

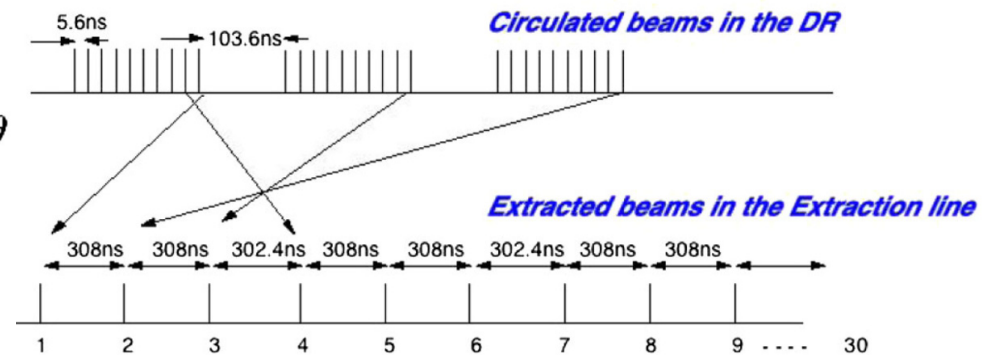
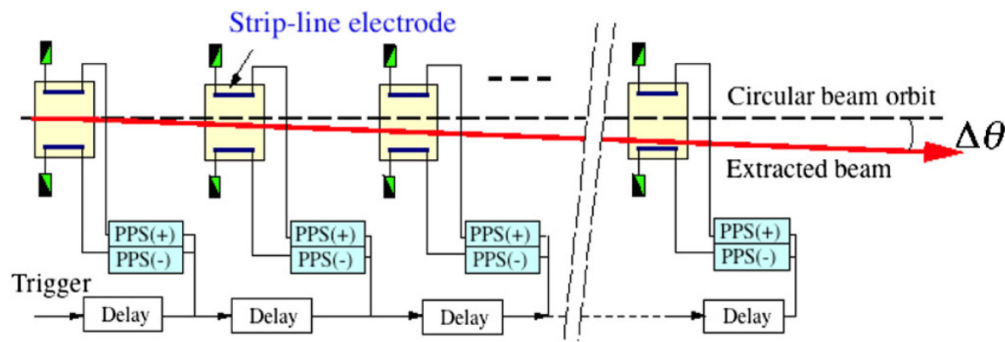
Fast injection/extraction kicker
Injection kicker for the e-driven positron source

Toshiyuki OKUGI, KEK

2020/11/10

4th Meeting of DR/BDS/DUMP subgroup

ILC fast injection/extraction kickers



	Injection	Extraction
Total kick angle(*)	0.79 mrad	0.19 mrad
Length of kicker region	16 m	16 m
Number of kicker	33	33
Length of stripline	0.3 m	0.3 m
Gap of electrode	50 mm	50 mm
Number of burst	1312 / 2625	1312 / 2625
Rise time	6ns / 3ns	6ns / 3ns
Repetition rate	5 Hz	5 Hz

*should be > 0.45 mrad
to keep the DR aperture
at EXT septum*

*should be $r > 22.4$ mm
to cover $\gamma(Ax+Ay) > 7e-2$ radm
at kicker and septum*

(*) There are no clear description in ILC TDR.

Kiyoshi Kubo evaluated the kick angle from DR optics deck. (kickers are not put to LTR, RTL beamline)

ATF test 1 – kick in DR

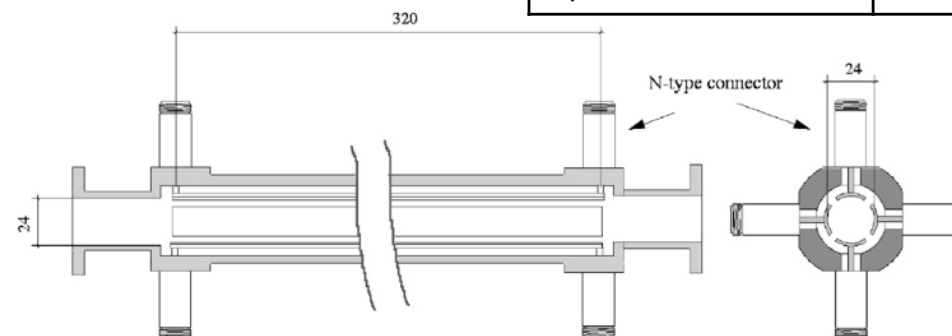
Specification of pulser

FPG5-3000M pulsers (fabricated by FID Co., Ltd.)

Voltage	+/-5 KV
Rise time	1-1.2 ns
Max. pulse	3000 pulses
Max. repetition rate	3 MHz

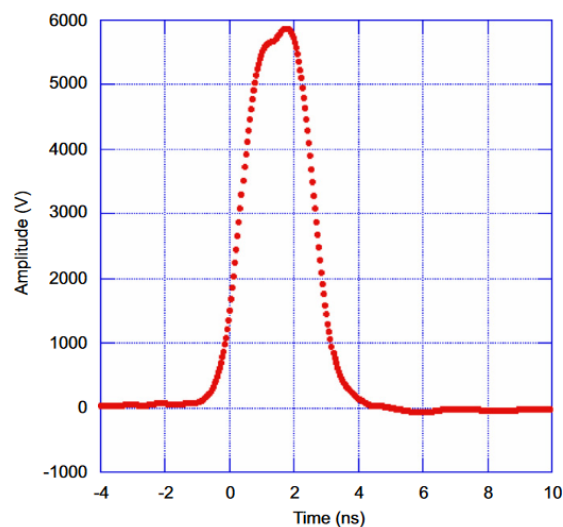
Stripline kicker

Kick angle @ 1.3 GeV	0.09 mrad
Length	0.3 m
Aperture	24 mm

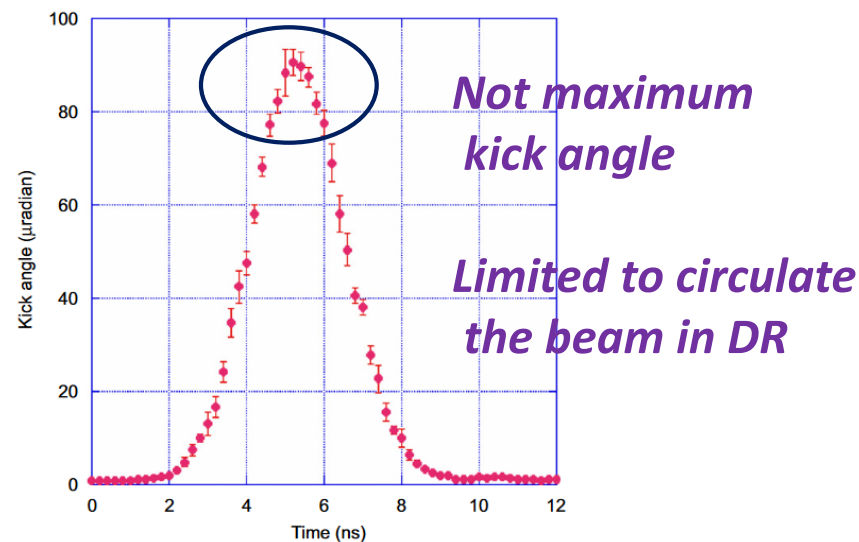


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Output voltage of the pulser



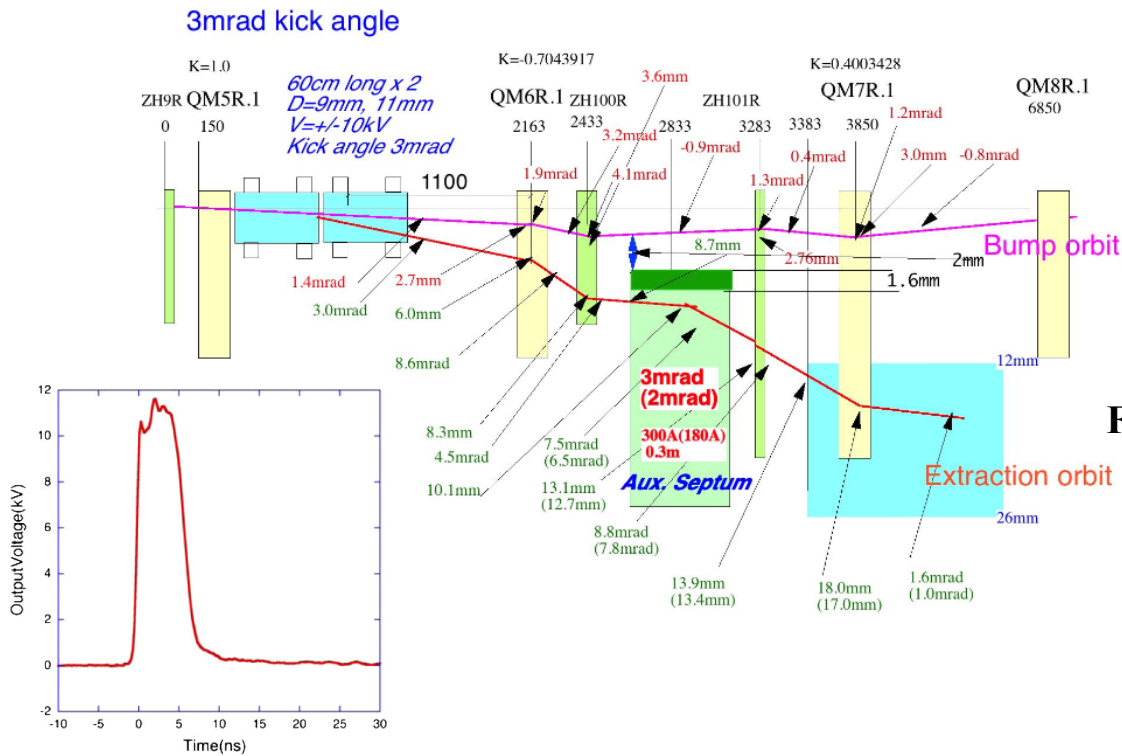
Kick amplitude measurement at ATF DR



- ✓ The specification of the pulser almost satisfied the requirements of the ILC.
- ✓ Since the test was carried out in DR, the kick angle was restricted.
Then, the test was not performed at the maximum voltage.

ATF test 2 – beam extraction test from ATF DR

Extra kick with Auxiliary septum & Local bump



Specification of stripline kicker

Kick angle @ 1.3 GeV	1.8 mrad / 1.5 mrad
Length	0.6 m
Aperture	9 mm / 11 mm
Max. repetition rate	3.3 MHz

Specification of pulser

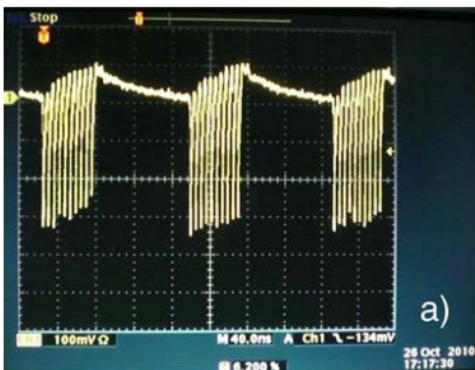
FPG10-3000KN pulsers (fabricated by FID Co., Ltd.)

Voltage	+/-10 KV
Rise time	1.5 ns
Max. pulse	60 pulses
Max. repetition rate	3.3 MHz

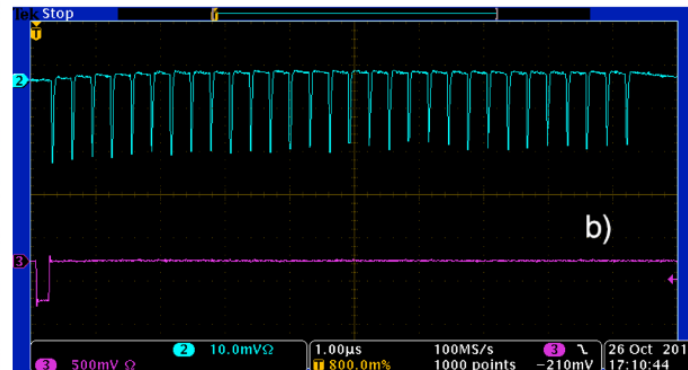
Multibunch beam extraction using the strip-line kicker at the KEK Accelerator Test Facility

T. Naito,* S. Araki, H. Hayano, K. Kubo, S. Kuroda, N. Terunuma, T. Okugi, and J. Urakawa
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **14**, 051002 (2011)

Stored beam in DR



Extracted beam from DR



	ILC design	ATF achieved
Beam energy	5 GeV	1.3 GeV
Bunch space in DR	3–6 ns	5.6 ns
Repetition rate in a burst	2 MHz	3.3 MHz
Number of macropulses	1312	30
Repetition rate of the macropulse	5 Hz	0.5 Hz
Rise and fall time ^b	<3–6 ns	<5.0 ns (3 ns)
Peak kick stability	0.07%	0.034% (@ single bunch)
Amplitude change in a burst	0.07% ^c	1%^d

Summary of the ATF kicker test and ILC requirement

	ILC requirement	FPG5-3000M		5kV, 6ns	FPG10-3000KN		10kV, 3ns
		ATF test	Scaled to ILC		ATF test	Scaled to ILC	
Voltage		5 kV			10 kV		
Beam energy	5 GeV	1.3 GeV	5 GeV		1.3 GeV	5 GeV	
Total kick angle	0.79 mrad	0.09 mrad	0.37 mrad	0.86 mrad	3.00 mrad	1.71 mrad	0.74 mrad
Number of kicker	33	1	33	20	2	20	33
Kick angle / 1 kicker	24 urad	90 urad	11 urad	39 urad	1500 urad	78 urad	22 urad
Length of stripline	0.3 m	0.3 m		0.6 m	0.6 m		0.3 m
Gap of electrode	50 mm	24 mm	50 mm		11 mm	50 mm	
Number of burst	1312 / 2625	3000		???	60		???
Flat top		3 ns		6 ns	6 ns		3 ns
Repetition rate	5 Hz	3.125 Hz	5 Hz		0.5 Hz	5 Hz	

ATF kicker test 1 (FPG5-3000M ; 5kV, short pulse)

Kick Angle ; **NOT ENOUGH**

Burst Pulse Length ; **ENOUGH**

ATF kicker test 2 (FPG10-3000KN ; 10kV, long pulse)

Kick Angle ; **ENOUGH**

Burst Pulse Length ; **NOT ENOUGH**

Plan ; Development of the pulser

➤ 5KV, 6ns (long pulse)

✓ Kick Angle ; **enough**

✓ Burst Pulse Length ; **need check**

✓ High luminosity ; **Impossible**

➤ 10kV, 3ns (pulse shaped short pulse)

✓ Kick Angle ; **comparable**

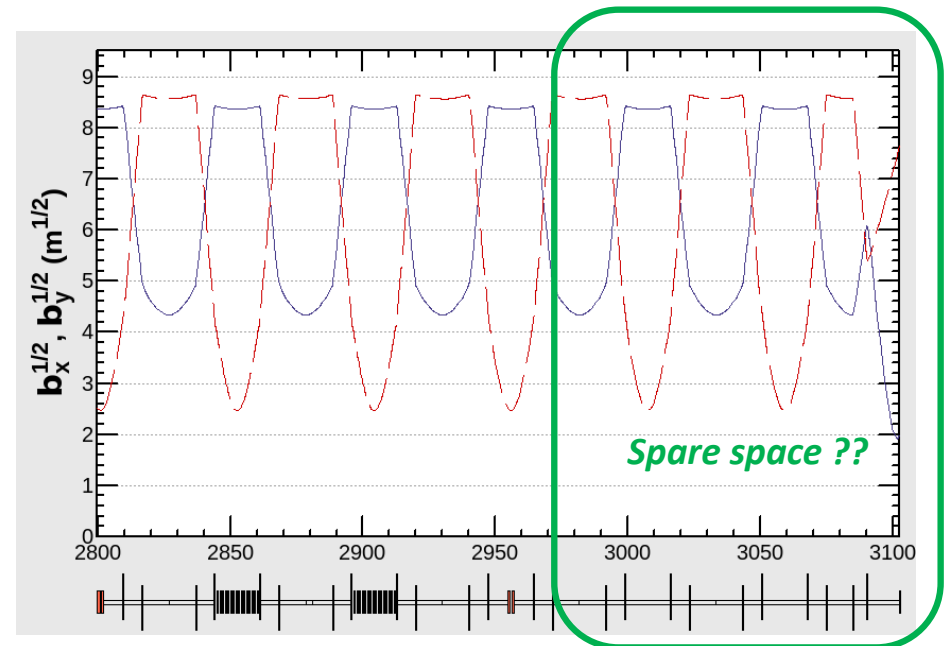
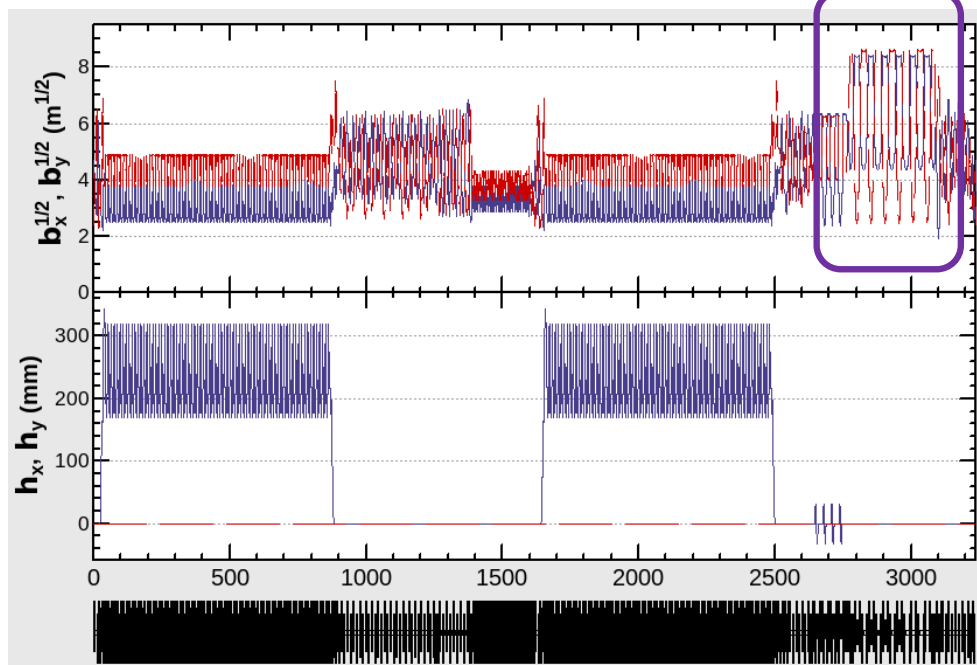
✓ Burst Pulse Length ; **need check**

✓ High luminosity ; **Possible**

Alternative technical work for the fast kicker

- Design update of the injection/extraction section in the ILC DR to be able to be acceptable for the FPG5-3000M (5kV, short pulse), which was already tested in the ATF DR for the low frequency, short burst operation.
 - ✓ Lengthen the kicker section by roughly twice.
 - ✓ Adjustment the DR tunes to make a larger dynamic aperture.
- etc.*
- Then, the long-term stability will be tested at the ATF extraction line for high frequency (> 5Hz), long burst (> 1312) operation.

Injection/extraction section



Injection septum Injection kickers Extraction kickers Extraction septum

Long-term stability test for the fast kicker

Location ; ATF extraction line

- ✓ Frequency of the beam pulse ; 3.125 Hz (used only nominal operation)
- ✓ Kicker frequency ; Max 6.25 Hz (can be used for the high luminosity option)
- ✓ Burst kicker pulse ; > 1312 (> 2625)

The beam used in the test is a single bunch, but the stability of the kicker's overall burst pulse will be examined while changing the timing.

Candidate kicker pulser ;

- ✓ For the modified ILC DR optics ;
 - 0) FPG5-3000M (5kV, 3ns)
- ✓ For the TDR ILC DR optics ;
 - 1) 5KV, 6ns (long pulse)
 - 2) 10kV, 3ns pulser (pulse shaped short pulse)
 - 3) others
 - Could you please test other pulsers than FID Co., Ltd., if you have ?

What we should do in the ILC preparatory phase

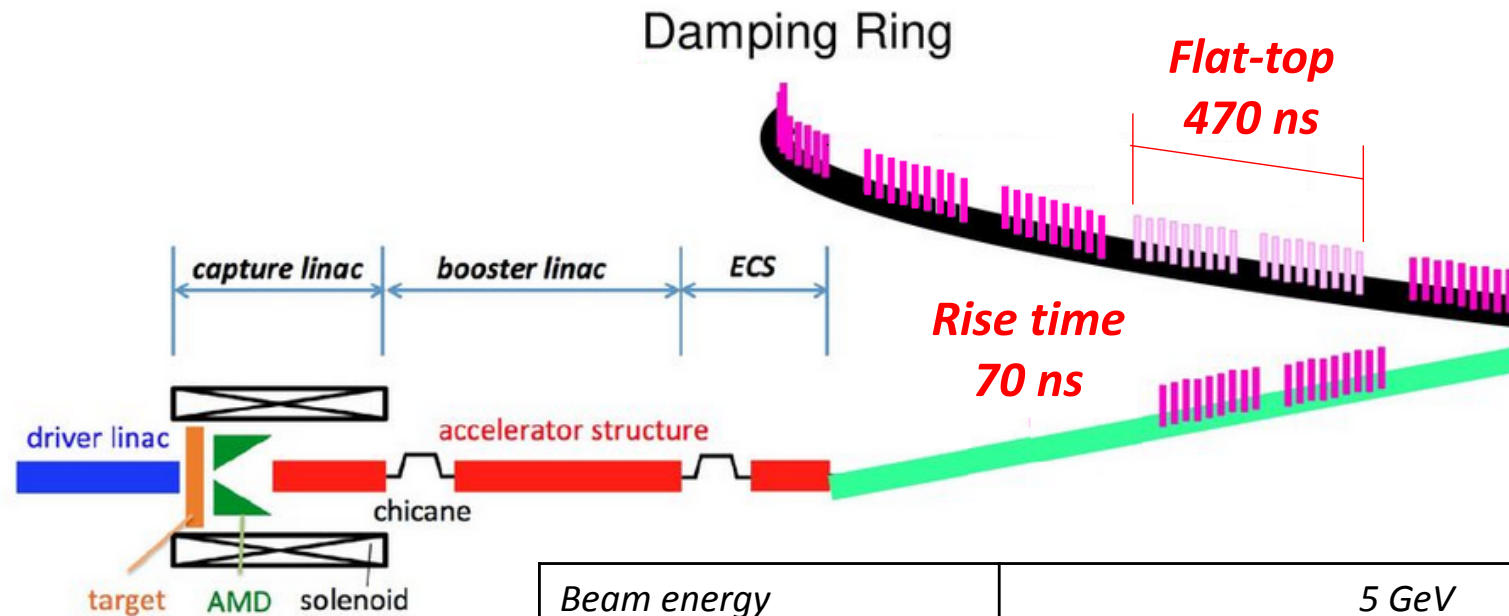
Fast injection/extraction kickers for the ILC DR

- ◆ ***System design of the kicker***
 - *Do we need to modify the DR optics injection/extraction section ?*
- ◆ ***Long-term stability test at the ATF extraction line.***
 - *What kind of the kicker pulser will be used for the test ?*
- ◆ ***The development of the additional kicker pulser, if need***
 - ✓ *Which institute will it be able to do for each items (potential) ?*
 - ✓ *How much cost will it need (except for the human resource) ?*
 - ✓ *How many human resource will it need ?*

Injection kicker for the electron driven positron source

Two bunch trains of the damping ring are injection by single kicker pulse simultaneously.

- ✓ kicker rise time is defined by the train interval of the DR.
- ✓ Kicker flat-top is defined by the 2 train lengths (+ 1 train interval).

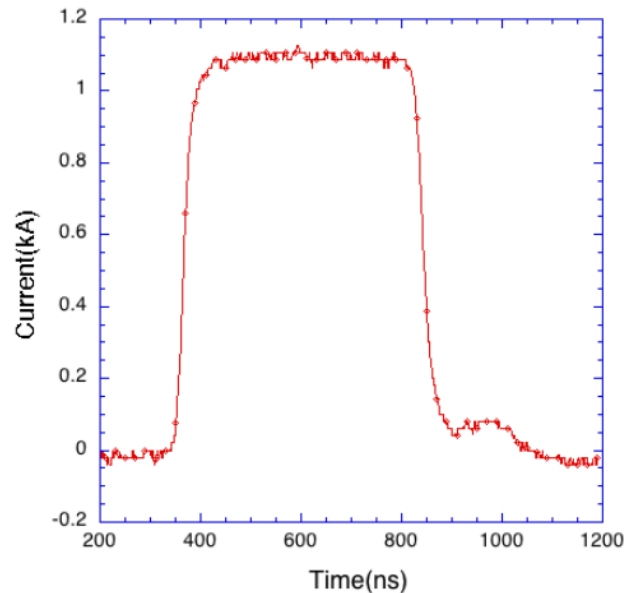


Beam energy	5 GeV
Total kick angle	0.79 mrad
Length of kicker region	16 m
Aperture	50 mm
Flat-top	470 ns
Rise time	70 ns
Repetition rate	300 Hz
Average rep. rate	100 Hz (20 ON – 40 OFF -20 ON – 40 OFF ..)

SLC epoxy kicker

Waveform of the epoxy kicker at the ATF

- ✓ 300 ns flat-top, 60 ns rise/fall time
- ✓ $B = 500$ gauss
- ✓ Flat-top was generated by using PFL (long cable), but the operation frequency was very low to reduce the heating of the kicker devices.



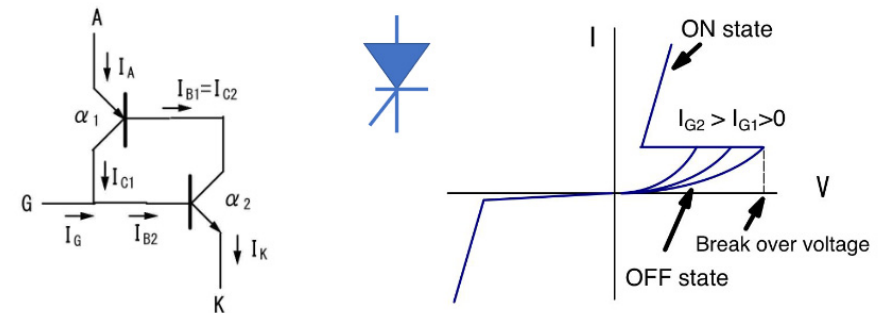
Problem 1; High frequency operation

- ✓ We should evaluate the how much magnetic field can be generated for the longer pulse, high frequency operation
- ✓ Then, we should evaluate how much kickers is required for the ILC DR, and whether the kicker space is enough or not ?

Problem 2 ; Switching device : thyatron

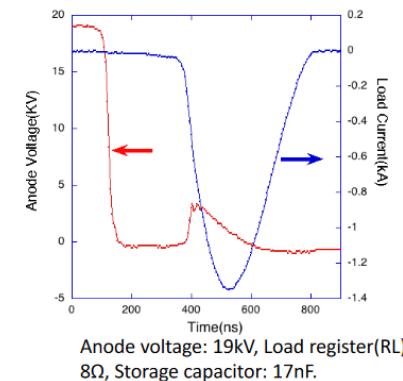
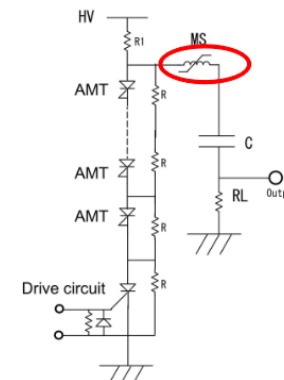
- ✓ Production stopped
- ✓ Large timing jitter

replaced to the thyristor diode
(avalanche mode)



The switching device is just conceptual design,
the prototype test is not performed.

- A large current can flow by using a magnetic switch circuit in the preliminary test.
- Timing delay occurs by using the magnetic switch, but jitter (about 1ns) is small.



CLIC Induction kicker

Stripline design for the extraction kicker of Compact Linear Collider damping rings

C. Belver-Aguilar and A. Faus-Golfe F. Toral M.J. Barnes

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS 17, 071003 (2014)

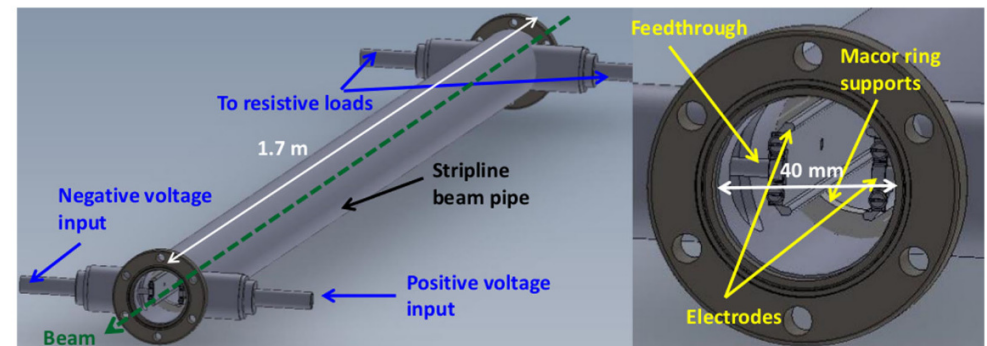
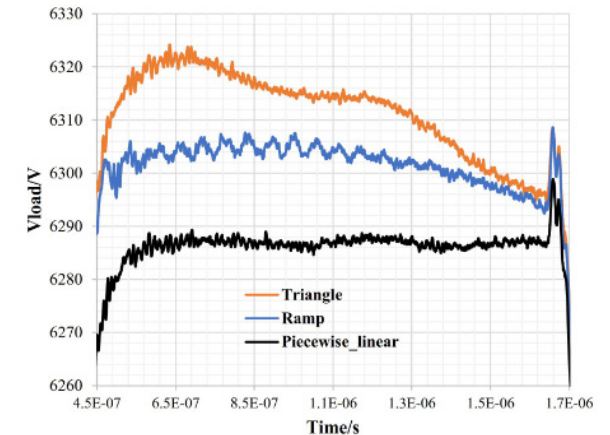
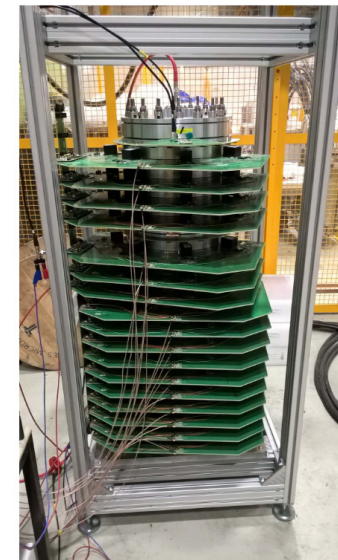
For 2.86 GeV beam		PDRs	DRs
Kicker parameters	Symbol	1/2 GHz	1/2 GHz
Deflection angle (mrad)	α	2.0	1.5
Aperture (mm)	a	40	20
Effective length (m)	L	3.4	1.7
Field rise and fall time (ns)		428/1000	560/1000
Pulse flat top (ns)		900/160	900/160
Flat top reproducibility		$\pm 1 \times 10^{-4}$	$\pm 1 \times 10^{-4}$
Injection stability		$\pm 2 \times 10^{-2}$	$\pm 2 \times 10^{-3}$
Extraction stability		$\pm 2 \times 10^{-3}$	$\pm 2 \times 10^{-4}$
Injection inhomogeneity (%)		$\pm 0.1^a$	$\pm 0.1^a$
Extraction inhomogeneity (%)		$\pm 0.1^a$	$\pm 0.01^b$
Repetition rate (Hz)	f_{rep}	50	50
Vacuum (mbar)		10^{-10}	10^{-10}
Stripline voltage (kV)	V_k	± 17.0	± 12.5
Stripline current (A)	I_k	± 340	± 250
Longitudinal beam impedance (Ω/n)	Z_{\parallel}	0.05	0.05
Trans. beam imped. ($k\Omega/m$)	Z_{\perp}	200	200

- ✓ Kick angle seems OK.
- ✓ Flat-top seems OK
- ✓ Repetition ??
- ✓ Rise/fall time ??

Prototype Inductive Adders With Extremely Flat-Top Output Pulses for the Compact Linear Collider at CERN

Janne Holma¹ and Michael J. Barnes²

IEEE TRANSACTIONS ON PLASMA SCIENCE, VOL. 46, NO. 10, OCTOBER 2018



What we should do in the ILC preparatory phase

Injection kicker for the electron driven positron source

◆ *System design of the kickers*

- ✓ *Which institute will it be able to do (potential) ?*
- ✓ *How much cost will it need (except for the human resource) ?*
- ✓ *How many human resource will it need ?*

◆ *The development of the kicker and the pulser, if need*

- ***Do we need the development of the devices ?***
- ***If YES,***
- ✓ *Which institute will it be able to do (potential) ?*
- ✓ *How much cost will it need (except for the human resource) ?*
- ✓ *How many human resource will it need ?*