LCLS-II Technical Note

LCLS-II Cryomodule Quadrupole Roll Alignment Tolerances

LCLS-II TN-15-26

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Arun Saini, N. Solyak

1 Introduction

Nominal RMS alignment tolerances of components in LCLS-II cryomodules are listed in Table 1. Beamdynamics studies have been performed using those errors and results were presented elsewhere [1].

Table 1: Nominal RMS misalignment tolerances of elements in the LCLS-II cryomodules [2].

Error Source	RMS error	unit
Cavity X,Y misalignments wrt. CM	0.5	mm
Quadrupole X,Y misalignments wrt. CM	0.5	mm
BPM X,Y misalignments wrt. CM	0.5	mm
Cryomodule X,Y misalignments wrt. Linac	0.3	mm
Cavity Z misalignments wrt. CM	2	mm
Quadrupole Z misalignments wrt. CM	2	mm
BPM Z misalignments wrt. CM	2	mm
Cryomodule Z misalignments wrt. Linac	2	mm
Cavity tilt misalignments	0.5	mrad
Quadrupole tilt misalignments	3	mrad
BPM tilt misalignments	3	mrad
Cryomodule tilt misalignments	0.05	mrad
Cavity roll misalignments	10	mrad
Quadrupole roll misalignments	3	mrad
BPM roll misalignments	3	mrad
Cryomodule roll	2	mrad

2 Magnet Installation in Cryomodule

Quadrupole magnet is placed at the end in each LCLS-II cryomodule. Figure 1 shows a snapshot of cavity, BPM and magnet assembly.

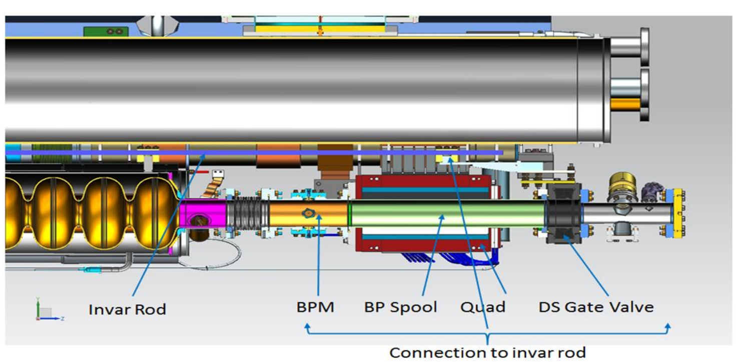
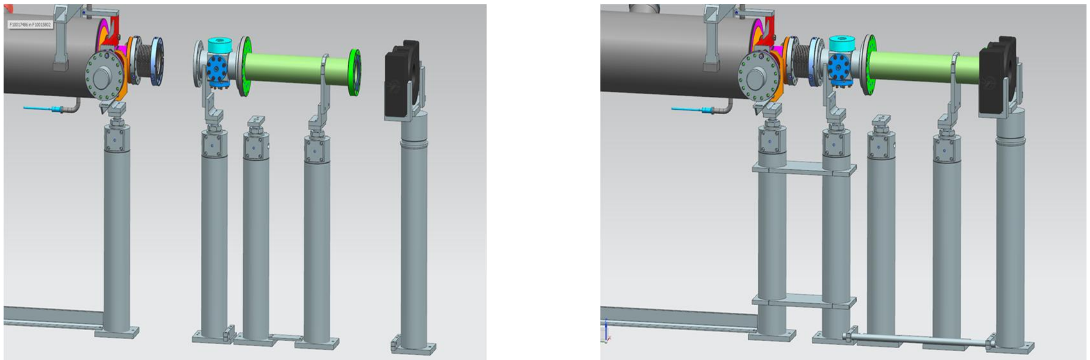


Figure 1: A snapshot of magnet assembly in cryomodule.

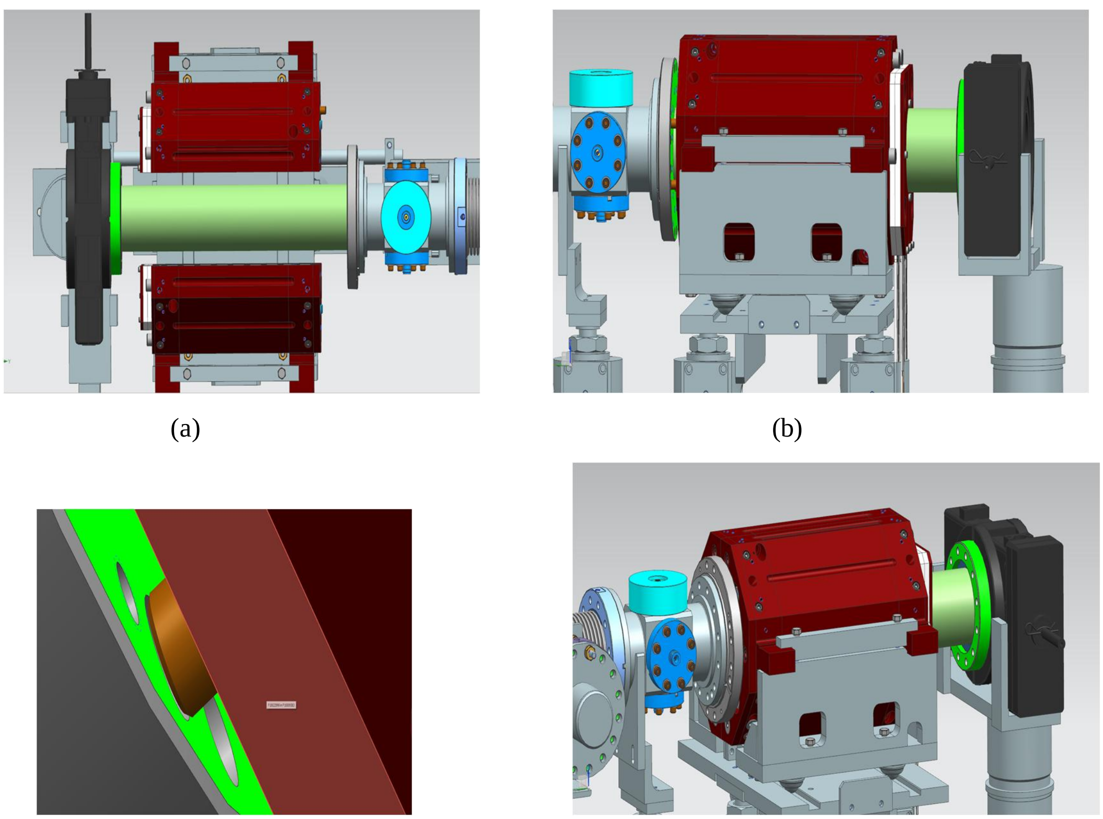
Cavity string, BPM, spool tube and downstream gate valve are installed in a clean room. Figure 2 shows their assembly procedure. First BPM and spool piece are assembled on a bench and then all parts are aligned and connected.



(a) (b)

Figure 2: (a) BPM, spool and Gate valves before and (b) after assembly in clean room.

Figure 3 shows magnet installation procedure outside the clean room. Connecting pins of magnets are aligned to respective holes in spool big flange. This rotation results in quadrupole roll errors. It is worth to mention here that rotation of spool flange (instead of magnet) is avoided as it could cause a twist at cavity bellows-end. This in turn, might result in a vacuum leak in cavity.



(a) (b) (c) (d)

Figure 3: Magnet Installation procedure (a) Preparation of magnet around spool. (b) The half of the magnet connected around spool tube. (c) Pins of magnets are aligned w.r.t. holes in big spool flange. (d) Magnet attached to spool tube.

2.1 Mechanical tolerances for pin-holes locations

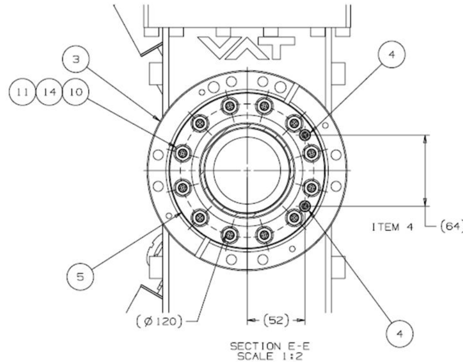


Figure 4: Lateral view of spool flange.

Assuming all holes are located at radius of 60 mm, 3 mrad quad roll allows ~180 μm shift in pin-hole positions. However, measurement at DESY suggests that pin-holes are usually out of tolerances by 0.35 mm. Thus, relaxing quadrupole rolls to 6mrad would help to satisfy the mechanical tolerances on pin-holes locations.

3 Implication of Quad Rolls on Beam Optics

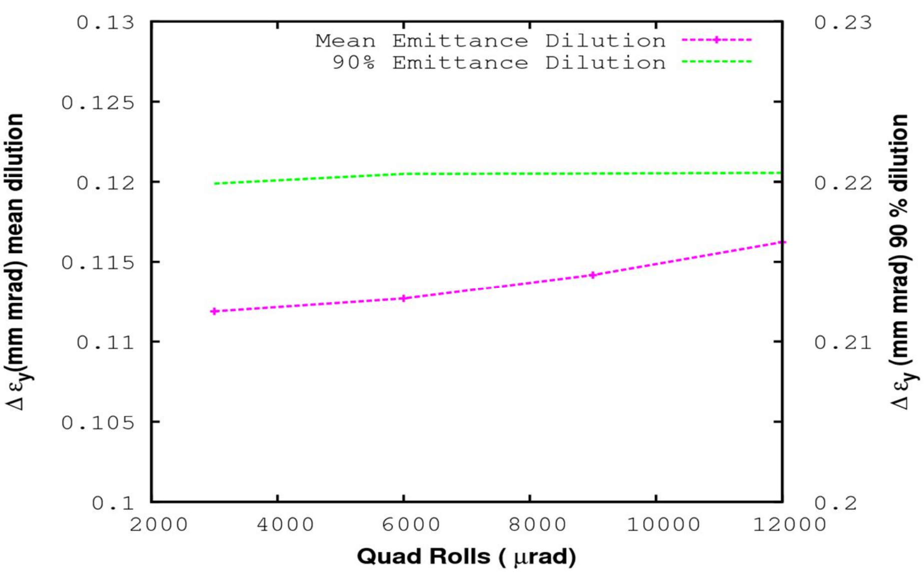


Figure 5: Variation in Mean emittance and 90 % emittance growth with quadrupole rolls in L3 section.

In order to understand implication of quad rolls on beam optics, we applied all other nominal misalignment errors (shown in Table 1) and varied quad rolls errors. Because L3 is longest section of linac, we perform this study for L3 section. We used 50 machines for this analysis. Figure 5 shows variation in mean emittance growth (primary y-axis) and 90 % emittance growth (secondary y-axis) with quad rolls. It can be observed from figure 5 that there is no significant emittance growth even after applying RMS quad rolls of 12 mrad.

Quadrupole rolls result in coupling between horizontal and vertical planes that leads to emittance exchange between them. However, beam transverse size in LCLS-II linac is round. Beam phase advance and emittance in horizontal and vertical planes are also same. Thus, this optics inhibits emittance exchange condition. Thus, even with large quad rolls, there is no significant emittance growth.

4 Conclusion

Relaxing quad rolls from 3 mrad to 6 mrad allows to meet the mechanical specification of pin-hole on spool flange. We did not observe any significant implication of quad rolls on beam optics for L3 linac.

References:

[1] “Studies of Misalignment Tolerances for SC Linac of LCLS-II,” LCLSII-TN-14-03.
https://portal.slac.stanford.edu/sites/lcls_public/lcls_ii/acc_phy/technotes_lib/LCLS-II-TN-14-03.pdf

[2] “SCRF 1.3 GHz Cryomodule,” Physics Requirements Document (PRD), LCLSII-4.1-PR-0146-R0.
https://docs.slac.stanford.edu/sites/pub/Publications/SCRF_1.3_GHz_Cryomodule.pdf