XFELO 、最近の話題

羽島　良一

2012年3月28日

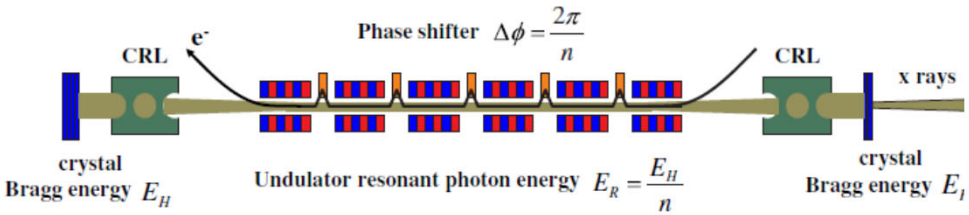
ERLビームダイナミクスWG

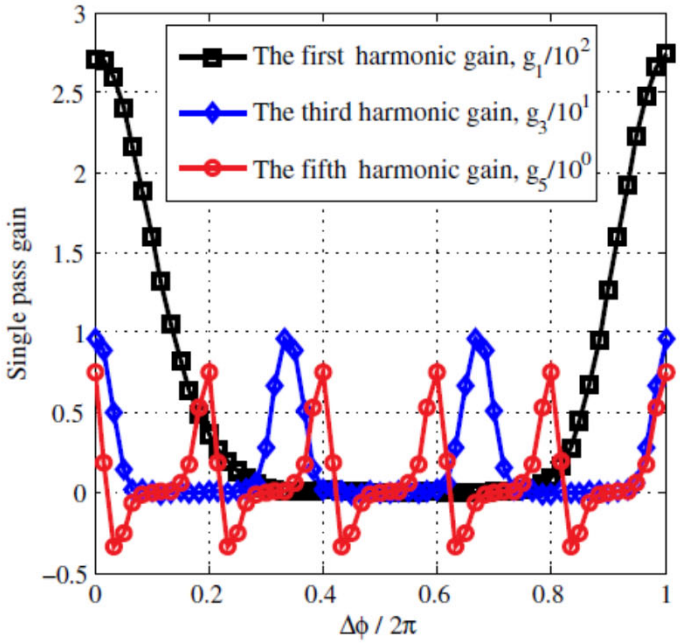
3次高調波によるXFELO

PRL 108, 034802 (2012) PHYSICAL REVIEW LETTERS week ending 20 JANUARY 2012

Proposal for an X-Ray Free Electron Laser Oscillator with Intermediate Energy Electron Beam

Jinhua Dai, Haixiao Deng,* and Zhimin Dai
Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai, 201800, China
(Received 16 July 2011; published 19 January 2012)



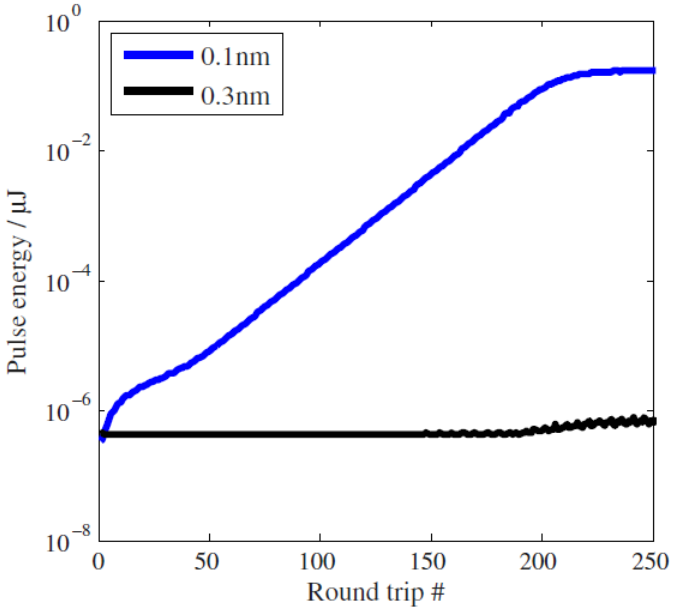


3.5 GeV electron で 12keV のXFELO を発振

アンジュレータ間の位相シフトで基本波の
発振を抑制し、3次高調波のみを発振する

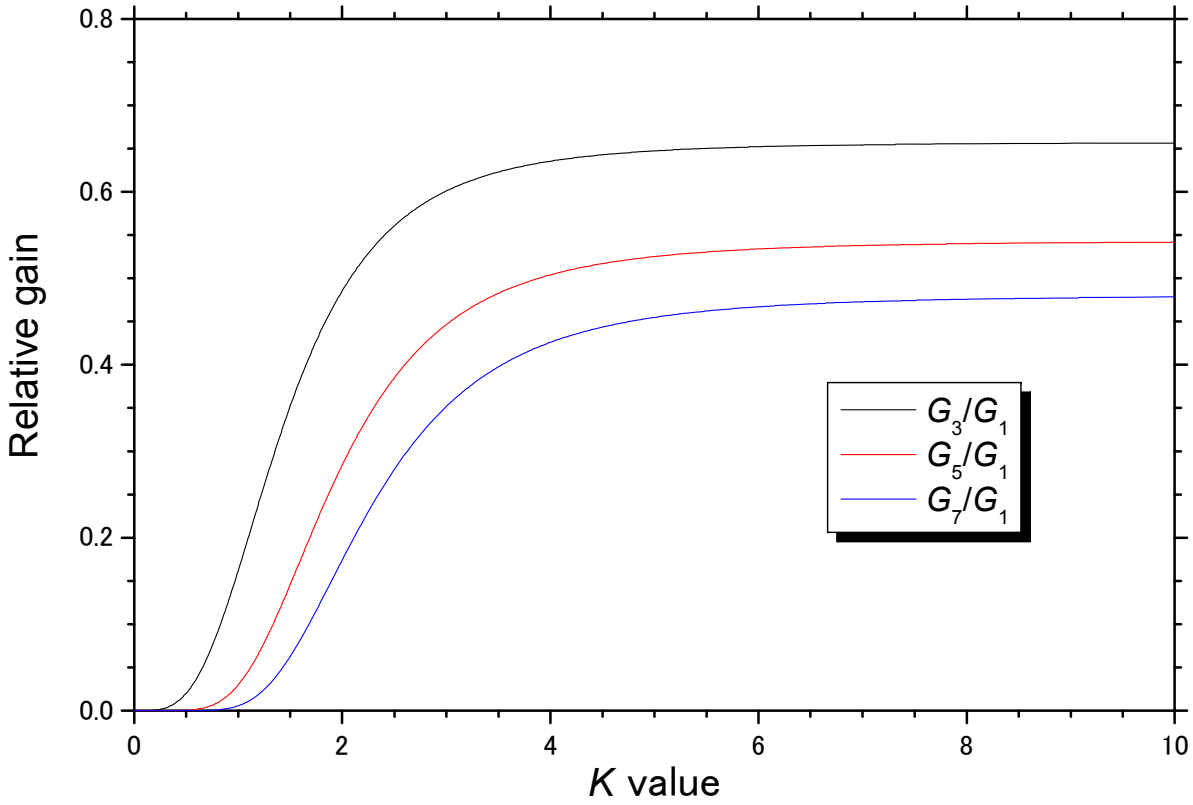
3次高調波によるXFELO

Parameters	Third harmonic	Fifth harmonic
Crystal Bragg energy E_H	12.42 keV	20.71 keV
Phase jump $\Delta\varphi$	$4\pi/3$	$6\pi/5$
Undulator period λ_u	15 mm	15 mm
Undulator number N_u	1200	1200
Undulator parameter K	1.3244	1.3244
Beam energy E	3.5 GeV	3.5 GeV
Slice energy spread σ	100 keV	100 keV
Beam peak current I	20 A	100 A
Slice emittance ε_n	0.083 μm-rad	0.083 μm-rad
Single-pass gain g_h	65%	72%
Total cavity reflection r	80%	80%
Cavity length L_c	150 m	150 m
Bragg crystal	C(4,4,4)	C(5,5,9)
FWHM spectral width	5.5 meV	24.6 meV
FWHM temporal width	463 fs	107 fs
Photons/pulse	0.86×10^8	0.24×10^8
Output peak power	0.35 MW	0.74 MW



高調波のゲイン計算

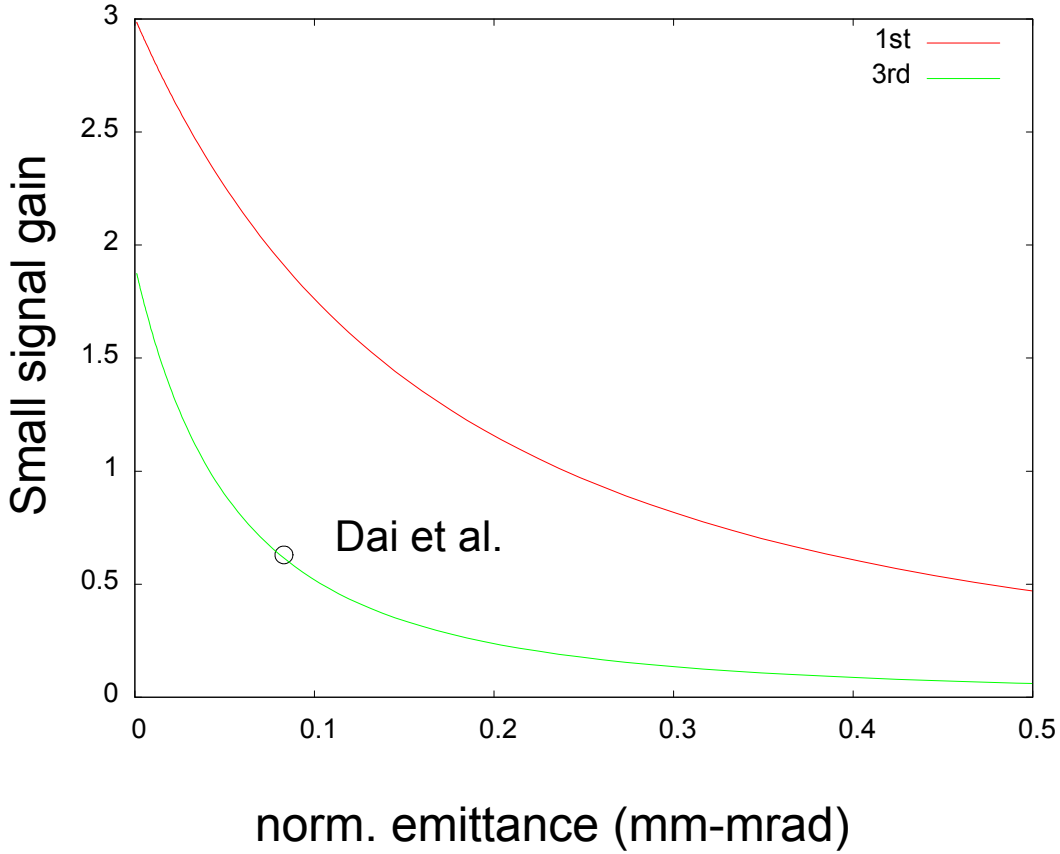
産総研、清さんによる



$$G_n = n \frac{[JJ]_n^2}{[JJ]_1^2} G_1$$

Filling factor（エミッタンス）、
エネルギー広がりの効果を
別途加える。

解析式によるゲインの確認



beta ＝20m とすると
Dai et al. 論文のゲインを
ほぼ再現した。

	Kim et al.	Hajima et al.	Dai et al.
E (GeV)	7	5	3.5
ε_n (mm-mrad)	0.082	0.13	0.083
σ_E (keV)	1400	250	100
charge	19	7.7	20
σ_t (ps)	2	0.38	(0.40)
I_p (A)	-	-	20
Undulator pitch (mm)	18.8	14.3	15
Undulator period	3000	3000	1200
Undulator K	1.414	0.8344	1.3244
*Gap (mm)	(5)	(5)	(3.25)
Gain (%)	26	40	65
X-ray Bandwidth (meV)	2.3	-	5.5
Length (fs)	850	510	463
Photon/pulse	10^9	$0.7\text{x}10^8$	$0.86\text{x}10^8$

すべて 12keV (1 Å)
*Gap → Halbach type を仮定したとき

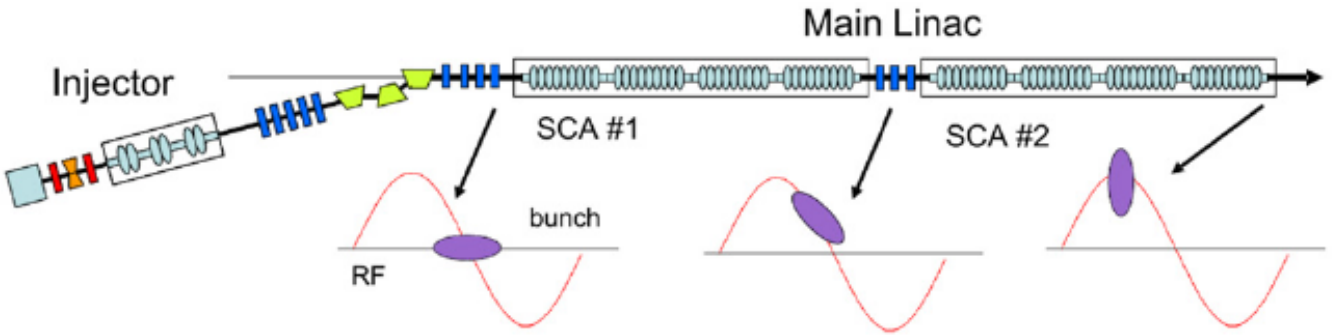
K-J. Kim 氏からの問い合わせ

The question is whether you can produce and accelerate such beams. If yes, the beam is suitable for an XFELO, possibly with >100 MHz rep rate, with high average brightness.
Kwang-Je

> the gain calculation I did was for our "nominal" beam and undulator parameters (E=7 GeV, Nu = 3000, etc.) with the following changes:
> Charge = 1.0 pC
> Length = 0.25 ps (I = 1.6 A)
> emittance = 0.062 mm*mrad [per Rosenzweig et. al.'s NIMA 593, 39 (2008)]
> energy spread = 100 keV
>
> I find that the gain is maximized at 0.5 when Z_R = Z_¥beta = 14 m.
>
> If I increase the energy spread to 250 keV the gain is 0.4.

ERL injector and velocity bunching

R. Hajima et al. / Nuclear Instruments and Methods in Physics Research A 637 (2011) S37–S42



Parameters of electron bunch at the end of the main linac are bunch charge 7.7 pC, energy 27.7 MeV, rms bunch length σ_t=380 fs, rms energy spread σ_E=250 keV, rms normalized emittance ε_x=0.16 mm-mrad, and ε_y=0.13 mm-mrad. The energy

7.7 pC,　380 fs,　0.16 mm-mrad,　250 keV

？？？　1 pC,　250 fs,　0.062 mm-mrad,　100 keV　？？？

ビームダイナミクス以外の検討＝ビームモニタ？