Physics > Accelerator Physics

Harmonic lasing in X-ray FELs

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(Submitted on 11 May 2012)

Harmonic lasing in a free electron laser with a planar undulator (under the condition that the fundamental frequency is suppressed) might be a cheap and efficient way of extension of wavelength ranges of existing and planned X-ray FEL facilities. Contrary to nonlinear harmonic generation, harmonic lasing can provide much more intense, stable, and narrow-band FEL beam which is easier to handle due to the suppressed fundamental frequency. In this paper we perform a parametrization of the solution of the eigenvalue equation for lasing at odd harmonics, and present an explicit expression for FEL gain length, taking into account all essential effects. We propose and discuss methods for suppression of the fundamental harmonic. We also suggest a combined use of harmonic lasing and lasing at the retuned fundamental wavelength in order to reduce bandwidth and to increase brilliance of X-ray beam at saturation. Considering 3rd harmonic lasing as a practical example, we come to the conclusion that it is much more robust than usually thought, and can be widely used in the existing or planned X-ray FEL facilities. In particular, LCLS after a minor modification can lase to saturation at the 3rd harmonic up to the photon energy of 25-30 keV providing multi-gigawatt power level and narrow bandwidth. As for the European XFEL, harmonic lasing would allow to extend operating range (ultimately up to 100 keV), to reduce FEL bandwidth and to increase brilliance, to enable two-color operation for pump-probe experiments, and to provide more flexible operation at different electron energies. Finally, in this paper we discover that in a part of the parameter space, corresponding to the operating range of soft X-ray beamlines of X-ray FEL facilities (like SASE3 beamline of the European XFEL), harmonics can grow faster than the fundamental wavelength.

Subjects:	**Accelerator Physics (physics.acc-ph)**
Report number:	DESY 12-070
Cite as:	**arXiv:1205.2503 [physics.acc-ph]**
	(or **arXiv:1205.2503v1 [physics.acc-ph]** for this version)

Submission history

From: Evgeny Schneidmiller [view email]
[v1] Fri, 11 May 2012 12:43:15 GMT (150kb)

Which authors of this paper are endorsers?