LCLS MEMORANDUM

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To: Recipient name(s)
From: P. Emma, H-D. Nuhn, J. Welch

Subject: Outstanding commissioning problems to work out

In anticipation of the workshop on commissioning at UCLA, January 19 and 20 we have compiled a short list of relevant analysis needs which may help advance the development of specifications and designs for xray diagnostics as well as commissioning plans.

1. In an ideal undulator the total spontaneous radiation power is proportional to the distance along the undulator, at least until a significant amount of the power is lost to the vacuum chamber through the $1/\gamma$ or $\sqrt{1+K^2/2}/\gamma$ angular divergence. At 4.54 GeV an angle of $\sqrt{1+K^2/2}/\gamma$ intersects a 3 mm radius vacuum chamber in about 10 m. Clearly the vacuum chamber has a major role in determining the total spontaneous radiation power at the diagnostic locations. For the design of diagnostics we need a detailed calculation taking into account losses to the vacuum chamber of the intensity and spatial distribution of the *detectable* spontaneous radiation and FEL radiation at all diagnostic stations: within the undulator, in the front end enclosure, in the Near Hall, and in the Far Hall. The effect of the vacuum chamber might be roughly bracketed by two assumptions: one that the chamber is perfectly absorbing and the other that the chamber is perfectly reflecting and the reflected rays are uniformly distributed across the chamber cross section. In this regard the following electron beam conditions are of particular interest for commissioning and operation:

   - 4.5 GeV with relaxed electron parameters (see table below)
   - 4.5 GeV with standard CDR parameters
   - 14.1 GeV with standard CDR parameters

2. Will it be possible to tune up the undulator *in situ*? We need to quantify our ability to measure the effect of phase or average K errors from individual segments by either the trajectory distortion method or by intensity measurements with the intra-undulator xray diagnostic stations. To do this we must first calculate the nominal intensity at these locations, then calculate the changes that will occur for a given phase error, and then calculate how well the diagnostics can see these changes. These calculations should be carried out for the 14.1 GeV conditions as well as the relaxed commissioning parameters at 4.5 GeV. A certain amount of phase control for individual segments will be available in the form of the piezoelectric tuners at the segment end, and hopefully from the comb structure for adjusting overall K. These calculations will show if such control can be used during operation to tune up the FEL. Along this line of enquiry one might consider whether the laser heater can be used to delay saturation in order to get more phase error sensitivity for the downstream undulator segments.

Table 1: Parameters for FEL saturation at 15 Å with 0.5 nC of bunch charge. Also listed is the nominal design at 1.5 Å with 1 nC. In both cases: $K = 3.64$ and $\lambda_u = 3$ cm.

parameter	**symbol**	**15.0 Å**	**1.5 Å**	**units**
electron energy	E_0	4.54	14.1	GeV
bunch charge	Q	0.5	1.0	nC
transverse norm. emittance	$\gamma\epsilon_{x,y}$	4.0	1.2	μm
final peak current	I_{pk}	1.0	3.4	kA
final rms bunch length	σ_z	44	25	μm
final rms energy spread	σ_E/E_0	1.8	1.0	10^{-4}
rms e^- beam size	$\sigma_{x,y}$	67	33	μm
FEL parameter	ρ	5.7	4.5	10^{-4}
est. und. BPM resolution	σ_{BPM}	6	2	μm
3D gain-length × 20	$20L_G$	115	85	m
FEL power at saturation	P_{sat}	0.7	18	GW
orbit straightness (over 10 m)	δx	6	2	μ m
segment tuning	$\Delta B/B$	4	1.3	$\times 10^{-4}$ (rms)