TUP057

MEASUREMENT OF HIGH-GAIN FREE-ELECTRON LASER TEMPORAL COHERENCE LENGTH BY A PHASE SHIFTER

Gaunqun Zhou, IHEP, Beijing, P.R. China
Juhao Wu, Cheng-Ying Tsai, SLAC National Laboratory, Menlo Park, CA, USA
Moohyun Yoon, Department of Physics, POSTECH, Pohang, Korea
Chuan Yang, NSRL, USTC, Hefei, Anhui, China

Abstract: High-gain free-electron lasers are now well established as ultra-fast, ultra-brightness, coherent X-ray sources. Since coherence is one of the fundamental properties of light source, continuous efforts on high-gain free electrons laser (FEL) coherence measurement are made. Here, we propose a possible approach, employing the phase shifter to induce electron beam delay to measure the temporal coherence length. Simple analysis, numerical simulation and preliminary experiment results are presented. This approach is frequency-independent.

†gzhou@SLAC.Stanford .EDU † jhwu@SLAC.stanfor.EDU

Theory

one-dimension linear model based on coasting beam approximation:

Time domain

$$\frac{\partial A(\bar z,\bar s)}{\partial \bar z}+\frac{\partial A(\bar z,\bar s)}{\partial \bar s}=B(\bar z,\bar s) \quad (1)$$

$$\frac{\partial B(\bar z,\bar s)}{\partial \bar z}=P(\bar z,\bar s) \quad (2)$$

$$\frac{\partial P(\bar z,\bar s)}{\partial \bar z}=iA(\bar z,\bar s) \quad (3)$$

Frequency domain

$$\frac{\partial a(\bar z,\Delta)}{\partial \bar z}+i\Delta a(\bar z,\Delta)=b(\bar z,\Delta) \quad (4)$$

$$\frac{\partial b(\bar z,\Delta)}{\partial \bar z}=p(\bar z,\Delta) \quad (5)$$

$$\frac{\partial p(\bar z,\Delta)}{\partial \bar z}=ia(\bar z,\Delta) \quad (6)$$

Cubic equation solution

$$\mu^3-\Delta\mu^2+1=0 \quad (7)$$

$$\mu=-\frac{\sqrt{3}}{2}i+\frac{1}{2}+\frac{\Delta}{3} \quad (8)$$

Field solution in frequency domain

$$a(\bar z,\bar s)=\frac{1}{3}[a(0,\Delta)+(-\frac{1}{2}i+\frac{\sqrt{3}}{2})b(0,\Delta)+(\frac{1}{2}-\frac{\sqrt{3}}{2}i)p(0,\Delta)]e^{\frac{\sqrt{3}}{2}\bar z+(\frac{\Delta}{3}+\frac{1}{2})i\bar z} \quad (9)$$

Field solution in time domain

$$A(\bar z,\bar s)=\frac{1}{3}[A(0,\bar s+\frac{\bar z}{3})+(-\frac{1}{2}i+\frac{\sqrt{3}}{2})B(0,\bar s+\frac{\bar z}{3})+(\frac{1}{2}-\frac{\sqrt{3}}{2}i)P(0,\bar s+\frac{\bar z}{3})]e^{\frac{\sqrt{3}}{2}\bar z+\frac{i}{2}\bar z} \quad (10)$$

Including phase shifter

$$\frac{\partial A(\bar z,\bar s)}{\partial \bar z}+\frac{\partial A(\bar z,\bar s)}{\partial \bar s}=B(\bar z,\bar s+\delta\bar s) \quad (11)$$

$$\frac{\partial B(\bar z,\bar s+\delta\bar s)}{\partial \bar z}=P(\bar z,\bar s+\delta\bar s) \quad (12)$$

$$\frac{\partial P(\bar z,\bar s+\delta\bar s)}{\partial \bar z}=iA(\bar z,\bar s+\delta\bar s) \quad (13)$$

Field solution in time domain

$$A(\bar z,\bar s)=\frac{1}{3}\{A(\bar z_0,\bar s+\frac{\bar z}{3})+[(-\frac{1}{2}i+\frac{\sqrt{3}}{2})B(\bar z_0,\bar s+\frac{\bar z}{3})+(\frac{1}{2}-\frac{\sqrt{3}}{2}i)P(\bar z_0,\bar s+\frac{\bar z}{3})]e^{ik_s\delta\bar s}\}e^{\frac{\sqrt{3}}{2}\bar z+\frac{i}{2}\bar z} \quad (14)$$

Expected to have interference Pattern

The work was supported by the US Dependent of Energy (DOE) under contract DE-AC02-76SF00515 and the US DOE Office of Science Early career Research Program grant FWP-2013-SLAC-100164

Numerical simulation

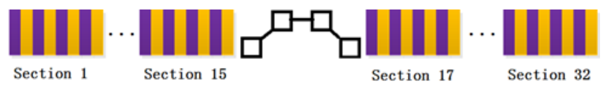
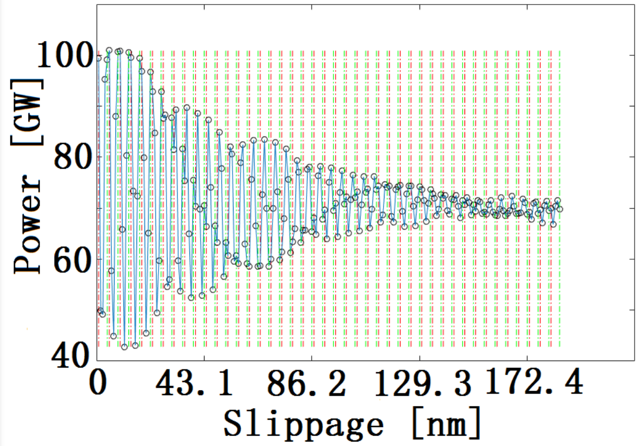
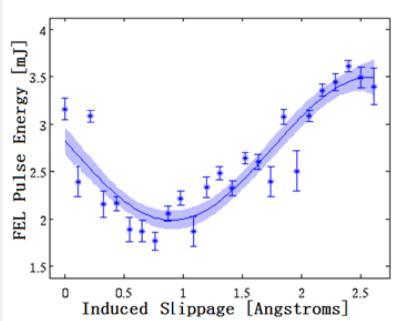


Figure 1: LCLS undulator system, the phase shifter is placed at Section 16

In our case, the temporal coherence length is about $N\lambda_s/3 \sim 151.53$ nm, where N is the total number of undulator periods. At the end of the 15th undulator, N equals to 1650. We can find that the temporal coherence length is roughly about 150 nm.



On-going experimental efforts at LCLS



At the moment, we have scanned the phase difference within 2π. The experimental results agree with our analysis and simulation well. It is worth to point out that this approach is frequency-independent.

Summary and Conclusion

In this paper, we have presented a simple analysis of FEL including a phase shifter in time domain. We find that when phase difference is quite small, FEL power oscillates with respect to the electron beam delay. However, when the phase difference is greater than the temporal coherence length, the radiation would not change much. Based on the analysis, we propose an approach to measure the FEL temporal coherence length by scanning the electron beam delay. Numerical simulation and preliminary experiments at LCLS show that this approach can be potentially developed to measure the FEL temporal coherence length. Effects of the momentum compact factor R_{56} on temporal coherence will be presented in further studies and the experiments using this approach to measure the FEL temporal coherence length at LCLS is on our schedule. Also, this study will help us understand the performance of slippage enhanced SASE.