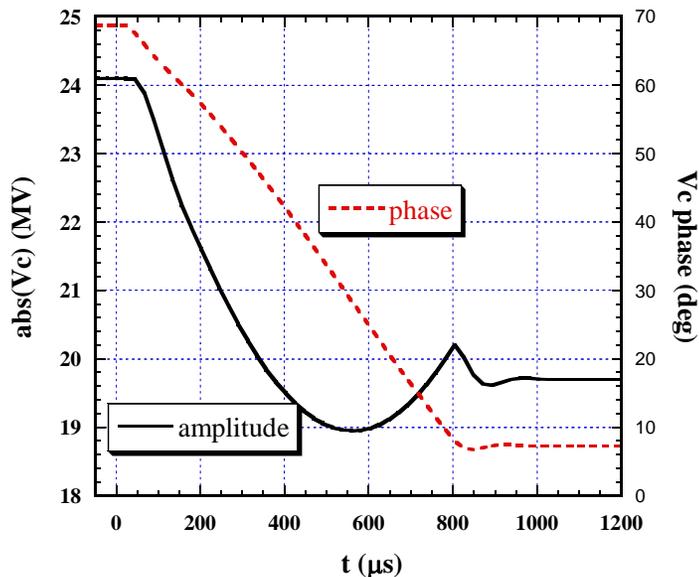# Vc and longitudinal oscillation during extraction
Beam current from nominal to zero

Input RF and resonance freq. is fixed.
Steady state before extraction.
One bunch of each train is extracted every turn.
(76 trains/ring, 35 bunches/train)

Large oscillation. Not acceptable.

Need RF control during extraction

- Extracted beam should be stable
- Vc should be constant.
  - Beam loading change should be compensated by RF control
- Cavity resonance frequency cannot be controlled so fast (?)
- Need extra RF power

RF power for lower current

If cavity resonance frequency cannot be controlled as fast as beam extraction, more power will be needed at low current.
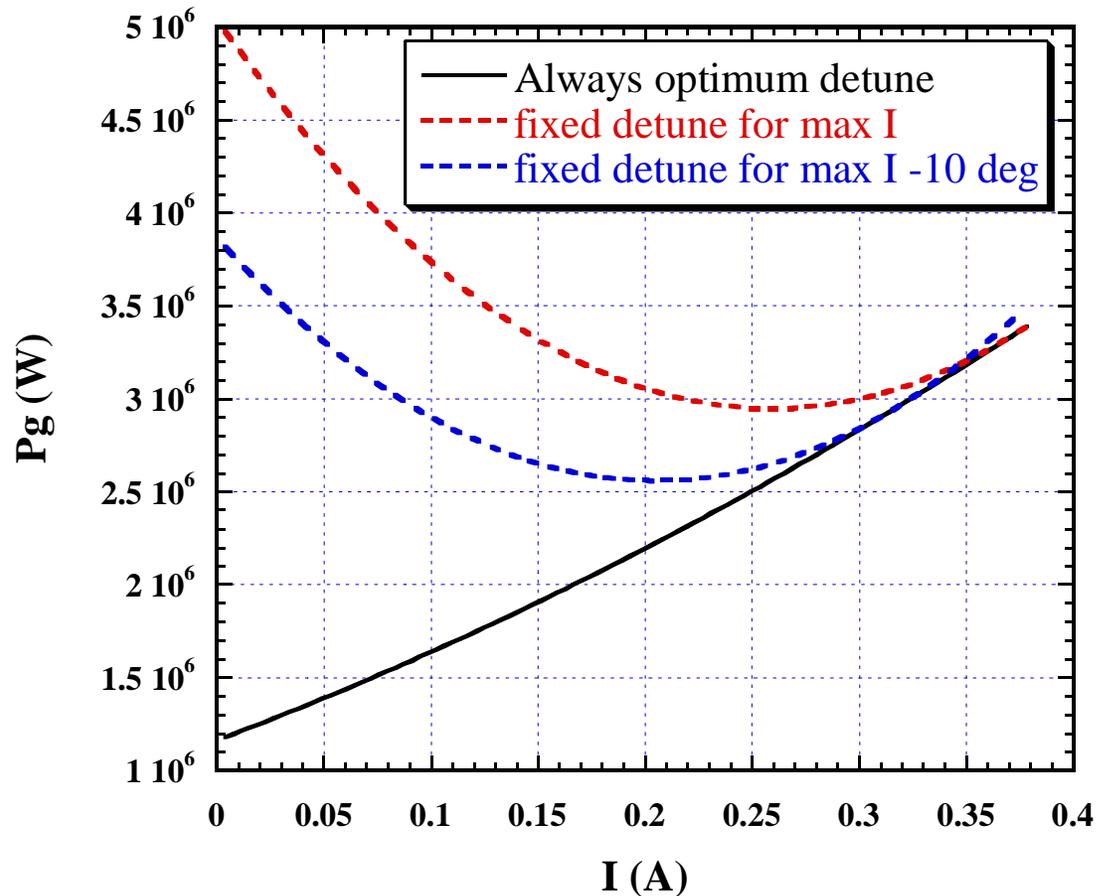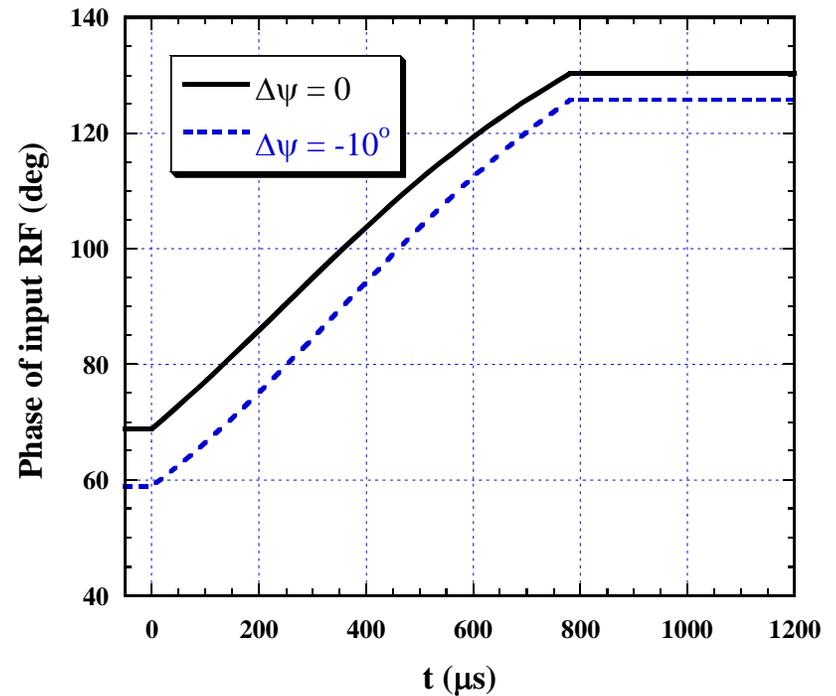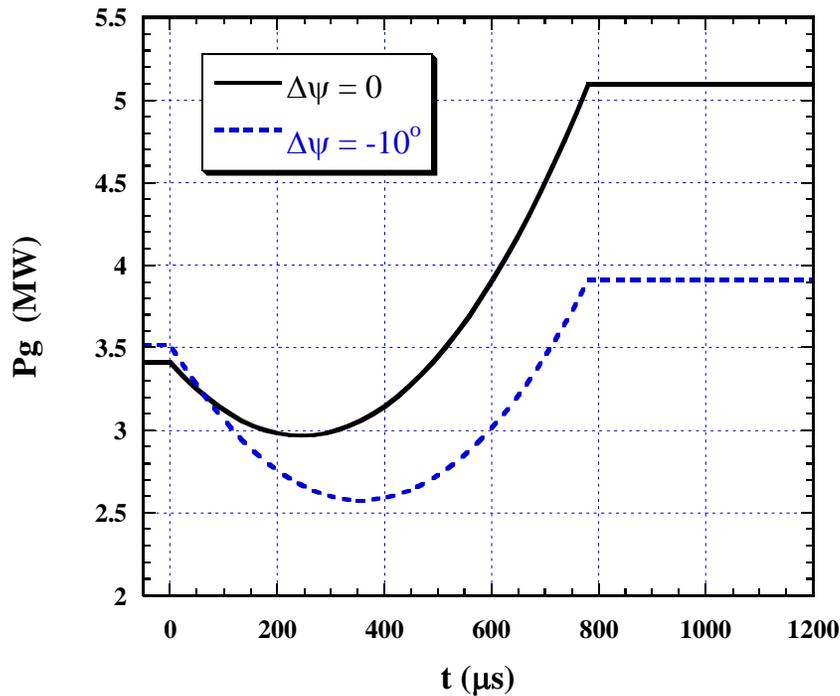
Reduce Detuning ?

$\Delta\psi$ is detuning offset angle (deviation from optimum detuning)
Setting detuning angle smaller than the optimum at maximum current,.
RF power for low current can be reduced.
 (need more power at max current) $P_g (I \approx 0) \propto 1/\cos^2(\psi)$
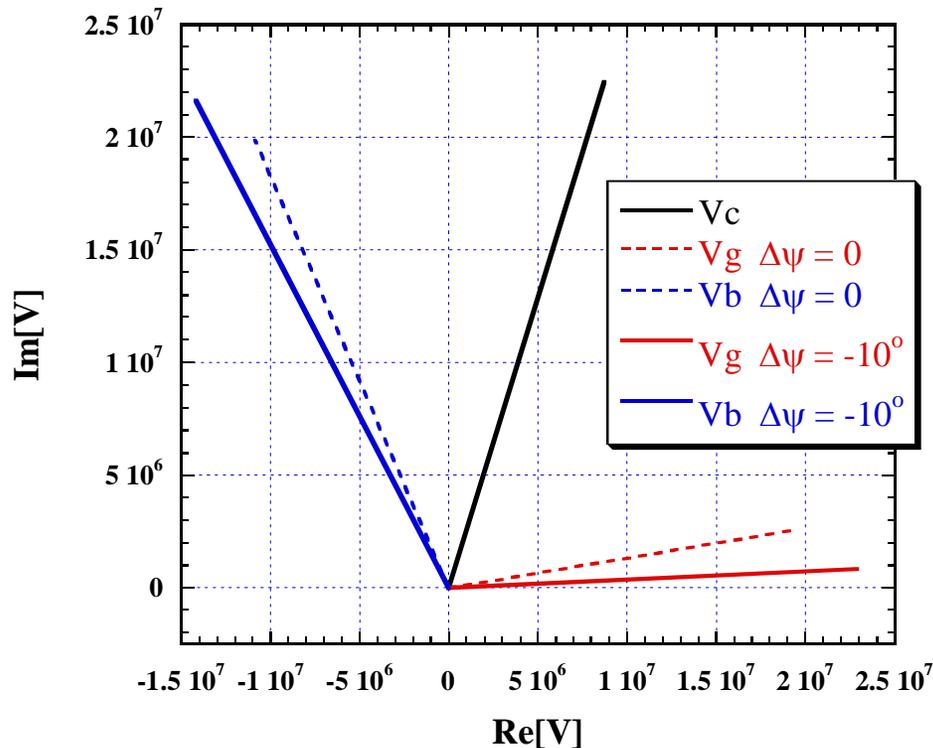
Input RF control during extraction

Input power and phase should be programed as shown.
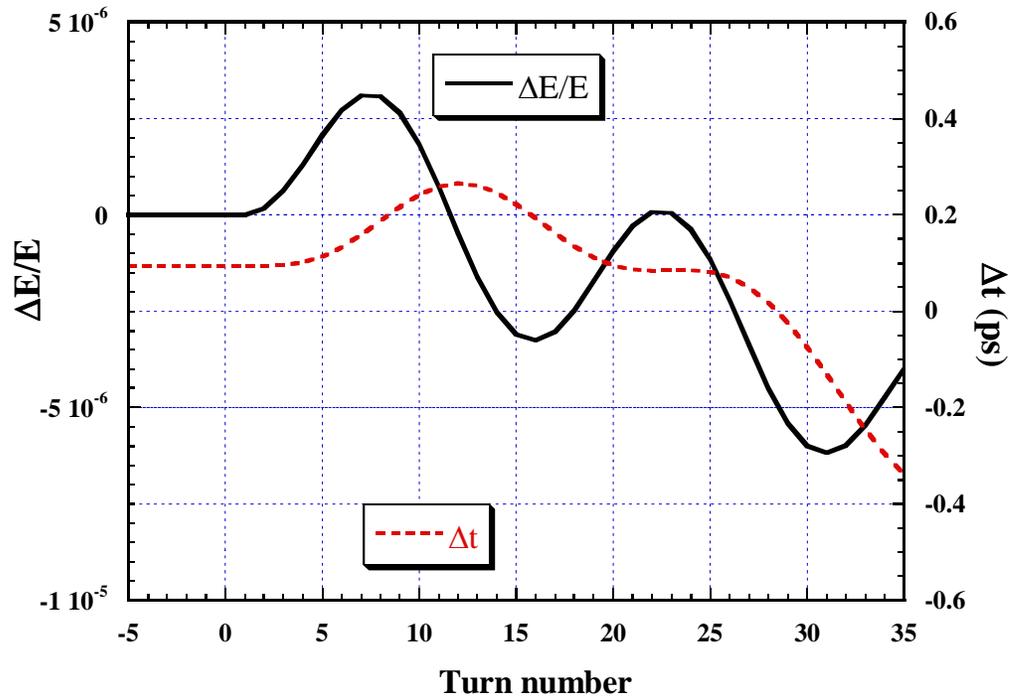(Resonance frequency is assumed to be fixed.)

Beam motion during extraction, with RF control

Head bunch and tail bunch of each train feel different voltages.
 (Transient beam loading)
They change slightly during extraction, even if average voltage is constant.

Energy and timing of head bunch of a train (extracted last)

No problem, probably. If average voltage is controlled.

Summary

- Transient beam loading (due to train gaps) is no problem.
- Extra power is necessary for alternate pulse operation for low energy experiment.
  - Need accurate RF control for stable extracted beam.
    - Average Voltage (phase and amplitude) should be constant.
    - Transient beam loading will not be a problem.
  - Extra power can be reduced by choosing detuning angle offset (detuning offset of resonance frequency)
  - Optimizing Loaded Q may help too ?

Study was done for RDR parameters (may not be exactly). And some parameters may not be accurate.

- Repeat with updated parameter set. (?)