WG B- Beam Dynamics In High Intensity Linacs

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Abstract

Grid noise and entropy growth, equi-partioning, equi tune depression, halo, and losses were a few topics, which were discussed thoroughly during parallel session for beam dynamics in high intensity linacs (group B). Linac designs for the future, under construction, upgrade and the existing linacs from around the world were presented in three working sessions.

A total of 17 talks were presented. Three presentations are general beam dynamics in nature and twelve talks were project specific. One talk was new experimental work on the Gabor lens to neutralize space charge. The detail of each contribution can be found in these proceedings. Here we report the summary of the discussions and some concluding remarks of general interest to all the projects presented in the working group.

INTRODUCTION

Beam Dynamics of High Intensity Linacs (working group B) had 17 invited/contributed talks and two poster presentations. Unfortunately five participants could not attend due to visa problems. Two talks were upgraded from the poster session.

Three talks were presented on tele-conference. The first time it took unusually long time to set up, and one of the discussion sessions was cancelled. These presentations included two on linac beam dynamics, nine on design of linacs for specifics projects. Out of them two talks were designed to generate discussion and had one two hours long discussion session.

GENERAL BEAM DYNAMICS FOR LINACS

Noll presented his new code BENDER, which allows fully self-consistent inclusion of space charge compensating electrons.

Hofmann discussed grid noise and entropy growth in PIC code, in particular with TraceWin examples. He found in his studies there exists an optimum number of grid cells below which grid heating dominates and above collision heating. Secondly, anisotropy effects are in good agreement with theory.

Nghiem proposed new concepts and methods for beam analysis, beam loss prediction, beam optimization, beam measurement and beam characterization in case of “very high intensity beams”.

Eshraqi proposed a linac design based on equi-tune-depression instead of equi-partition lattice design for linacs. He showed that since linac beams are usually pretty spherical choosing an equi-partitioned point in the linac is very close to having an equi-tune-depressed lattice.

Other noteworthy results were reported by Yong Liu. For J-PARC linac simulations he showed that his non equi-partitioned lattice is an order of magnitude more sensitive to errors than an equi-partitioned lattice.

For the Gabor lens study partial agreement with modelling was achieved, but more work is needed to better understand the limitations.

Groenings work on emittance transfer between horizontal/vertical is of interest for linacs as injectors into rings with horizontal multi-turn injection. The transfer requires stripping and matches with low charge state ion linacs as for the FAIR synchrotron.

In HB2012, Lagniel raised the question about validity of equi-partition theory and lattices in his talk entitled, “Equipartition Reality or Swindle”[1], Discussions in HB2012 hinted there is more work (simulations) needed to reach consensus [2]. Since then further simulations were published by Hofmann in response to Lagniel’s arguments [3].

BEAM DYNAMICS DESIGN OF LINACS

Table 1 gives a brief description of the linacs discussed in the WG-B at HB2014. Two high power linacs, ESS and ADS, were optimized for different parameters. The ESS linac is optimized for cost by reducing the number of cavities and increasing the peak current by 25% and the cavity gradient by 11.25% keeping the beam power at 5 MW. The ADS lattice is optimized for losses by increasing the longitudinal acceptance and avoiding the longitudinal parametric and transverse structure resonances and longitudinal –transverse coupling.

The J-PARC linac was upgraded to 400 MeV from 181 MeV, ion source and RFQ were also changed with better performing units. They were expecting a signature of intra-beam-stripping but did not fine any indication of intra-beam stripping. The SNS linac production tune still does not match with modelling in spite of better calibration of the measurement devices and modified methods. The linac was able to achieve the design goal of 1.4 MW beam power.

DISCUSSIONS SESSION

In the discussion session following topics were discussed:

- Equi-partition verse equi-tune-depressed lattice were discussed:

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It was not clear, if the equi-tune-depression idea has a real physics basis other than intuition.

- Non-equipartitioned J-PARC linac lattice is more sensitive to error:
  In HB2012 it was reported that intra-beam stripping optimized lattices will have 50% more emittance growth [3], but no one suspected that the error sensitivity would be an order of magnitude worse. The suspicion is that due to the bigger beam size in intra-beam stripping lattices, they sample more nonlinearity of the RF field.
- Grid noise and entropy growth in PIC codes:
  In the interest of keeping simulation noise at low level it is not advisable to go beyond 8-10 grid cells in TraceWin or work with less than 10^5 particles (error studies).
- Relations between emittance and halo:
  Several examples were discussed, where these two quantities do not depend on each other.
- Automatic correction for closed orbit and micro-loss:
  While automated closed orbit correction is successfully working in several accelerators, the same algorithm should work to reduce losses. It could lead to local minimization, since one cannot go very far from the working point with full power, which might damage the accelerator before finding the minimum. This technique may reduce losses but cannot predict a path to upgrade.
- Figure of merit: emittance or losses:
  High power linacs with fixed target are usually CW and have their figure of merit as beam loss, whereas high intensity linacs as pulsed injectors need as figure of merit the emittance.

REFERENCES

[1] Jean-Michel Lagniel, “Equipartition, Reality or Swindle?”, HB2012

[2] D. Raparia, P. A. P. Nghiem and Z. Li, “Summary of Working group B”, HB2012

[3] I. Hofmann, “A New Approach to linac resonances and equipartition?” http://arxiv.org/abs/1210.7991

Table 1: LINAC Presented in HB2014

	Ions	RR (Hz), PL(ms) /CW	Freq. MHz	C mA	E GeV	P MW	$Trans_{SC}$ MeV	Structures	Chop. Loc.	E_{RFQ}(MeV) L_{MEBT}(m)
ESS	P	RR :14 PL:2.86	352.2/704	62.5	2.0	5	90	DTL,SSR,EC1,EC2	MEBT	E: 2.5 L: 4
FRIB	P-U	CW	40.25/80.5/322	8.4p	0.2 (/u)	0.400	0.3 (/u)	QWR,HFR	-	E: 0.3/u L: 4.8
C-ADS	P	CW	162.5,325/650	10	1.5	15	2.1/3.2	HW09,SSR12,SSR21, SSR40,EC63,EC82	-	E: 2.1,(3.2) L: 2.7 ,4
C-SNS	H^-	RR: 25 PL=0.5	324	20	80		-	DTL	LEBT	E: 3 L: 0
T-Singhua	P	RR: 50 PL: 0.5	325	50	13	0.16	-	DTL	-	E: 3 L: 0
J-PARC	H^-	RR: 25 Pl: 0.5	324/972	50	400		-	DTL,ACL	MEBT	E: 3 L: 3
SNS	H^-	RR: 60 PL: 1	402/804	38	1		185	DTL,CCL,EC62,EC82	LEBT & MEBT	E: 2.5 L: 3.64
IFMIF	D+	CW	175	2x125	0.04	2x5	5	HW	LEBT	E: 5 L: 9.8

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