USPAS FEL 2021 Homework Set 4

4.1 The hard X-ray self-seeding spectra at a new X-ray FEL are shown in Figure 1 below. The following pieces of information are known about this X-ray FEL:

SASE temporal pulse length (FWHM)	$\Delta t_{SASE} = 30$ fs
Measured SASE bandwidth (FWHM)	$\Delta E_{SASE} = 10$ eV
Measured Self-seeded bandwidth (FHWM)	$\Delta E_{SS} = 0.72$ eV

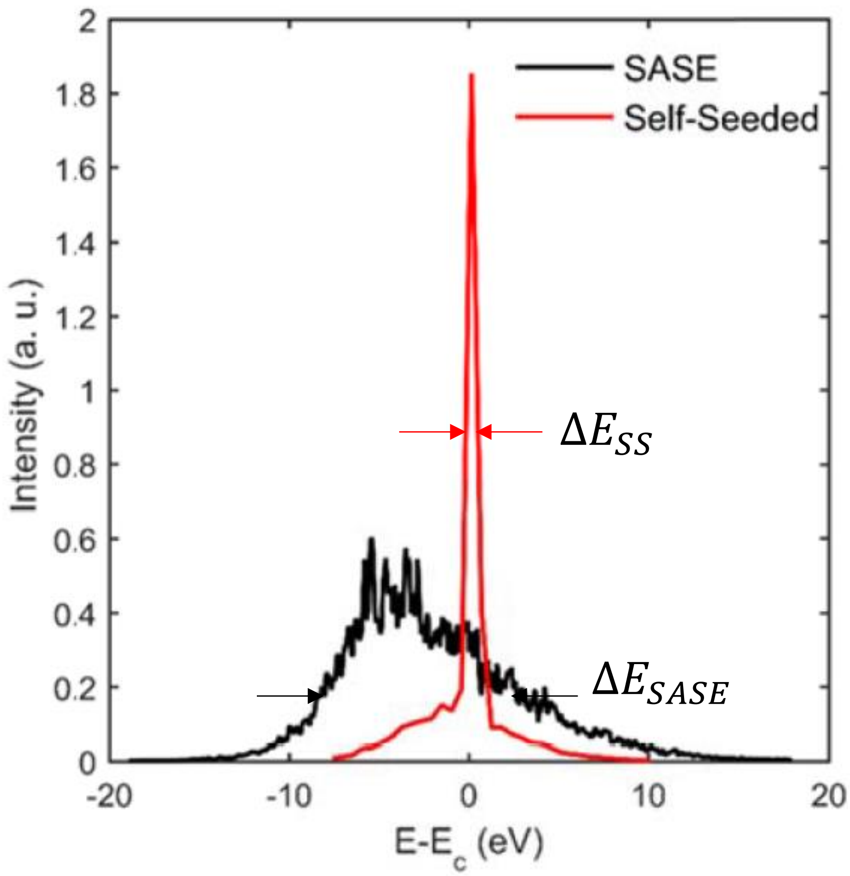

Figure 1

a) Calculate the number of modes (spikes) in a typical SASE pulse. Show the approach you use to arrive at the result.
b) Calculate the SASE pulse energy fluctuation relative to the average SASE pulse energy.
c) Calculate the number of modes (spikes) in a typical Self-Seeded pulse. Again, show your approach.
d) Calculate the Self-Seeded pulse energy fluctuation relative to the average Self-Seeded pulse energy.

4.2 Sideview of the SACLA HXRSS channel-cut Si crystal (Fig. 2).

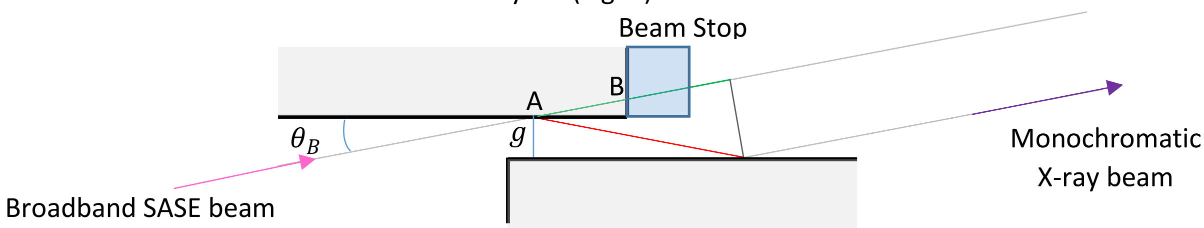

Figure 2

a) Show that the monochromatic x-ray beam following the diffracted path (red) travels a distance Δl

$$\Delta l = 2gsin\theta_B$$

longer than the broadband SASE beam following the straight-through path (green); g is the gap of the channel in the Si 111 channel-cut crystal.

b) What is the reason for keeping the distance between point A and point B as short as possible? As shown in Figure 2, point A is where the broadband SASE beam enters the Si crystal, and point B is where it exits the Si crystal and enters the beam stop.

4.3 The LCLS soft x-ray self-seeding chicane consists of four dipole magnets (Fig. 3) with equal lengths of 0.365 m. The distance between the B1 and B2 (and also between B3 and B4) magnets is 0.828 m. You are required to match the electron beam delay to the 663 fs delay of the x-ray beam. Using the above information, calculate the angle θ that the electron beam makes with respect to the horizontal path.

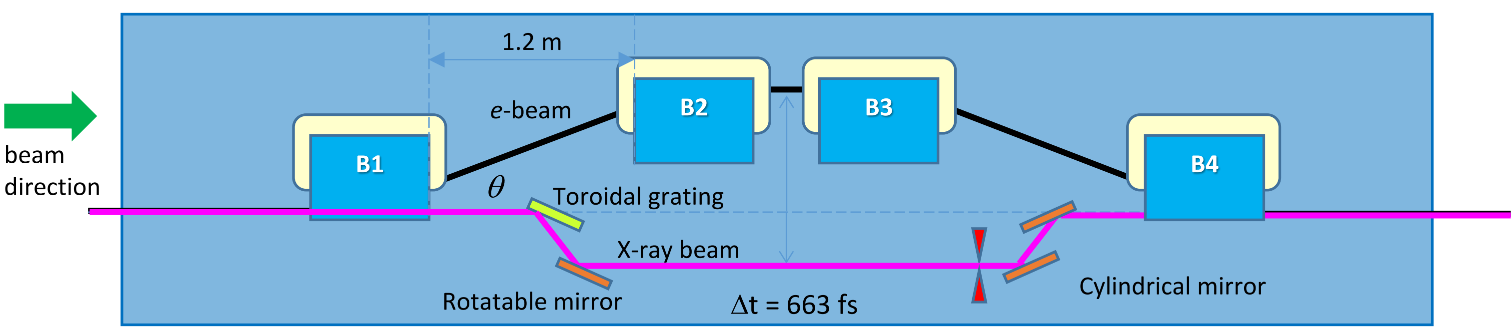

Figure 3

4.4 From slide 48 of the FEL_3 lecture notes, expand the expression for the small-signal gain at the peak of the gain curve to show that the small-signal gain can be written as

$$G_{SS} = (0.0675)4\pi \left(\frac{N_u}{\gamma}\right)^3 \left(\frac{\widehat{K}\lambda_u}{\sigma_b}\right)^2 \left(\frac{I}{I_A}\right)$$