Frequency mixing in SASE3

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FEL R&D Meeting, DESY-XFEL

Oct. 7, 2020

Motivation

- Users of hard X-rays (SASE1&2) prefer higher electron energy. This is a problem for SASE3 users. For example, at 17.5 GeV the lowest photon energy is 1 keV, i.e. the interesting range 700-900 eV is missing.
- Mid- and long-term solutions: upgrade a part of SASE3/increase the length of SASE3 using longer period segments.
- Short-term solution: use the fact that APPLE afterburner (to be installed next year) can be tuned to about 60% longer wavelength than SASE3. Thus, for example, at 17.5 GeV one can reach the same wavelength as now at 14 GeV.
- To drive afterburner at longer wavelength one needs to prepare density modulation (bunching) in SASE3 outside of its range!
- Use frequency mixing: generate two frequencies in SASE3 and create (due to nonlinear process) the difference frequency. For example, 1.7 keV and 1 keV with the difference 0.7 keV.

Idea of a test experiment

- Frequency mixing is an old and simple concept (radio- and laser physics) but it was demonstrated neither in SASE FELs nor in X-ray range.
- We do not need to wait for the afterburner to do a test experiment: last segments of SASE3 can play a role of the afterburner. But, of course, all three frequencies must be within the range of SASE3.

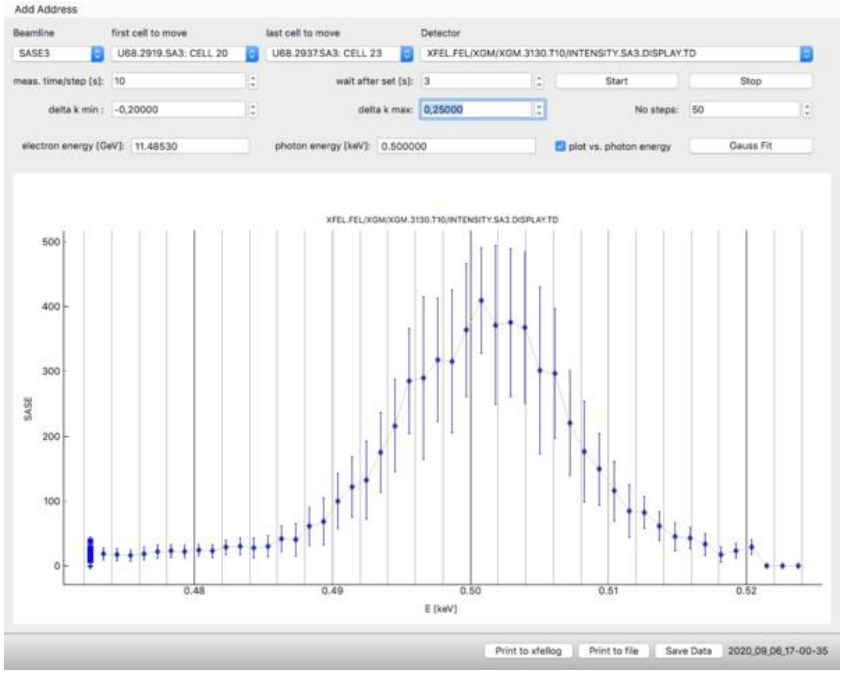
Generation of two frequencies, alternating K configuration

R56 (non-resonant undulators)

Radiator tuned to the difference frequency

Experiment at SASE3 (6.09.20)

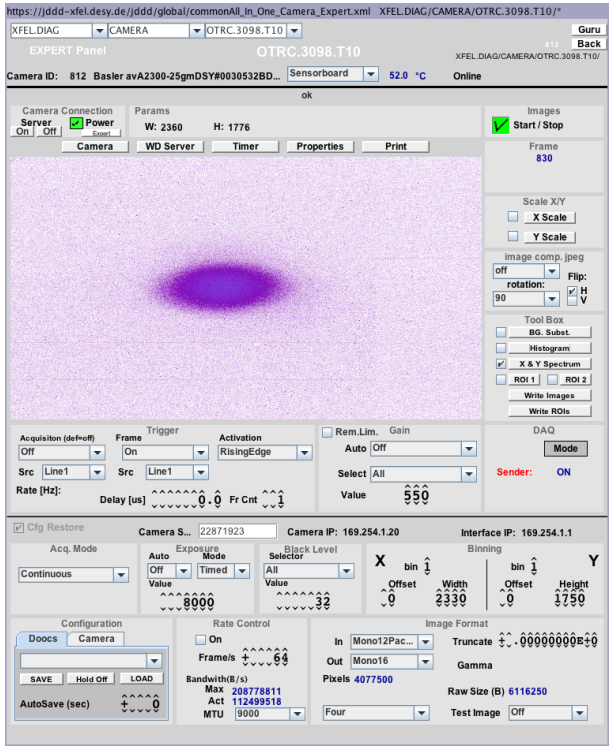
- 1200 eV – 700 eV = 500 eV at electron energy 11.5 GeV
- Tried different configurations, for example: first 12 segments for generation of 1200 eV and 700 eV (like 3+3+3+2+1) then 5 detuned segments for R56, then 4 segments tuned to 500 eV.
- With 4 segments at 500 eV got 400 uJ, with 5 segments - 700 uJ.



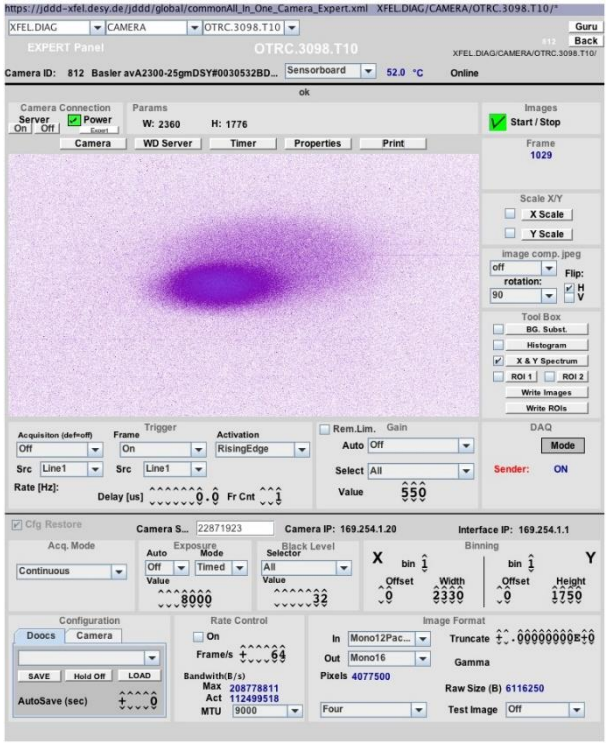
K-scan of the last 4 segments (radiator): resonant behaviour at 500 eV

Experiment at SASE3 (6.09.20)

Last 4 segments (radiator) at 530 eV



Last 4 segments (radiator) at 500 eV



Conclusion: frequency mixing was demonstrated for the first time in a SASE FEL and in X-ray range. Futher studies and optimizations are needed to prepare for operation with APPLE afterburner next year.