KEK Optics Commissioning An overview of linear non-linear optics

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Thanks to everyone at KEK who helped us achieve nice results!





Plan

Intro Context Measurements

Linear Optics

LER: Kicks and Detuning

Resonance Driving Terms

Chromaticity

Conclusion





Context

Spent last February at KEK in Japan for commissioning

- HER and LER rings
 - Electrons and Positrons
 - Fixed energy
- One IP: Belle-II detector
 - Studies of B meson $(u\bar{b}, d\bar{b}, s\bar{b}, c\bar{b})$
- From "detuned" to squeezed optics
- Linear Optics (β-beating)
- Non-Linear (chromaticity, amp.det.)







Measurements

• A few turn-by-turn measurements were done at each configuration

Ring	Day	eta_x* [mm]	$\beta_y * [mm]$	Q_x	Q_y
LER	06	384	48.6	44.556	46.635
	09	384	48.6	44.553	46.621
	20	200	8	44.527	46.604
	22	200	8	44.535	46.590
	29 -	100 _	3	44.523	46.580
HER	06	400	81	45.572	43.616
	04 -		1	45.532	43.598
	20 -	200 _	8	45.530	43.595
	22	200	8	45.535	43.596
	26	200	8	45.535	43.596
	27	200	8	45.537	43.591
	29 -	100 -	3	45.532	43.587



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Intro

Linear Optics Turn By Turn Data GUI Spectrum β-Beating

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Turn By Turn Data



- A few ways to excite the beam
 - Injection kicker in H plane
 - · Injection oscillations via offset

GUI

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- Integrated SuperKEK in OMC's GUI
- Makes things easier

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° Like the identification of consistently bad BPMs

Spectrum

With high amplitude kicks, the tunes are visible





β -Beating

Let's consider two configurations for each ring

- Detuned
- Squeezed at $\beta_y = 8$ mm

ľ	Ring	Day	$eta_x*~[{ m mm}]$	$\beta_{y}*$ [mm]	Q_x	Q_y	Kicks
	LER	06	384	48.6	44.556	46.635	H & V
		09	384	48.6	44.553	46.621	Н
1		20 -	200 -	8	44.527	46.604	<u>H</u> -
		22	200	8	44.535	46.590	Н
	HER	06	400	81	45.572	43.616	H & V
1		20 -	200 -	8	45.530	43.595	<u>H</u> -
		22	200	8	45.535	43.596	V
		26	200	8	45.535	43.596	V



LER Detuned



- Vertical plane noisy
 - action 5 times lower than horizontal



LER Squeezed 8mm



- Beating near IP? Analysis artefact or real?
 - K-Modulation would be more precise

HER Detuned



- Vertical plane very noisy
 - action 4 times lower than horizontal

HER Squeezed 8mm



- Some BPMs are removed
 - Non-ideal phase advance of BPMs



Recap

- Good reproducibility between kicks
 - Clean data in horizontal
 - Noisier but exploitable in vertical
- Measurements fairly reproducible
- One region with bad BPMs
- β -beating below 10% for all configurations and both rings

Ring	Configuration	β -b. rms H	β -b. rms V
LER	Detuned	4%	5%
	Squeezed 8mm	6%	
HER	Detuned	6%	8%
	Squeezed 8mm	7%	5%





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Linear Optics

LER: Kicks and Detuning

Tune Stability Kicks and Method Detuning and Action Dependence Amplitude Detuning

Resonance Driving Terms

Chromaticity

Conclusion





LER Shots



• Tune stability is good in H, not that much in V

 $^{\circ}\,$ Bad tune measurement due to low amplitude oscillations



HER Shots



• Better measurements and stability is achieved in HER



Kicks and Method



- Tune computed as a running window over 200 turns
- Noticeable detuning after each kick

Detuning and Action Dependence



• Tune shift seems correlated to the kick amplitude

Amplitude Detuning



Tune taken from the first 200 turns

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• Amplitude detuning term $\frac{\partial Q_x}{\partial 2J_r}$ can be measured

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Tune Diagram Spectrum RDTs

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Tune Diagram



- Many resonances exist around the working point
- Two of interest: $Q_x + 2Q_y$ and $3Q_x$, from sextupoles

Spectrum



• Resonance $3Q_x$:

FRE 😥

W

- $^\circ~-2Q_x$ in horizontal: $f_{3000,x}$
- Resonance $1Q_x + 2Q_y$:
 - $\circ~-1Q_x-1Q_y$ in vertical: $f_{1020,y}$

HER 06 - $f_{1020,y}$



- Measured RDT about 3 times larger than expected from the model
- Decoherence factor not yet taken into account in analysis

LER 06 - $f_{3000,\boldsymbol{x}}$



- Measured RDT also about 3 times larger than expected
- Decoherence smaller than for HER

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Procedure HER - Detuned LER - Detuned

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Procedure



Varying the RF induces a change in the momentum offset δ A detuning then occurs due to chromaticity:

$$Q(\delta)=Q_0+Q'\delta+\frac{1}{2!}Q''\delta^2+\frac{1}{3!}Q'''\delta^3+\mathcal{O}(\delta^4)$$





HER - Detuned



$\to \ {\rm Differences} \ {\rm in} \ Q''$



LER - Detuned



- $\to \ {\rm Differences} \ {\rm in} \ Q''$
- \rightarrow Differences in Q_y'''
- $\rightarrow \ Q^{(4)} \ {\rm matches \ well}$

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- Resonance Driving Terms
- Chromaticity
- Conclusion



Conclusion

- Nice reproducibility of linear optics
 - · Quite better in horizontal with a kicker
 - Across several days
 - Shot to shot
- Sextupolar RDT measurements in both rings
 - · Could not achieve clean measurements all the time
 - Some discrepancies yet to be explained
- Good chromaticity measurements for both rings
 - $^\circ\,$ Discrepancy for Q'' coming from octupolar(-like) sources
 - Discrepancy for LER's Q''_{y} , from decapolar(-like) sources
- Amplitude detuning measured for LER with detuned optics
 - $\circ~$ Model comparison would give a more detailed outlook on $Q^{\prime\prime}$

