Alignment of injector linac

KEKB Accelerator Review 24 February, 2015 Toshi Higo (Injector linac group)

Contents

- 1. Initial alignment along laser line
- 2. Hard ware alignment on each girder.
- 3. Floor movement
- 4. Near future development
- 5. Conclusion

Linac layout and alignment requirement



 σ < 0.1 mm: $\beta\gamma\epsilon$ 20 mm·mrad is almost satisfied.

 $\sigma > 0.1$ mm: emittance preservation is required by some methods.

<u>Requirement</u> Local σ < 0.1mm Global σ < 0.3mm

Alignment method



Hard wares around standard 9.6m girder



Major steps since last review

- 1. Established 500m laser straight reference line over C-5
- 2. Established reference points for DR
- 3. Installed target/FC followed by LAS with Solenoid and largeaperture Q magnets
- 4. First girder alignment done in 3—5 sectors by laser PD
- 5. Hard ware alignment on each girder done with laser tracker
- 6. Done alignment on old Q magnets with laser tracker
- 7. Done stiffening of girders, especially positron line
- 8. Completed initial alignment of 3—5 sector with laser PD
- 9. Further evaluated floor movement
- 10. Installation of heavy radiation shield on positron generation system underway

Stiffening of 9m-girder



Soft: metal plate spring → Stiff: slide roller with bolt fixing

Eigen mode frequency Several → more than 10 Hz



End hor. slider



Center pivot

2015/2/24

Positron generation and acceleration





New aluminum girders



Road cell with ball → Jack bolt

1. Initial girder alignment

Straight laser reference line

- 500m laser line was stabilized by feed back.
- We can routinely measure C-5 sector by laser PD system
- Some developments may still be needed
 - Easy sensitivity calibration and absolute zero position
 - Cares against radiation damage
- However, at a moment
 - Because the system is most practical, we utilize it for initial alignment
 - Automatic in/out devices were developed to monitor floor motion continuously

500m straight reference line by laser



Gaussian beam Tilt feedback



FIG. 5. Intensity profiles of the laser beam at (a) z = 0 m and (b) z = 500 m. Scale bars are 5 mm.



tained by numerical analyses. The Rayleigh lengths were estimated to be $z_{Rx} \simeq 308$ m and $z_{Ry} \simeq 321$ m in the x and y directions, respectively. The beam widths at the waist locations, $z_{x0} \simeq 358$ m and $z_{y0} \simeq 399$ m, were obtained to be $W_{x0} \simeq 18.8$ mm and $W_{y0} \simeq 18.0$ mm in the x and y directions, respectively.

PD sensitivity





Fitted with Rayleigh function along 500m linac was used in the present analysis

Recent estimation from mechanical girder movement in 3—5 sector

Sensitivity varies by a factor 2 , but the center identified as zero output voltage should be OK

Finished initial alignment of girders

- Girders in sectors 3—5 were quickly aligned in 2011 after the earthquake.
- 2. Positron generation area was installed by the summer 2014.
- 3. Until late July 2014, C—5 sectors were aligned with leaving V-shape residual.
- 4. In late Jan. 2015, all in the 3—5 sectors were aligned straight, except for the C-band unit at 44.

3—5 alignment in Summer 2014



Present 500m alignment over C-5

after completion of initial alignment in late Jan. 2014



Summary of girder alignment

- Girder alignment can be done with the present laser PD system probably within 0.2mm in sigma.
- Residual misalignment of the first initial alignment was 0.3mm in sigma, mainly comes from those aligned earlier but moved later in a year scale.
- Floor moves in a big scale, especially at expansion joint, so that the swift measurement is needed, or the movement should be taken into account.

2. Hard ware alignment on girder

Hard ware alignment on each girder

- Accelerator structures in units at sectors 3-4-5 were corrected during summer shutdown in 2014, followed by those in sectors A-B-C-1.
- Reflector base was put on the top of old Q magnets. Their alignment was measured and mostly corrected.
- New Q magnets with big bore were set w.r.t. the mechanical reference on girder. Confirmation is yet to be done.

Reflector setting for hard ware positioning



Mounted on coupler OD



Arm from PD to reflector



Reflectors for old Q-magnet

ACC str. In unit 34 Horizontal



ACC str. In unit 34 Vertical



Hard ware alignment on a girders in



2015/2/24

KEK Review Higo

Alignment error estimation

w.r.t. reference straight line

1. Laser straightness

Pointing stability being fedback $\rightarrow \sigma^{\sim}0.05$ mm

2. Girder alignment error

Setting errors $\rightarrow \sigma^{0.3}$ mm

PD sensor setting error on holder $\rightarrow \sigma^{0.015mm}$ Radiation damage of PD sensors \rightarrow ?

- 3. PD center to girder for setting laser tracker reference Arm setting error $\rightarrow \sigma_v \sim 0.05$ mm
- 4. Girder reference to hard ware setting Tracker confirmation of reference po

Tracker confirmation of reference position $\rightarrow 0.05$ mm/5m

5. All the above in random manner

~0.3mm which will be improved by more alignment times to probably 0.2mm level, unless any systematic error is left

3. Floor movement

Floor moves significantly

- It has been long pointed out.
- Laser PD monitor over half a year showed
 - Significant movement being localized at junction
 - Mostly vertical (upward from summer to winter) by a few to several mm.
- Following pages show the movements.



Variation in half a year from July to January





Floor vertical movement

in half a year from summer to winter



Long-term floor movement near junction



Not evident but ~0.05mm/month

Upward drift at junction ~0.3mm/month

Junction and after-pouring concrete





Expansion joint between two solid plates

15cm step not well stick on the base plate

Tunnel basic structure



PD for continuous measurement



Daily motion between junction



Longer-term motion



Estimation of floor movement some typical observed values

Unit mm

	Horizontal	Vertical											
Daily	0.1	0.1											
Week	0.1	0.1											
Half a year	0.5	2											
Speed	0.01mm/hour	0.01mm/hour											
We should s wit	We should study/develop the linac system with these values in mind.												

Trial to understand the expansion joint



Junction



Junction relative movement at 28



Down, West, South
Found daily movement, month-long drift, climate effect, etc.
These are related to those observed in laser PD long-term result.

KEK Review Higo

4. Near future developments

We should study and develop cures against floor movement

- Near future for Phase-I
 - Make quantitative analysis at more places and more in systematic manner
 - Try to monitor movement with beam
 - May study other monitor methods, such as HLS
- Development for phase-II and -III
 - Beam steering by targeting golden orbit
 - Movers, at least locally
 - Sophisticated compensation such as offset injection

Possible time frame in mind

	2015													2016												2017												2018												
	1	2		3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	: #	1	1 2	2 3	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	# 3	#
MR														Ρ	ha	ase	∋−l	ĺ	1n	С											Ρ	ha	s	e-i	II	<mark>2</mark> n	С			*	**	**	÷5r	n C						
DR			Τ																						C	R	c	or	ni	ss	sio	ni	ng	5																
Lin	a c	A	٨li	gr	۱m	e	nt																																											
	RF Gu												Jn	f	or	el	ec	tro	on																															
	More p														s	itr	on	b	ea	m																														
			Low emittance beam study																																															
									Study for lower emittance ar															nd	d higher charge																									
	In	Initial alignment																								Т	٥v	vai	ŗd	fι	III	be	ar	n																
	С	01	nt	in	u	bu	s	m	ea	su	re	m	en	ţ																																				
					PI	כ	fa	br	ica	ati	ion	1																																						
									Μ	or	е	m	ea	su	re	em	en	t	ро	int	s								_																					
				_						Strategy discussion																																								
											Design monitor and mo													ov	er	-																								
																	Α	f	ew	t	es	t s	sys	st	en	<u>n</u> 1	fal	b.	_																					
			_																	Ir	ıst	al	L																											
																							Т	es	st	fe	ee	db	ac	ck																				
			1																							Hard ware prepar											ara	aiton												
			1																														I	าร	ta	II														
			1																																	A	ct	ะนอ	ų I	us	ag	;e								

Concluding remarks on alignment

- **1.** Girder stiffening done.
- 2. Most of the hard wares set in the beam line, except for pulse-Q.
- 3. Initial girder alignment done with the residual ~0.3mm in sigma over 500m line.
- 4. Hard wares alignment on each girder improved to be 0.05mm in sigma.
- 5. Local smoothness will be improved by laser tracker.
- 6. Floor moves a few mm in half a year, mostly at expansion joint, while the daily motion ~0.1mm.
- 7. Floor movements should be evaluated at more points and with beam study to develop a practical cure method.