High-Repetition-Rate Self-Seeding Schemes Using a Resonator-Amplifier Setup.

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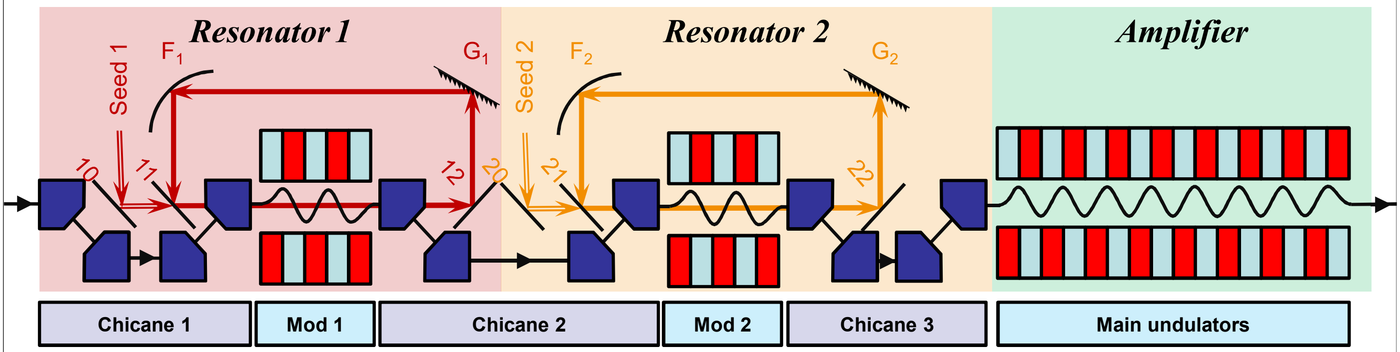
The resonator-amplifier setup



Each resonator consists of a small undulator, called modulator, two plain mirrors, a grating, and a focusing element. In addition, through one element an external seed can be coupled into the optical cavity. The complete resonator is then enclosed by two chicanes to bend the electron beam around the optical elements on the modulator axis. In the shown configuration both resonators share the second chicane. The resonators are followed by the amplifier, which is also used as the main undulator if the FEL is driven in SASE mode. The sketch does show the most versatile setup and does not reflect any scales. Also, the position of the optical components is only for demonstrative purposes.

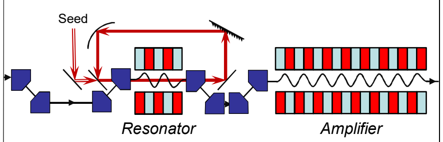
Abstract

The spectral and temporal properties of Free-Electron Lasers (FEL) operating on the basis of self-amplified spontaneous emission (SASE) suffer from the stochastic behavior of the start-up process. Several so-called "seeding"-techniques using external radiation fields to overcome this limitation have been proposed and demonstrated. The external seed is usually generated by demanding, high-power laser systems, which are not available with a sufficient laser pulse energy at the high repetition rates of superconducting FEL facilities. In this contribution we discuss several seeding schemes that lower the requirements for the used laser systems, enabling seeded operation at high repetition rates by the means of a resonator-amplifier setup.

High-Gain Harmonic Generation

The High-Gain Harmonic Generation uses an external seed laser to imprint a sinusoidal energy modulation onto the electron bunch inside a undulator called radiator. Then, by the means of a chicane, this energy distribution is converted into an electron density distribution, which contains a higher harmonic content, which will in turn lase in the main undulator section called amplifier..

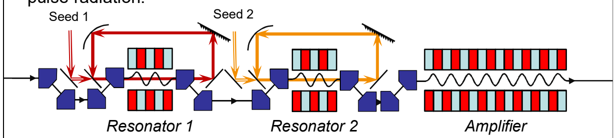
For the highest repetition rate, suitable laser systems are not available yet. However, one can use the radiation that is generated in the resonator and feed it back to the undulator entrance to seed the next electron bunch.



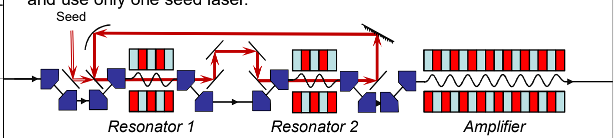
Echo-Enabled Harmonic Generation

The Echo-Enabled Harmonic Generation scheme uses an external seed laser to imprint a sinusoidal energy modulation onto the electron bunch inside a undulator called radiator. Then, by the means of a chicane, this energy distribution is converted into an electron density distribution of thin slices in the energy space. This distribution gets energy modulated again, and turned into even higher harmonic contents using a second chicane.

Here, two seed pulses are needed. Using the resonator amplifier setup, one can use two designated resonators to gain full control over the seed pulse radiation.



Another option is to use an optical delay line between the two undulators and use only one seed laser.



Summary and outlook

First studies for the single-stage High-Gain Harmonic Generation scheme have been performed and are presented in this conference (G. Paraskaki, "Study of a Seeded Oscillator-Amplifier", TUP077, this poster session). Further optimization has to be performed:

- Properties and material of mirrors
- Properties of the used grating
- Feasibility of time-conserving monochromators
- Geometric and temperature stability
- Tolerance studies
- Stabilization method for all subsystems

Summary and outlook

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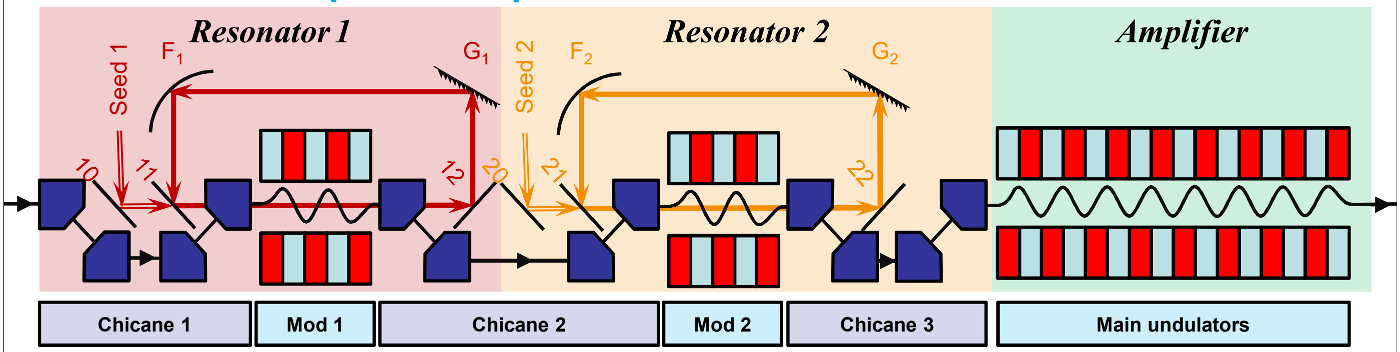
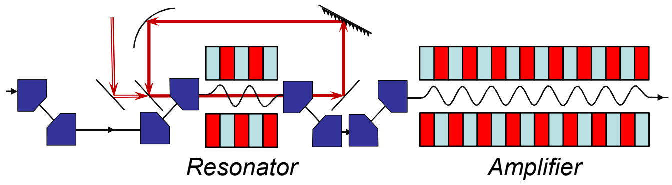


High-Gain Harmonic Generation at 4nm

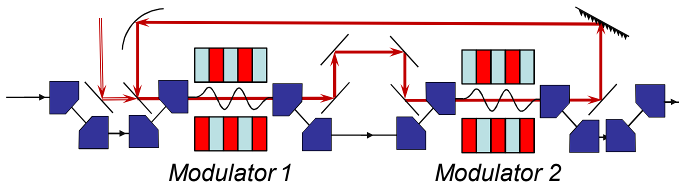


- One modulator needed
- Only minor changes to existing HGHG setups needed
- Can be compatible with SASE operation
- Using beam samplers, one has an online diagnosis over the build-up process
- Length of the optical cavity has to fit the repetition rate
- Seeding in the resonator is self-sustaining
- Initial laser only has to provide a seed at the repetition rate of the bursts, i.e. 10 Hz in the FLASH case

Echo-Enabled Harmonic Generation at 1nm

- Two modulators needed
- Only three additional mirrors per chicane needed
- Individual cavity length has to fit the repetition rate of the bursts

- Instead of two independent resonators, one can use a delay line
  - *This limits the flexibility.*
  - *Second modulator will always have lower intensities then the first*
  - *Cavity length will be longer*



Summary and outlook

Further optimization has to be performed:

- Properties and material of mirrors
- Properties of the used grating
- Feasibility of time-conserving monochromators
- Geometric and temperature stability
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- Stabilization method for all subsystems

Connected contributions

TUP074: FLASH Upgrade for Seeding

TUP076: Seeding R&D at sFLASH

TUP077: Study of a Seeded Oscillator-Amplifier

TUP078: Impact of Electron Beam Energy Chirp on Seeded FELs

TUP005: Feasibility Study of an External Laser Seeding for the European XFEL

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TUP073