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Speculation Concerning Diamond as an Optimum Crystal Based on Ability to Withstand High Electric Field Strengths

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SPECULATION CONCERNING DIAMOND AS AN OPTIMUM CRYSTAL BASED ON ABILITY TO WITHSTAND HIGH ELECTRIC FIELD STRENGTHS

As shown in the accompanying Table[1], the peak optical field strengths predicted for the LCLS are 3.3 to 3.8 V/Angstrom , a daunting value since it well known that fields of this magnitude are sufficient to "evaporate" crystals.

Some guidance as to which crystals are better able to withstand such fields is available from the work done in Field-Ion Microscopy studies. Atomic resolution is obtained by sharpening tungsten needle-tips to a radius of ~100 nm and applying a voltage. Due to the sharp curvature, fields of many volts per Angstrom are readily obtained. The field required to "evaporate" atoms from the end of such a tip is available . In some cases this must be calculated due to the difficulty in making tips. In other cases (such as tungsten) it can be measured. In Table 2 are listed values for the evaporation fields for a set of crystal materials of significance to x-ray optics (plus tungsten for comparison)

Table 2. Evaporation fields[2] in units of (V/ Angstrom)

Be	**4.6**
C	**10.3**
Si	**3.3**
Ge	**2.9**
W	**5.9**

Although these values are for static fields, an instrument called an "atom-probe field ion microscope" employing pulsed fields with pulse durations as short as 10 nanoseconds has been extensively tested.[3]

Carbon (i.e., diamond) is a clear standout in Table 2 with the highest evaporation field. There are many caveats to this conclusion, especially with regard to the short pulse duration (0.00028 nanosec) of projected FEL x-ray pulses. In the absence of firmer calculations , however, the above values for the evaporation fields when compared to the projected LCLS peak fields are not discouraging.

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[1] LCLS Design Study Report, http://www.slac.stanford.edu/pubs/slacreports/reports03/slac-r-521-ch10.pdf
[2] K.M Bowkett and D.A. Smith, "Field-Ion Microscopy", North-Holland, 1970.
[3] E.W. Muller and T.T. Tsong, "Field Ion Microscopy, Field Ionization and Field Evaporation", Pergamon,

Table 10.1-1. Optical and source parameters of the LCLS. Undulator K=3.71. N_U=3328 periods. Undulator period λ_U=3 cm.

Parameter	Value	
Radiation wavelength [Å]	1.5	15
Norm. emittance $\gamma\varepsilon$ [mm-mrad]	1.5	2.0
Electron energy [GeV]	14.35	4.54
Peak current [A]	3400	3400
Bunch duration [fs, FWHM]	277	277
Peak spontaneous power [GW]	81	5
Peak coherent power[a] [GW]	9	11
Average coherent power[b] [W]	0.31	0.35
Energy/pulse [mJ]	2.5	0.64
Coherent photons/pulse ($\times 10^{12}$)	1.9	23
Approximate bandwidth (BW) [%]	0.1	0.1
Peak brightness[c] ($\times 10^{32}$)	12	1.48
Peak degeneracy parameter [$\times 10^{9}$]	3.3	412
Average brightness[c] ($\times 10^{21}$)	40	4.9
Transverse size [μm, FWHM] [d]	78	93
Divergence angle [μrad, FWHM] [d]	1	8
Spontaneous fundamental opening angle [μrad, FWHM]	4.9	15.5
Spontaneous fundamental transverse size [μm,FWHM]	82	131
Peak Power Density [W/mm^2] [d] ($\times 10^{12}$)	1.88	1.62
Peak Field [V/m] [d] ($\times 10^{10}$)	3.8	3.3

a. Output fully transversely coherent.

b. At 120 Hz rep rate.

c. Photons/s/mm^2/mrad^2/0.1%BW.

d. At exit of undulator.