WG-B: BEAM DYNAMICS IN HIGH INTENSITY LINACS

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Abstract

Emittance coupling, equipartioning 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 18 talks were presented. Five presentations are general beam dynamics in nature and twelve talks were project specific. The detail of each contribution can be found in these proceedings. Here we report the summary of the discussions and some concluding remarks of the general interest to all the projects presented in the working group.

INTRODUCTION

Beam Dynamics of High Intensity Linacs (working group B) had 18 invited talks and 15 poster presentations. These presentations included three on linac beam dynamics, nine on design of linac for specifics projects, two reports from operating linacs, one on RFQ design recopies, one on loss mechanism in H- linacs and one for multi MW proton linac design challenges. Out them two talks were designed to generate discussion and had one two hours long discussion session.

GENERAL BEAM DYNAMICS FOR HIGH INTENSITY LINACS

Hofmann discussed in detailed emittance coupling in the intense beam and can be summarized as (1) equipartition beam is not necessary to avoid emittance exchanged, it is enough if one avoid resonance region in Hofmann charts, (2) emittance exchanged depends on the crossing speed (inversely proportional) of resonance stop-bands and (3) on equipartition, even main resonance will disappear but splitting of emittances and consistent emittance growth may happen.

Lagniel raised question about validity of equipartition in his talk entitled, “Equipartition Reality or Swindle”, which was followed by long and lively discussion. Discussions hinted there is more work (simulations) needed to reach any conclusion.

Nghiem tried proposed a new definition of the halo particles arguing existing definitions are too abstract and definitions decide in advance where should be the halo. According to proposed definition the location of steepest density variation, i.e. where the second derivative is maximum in case of 1-D distribution, separate halo particles from the core particles.

BEAM DYNAMICS DESIGN OF LINACS

Table 1 give a brief description of the linacs discussed in the WG-B at HB2012. These linacs accelerate variety of particles to different energies and beam powers using different frequencies. The block diagram of these linacs depends on the mode of operation; pulse or continuous wave (CW). The pulse linac usually used as injector to circular machine with higher pulse current and lower beam power compared to CW linacs. CW linacs are used for fix target except ESS, which is a pulse linac. The front-end of these linacs have the same structure namely, a source, a low energy transport (LEBT), and a RFQ. Following structure depends on the nature of operations, CW linac start superconducting structure right after RFQ to avoid large power consumption and associate problems of structure cooling. Pulse linacs have warm cavities after RFQ. The transition energy between warm and superconducting part of the linac is coming down as the superconducting technologies getting mature. For example, in case of SNS the transition energy is about 187 MeV whereas ESS proposing about 80 MeV. Superconducting structures at lower energies have much lower (< factor of 5) phase advance per meter in compare to warm structures (DTL, CCDTL). The lower longitudinal focusing forces per meter make beam susceptible to longitudinal beam halo, which tends to loss at higher energies. Although spoke cavities have not yet seen any beam through it, every future linac design have these cavities.

An essential element for pulse linac is a chopper and is generally located after RFQ, to provide gap in the pulse train for rise time of a kicker magnet (to kick the beam out of beam line or out of circular machine). The most demanding requirement for the chopper is in the case of Project-X, where beam need to chop bunch-by-bunch basis. It is interesting to see CSNS move chopper from MEBT to LEBT to reduce losses in linac, whereas ESS added the chopper after the RFQ.

A different design recipe for RFQ was presented. In this method the focusing parameter B is varied as the beam bunches to compensate RF defocusing, instead keeping it constant as in the present RFQs.

In spite of all these differences and peculiarities, the design guide line is the same for all these linacs: (1) a zero-current phase advance per period less than 90 degrees to avoid structure resonances, (2) a smooth phase advance per meter to avoid mismatches, (3) tunes chosen to avoid the radial – longitudinal coupling resonances in the Hoffmann chart (4) and tried to follow equipartition rule.

DISCUSSIONS SESSION

In the discussion session following topics were discussed:

- RFQ design to improve longitudinal beam quality.
  Realization in linac community is settling in that the longitudinal halo generated at lower energies are getting lost at higher energies. A long discussion was held how to improve longitudinal beam quality out of RFQ
- Transition energy of warm to super conduction section.
  Generally transition energy between warm and super conducting section of linac is chosen based on the available technologies rather than the beam dynamics considerations. ESS transition energy is based on the simulation to minimize the emittance growth.
- Calculated versus empirical lattice: Are operator tuning on the halo instead of core beam?
  It has been experienced of many operating linacs that production tunes are much different than the design tune. It was felt that the linacs are tuned on halo rather than the core of the beam to reduce the losses.
- J-PPARC upgrade: IBS versus equipartition lattice
  J-PARC upgrade includes adding warm linac from 180 to 400 MEV with frequency jump by a factor of three. To keep the equipartition lattice, one has to increase transverse focusing. This results smaller beam size, which increases intra - beam stripping. If one moves away from Equipartition rule, resulted emittance grows 50%, which will increase losses in the ring.
- High power versus high intensity linacs.
  High power linacs with fixed target are usually CW and have figure of merit as beam loss whereas high intensity linacs are pulse injector, with figure of merit as emittance.

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Table 1: Linac Presented in HB2012

	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)
Proj.-X	H^-	CW	162.5/325/ 650	1	3	3	2.1	HW,SSR,ECC	LEBT& MEBT	E: 2.1 L: 10
ESS	P	RR :14 PL:2.86	352.2/704	50	2.5	5	80	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
Linac 4	H^-	RR:2 Pl=0.4	352.2	40	160	0.005	-	DTL,CCDTL,SCL	MEBT	E: 3. L: 3.7
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	30	400		-	DTL,ACL	MEBT	E: 3 L: 3
FNAL	H^-	RR:15 PL: .08	201/804	60	400		-	DTL,CCL	LEBT	E: 0.750 L: 1
SNS	H^-	RR: 60 PL: 1	402/804	38	1		185	DTL,CCL,EC62,EC82	LEBT & MEBT	E: 2.5 L: 3.64
EBIS	He-U	RR: 5 PL: 0.04	100.625	10	0.002 (/u)		-	IH DTL	-	E: 0.3(/u) L: 0.81
IFMIF	D+	CW	175	2x125	0.04	2x5	5	HW	LEBT	E: 5 L: 9.8