Damping Ring Injection and Extraction

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Damping Ring EDR Kickoff Meeting
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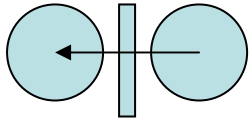
Rise-Fall-Rate Requirements

- **Linac energy efficiency --> 1 msec bunch train**
  - 1 msec bunch train is 300 km long
  - Train wraps around ~6 km ring ~50 times
- **Beamstrahlung bunch charge limit --> ~3000 bunches**
  - Average ring bunch spacing ~2 m --> ~6 ns
  - Clearing gaps, timing constraints, flexibility --> ~3 ns
    - This will come at $$ and robustness cost for kickers!
  - Average linac bunch spacing ~100 m --> ~300 ns
  - Low-Q --> 6000 bunches, 3 ns in ring, 150 ns in linac
- **Field rise and fall times of 3 ns**
- **3-6 MHz rate for 1 ms burst at 5 Hz**

Amplitude Requirements

- **Inject high-emittance e+ into center of ring aperture**
  - Move whole beam phase space across septum



$$\Delta x = R_{12}\Delta\theta \geq 2\sqrt{\varepsilon\beta_{sept}} \qquad R_{12} = \sqrt{\beta_{kick}\beta_{sept}}\sin\phi$$

$$\Delta\theta = kE\ell = k\frac{V}{w}\ell \qquad w = 2\sqrt{\varepsilon\beta_{kick}}$$

$$\left[\sqrt{\beta_{kick}\beta_{sept}}\sin\phi\right]\left[k\frac{V}{2\sqrt{\varepsilon\beta_{kick}}}\ell\right] \geq 2\sqrt{\varepsilon\beta_{sept}}$$

$$V\ell\langle\sin\phi\rangle \geq \frac{4}{k}\varepsilon$$

- **Injected e+ emittance --> ≥ 130 kilovolt-meters needed**
- **Less to extract damped e+, or to inject or extract e-**

Kicker "Magnets"

- **RDR assumption is striplines in vacuum**
  - Pulse direction opposite to beam so E and B add
  - Speed of light propagation
  - No inherent rise-fall-time limitations
- **Field pulse length is electrical pulse plus twice strip length, which must be less than twice bunch spacing**
- **RDR assumes strip length of 30 cm (1 ns)**
  - Electrical pulse width < 10 ns for 6 ns bunch spacing
  - Electrical pulse width < 4 ns for 3 ns bunch spacing
- **"Efficiency optimum" is strip length of half the bunch spacing and electrical pulse equal to bunch spacing**
  - All of pulser energy is used to deflect one bunch

Kicker Pulsers

- **A fully satisfactory pulser has yet to be demonstrated**
  - RDR text shows ATF test data with FID GmbH pulser that is nearly OK for 6 ns spacing
    - Width is fine, but baseline isn't clean
    - Higher amplitude would be nice
  - Too wide for 3 ns spacing
    - But perhaps close enough if some tricks are used….
- **Kickers and pulsers are a high-priority S3 R&D item**
- **And an EDR work package**

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Costs

- **Rather small fraction of ring cost, but not negligible**
- **Dominated by pulsers**
  - Estimated by price of FID GmbH units bought for R&D
    - Which didn't meet our specs….
  - No volume discount assumed
  - I worry about being in a single-source situation….

Pulser Technology

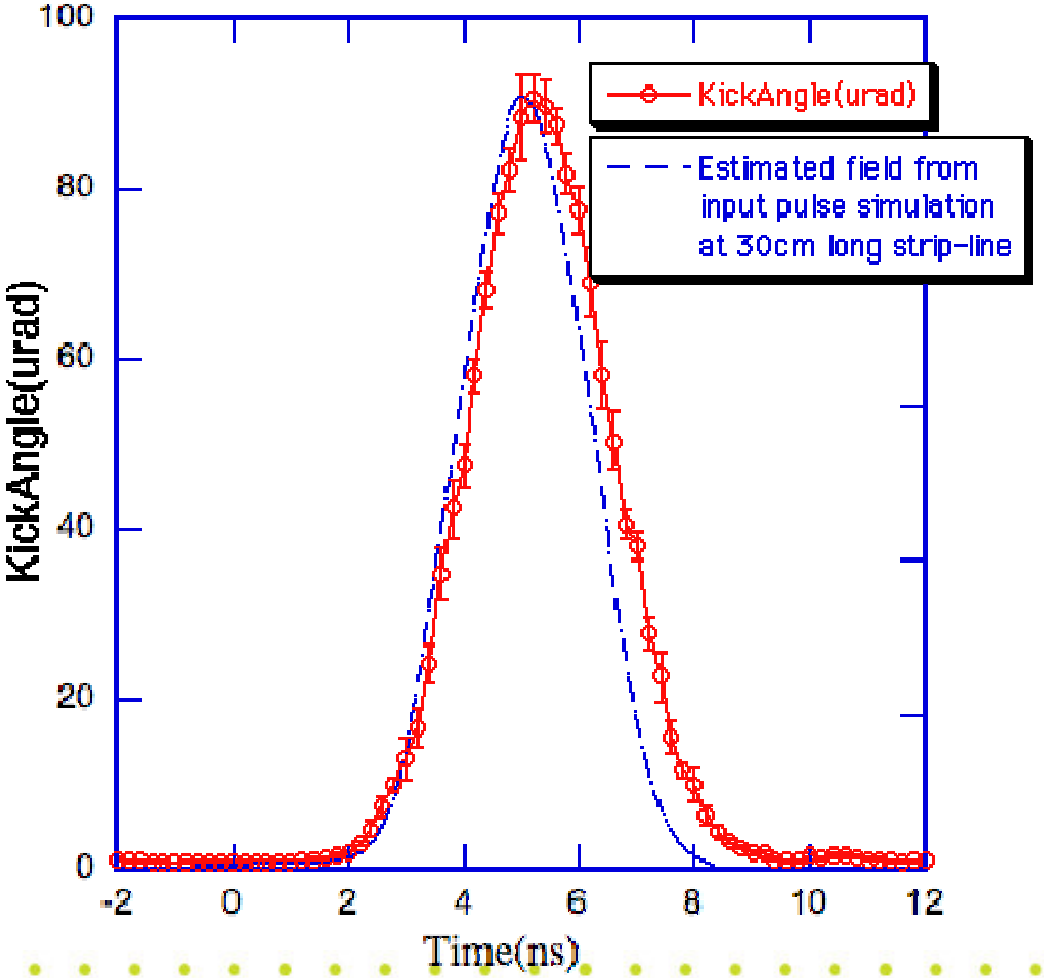
- **Thyratrons aren't fast enough**
- **FETs can be fast enough, but at low power per device**
  - Engineering of series-parallel combinations is hard
  - Speed-of-light across array is not insignificant
- **Fast Ionization Dynister (FID)**
  - GaAs triggered avalanche device
  - Sub-ns solid-state thyratron
  - Few vendors, expensive, little track record
- **Drift Step Recovery Diode (DSRD)**
  - Non-triggered fast-turn-off device
  - Needs triggered driver upstream (FET or FID)
  - Baseline noise from "charge" and "reset"

R&D Program

- **Tests of commercial pulsers (Behlke FETs, FID GmbH)**
  - In beam at ATF/2, FNAL photoinjector, DAFNE (soon)
- **Development of inductive-adder FET pulser**
  - SLAC-LLNL, to be tested at ATF
- **Development of DSRD circuits**
  - SLAC + industry partners
- **Development of stripline structures**
  - Simulation at many sites
  - Building for DAFNE and ATF/2
- **One of 3 topics at Cornell ILCDR workshop last fall**
- **Again this December at KEK workshop**

Performance Update

- **Naito-san's June DESY LCWS07 presentation of KEK results**



Beam kick profile

The timing of the kick pulse is scanned for the timing of the beam with 200ps steps. The kick angle is estimated from the beam oscillation amplitude.

Rise time = 3.2ns
(1%~100%)
Fall time = 4.0ns
(100%~1%)
[goal is sum < 6.15 ns]

Waveform compensator

Naito-san's June DESY LCWS07 presentation of KEK results

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Experimental set up

Zero Cross field

The rise/fall time is improved
to 2.2ns and 2.4ns
(not at same time in this setup)

Simulation of waveform compensator

(My) R&D Comments

- **With extra pulsers with offset timing, rise and fall time specs for 3 ns bunch spacing seem doable.**
- **While FID GmbH makes the fastest pulsers, not all their boxes have FIDs in them! Some have had FETs and DSRDs (not that I care, if they do the job).**
- **DSRDs seem to give dirty baselines at the few percent level, which is not insignificant for a 100 sigma kick! This needs more attention than it's getting.**
- **We may never have tested a device with a FID as the last stage. We should, it may have no baseline junk.**
- **FETs conceivably could work for 6 ns spacing, but it's hard to see for 3 ns spacing (bipolar avalanche transistor stack vendors seem to do better, why??)**

Stripline R&D

- **Issues**
  - Beam impedance
  - Uniformity of field across aperture (e+ injection)
    Degradation of rise/fall from feedthrus and tapers
  - Packing fraction
  - High voltage on feedthrus
  - Cooling
- **None of these sound un-solvable**
  - Just need to be done right someday

Injection/Extraction Straights

- **RDR version has e+ injection kicker broken into several regions 180° of phase apart**
  - Limited the orbit excursion inside the striplines
  - But had large orbit excursions in many quads
- **Proposed OCS8 has single e+ injector region**
  - But higher voltage to reduce excursion inside striplines
  - Still a few quads need special large apertures
- **OCS8 also more completely respects centralization of damping ring, with injection and extraction on opposite sides.**
- **But decks for injection, extraction lines need updating.**

Injection/Extraction Septums

- **RDR version has two pulsed septum magnets (thin and thick) for injection and extraction, similar to APS.**
- **ILC needs long flat top that presents problems**
  - Regulation of flatness, especially for extracted beam
  - Eddy current penetration into stored beam during pulse
- **Lattice isn't very tight, so almost certainly can use DC septums instead, even though they can't be as strong**
- **Should be easier, cheaper, better than pulsed.**

Near-Term Insertion Work

- **Optics and magnet conceptual design for DC septums**
- **Update external injection, extraction lines**
  - Do they belong to the damping ring any more?
- **Revise voltage, apertures, layout of kickers and optics**
  - I'm not sure we're fully optimized
- **Consider adding a kicker upstream of e+ injector**
  - for closed-bump off-axis stacking of e+ from keep-alive source to high intensity during early commissioning
  - Doesn't need to be as strong as on-axis injector
- **Goal is to get this stuff done by end of the year**

Conclusion

- **Injection/extraction for 3 ns spacing is challenging, not cheap, not yet fully demonstrated, but not obviously implausible**
- **Baseline is FID+DSRD pulsers, vacuum striplines**
  - Probably still need some with offset timing to tweak rise and fall times
- **Lots of R&D ongoing to demonstrate and improve pulsers and striplines**
- **Short-term project to move to DC septums and optimize injection-extraction straights**