Frequency mixing in SASE3

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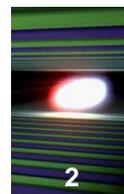
- Users of hard X-rays (SASE1&2) prefer higher electron energy. This is a problem for SASE3 users. For example, at 17.5 GeV the lowest photon energy is 1 keV, i.e. the interesting range 700-900 eV is missing.

- 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.
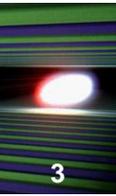
- Frequency mixing is an old and simple concept (radio- and laser physics) but it was demonstrated neither in SASE FELs nor in X-ray range.

- 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 |

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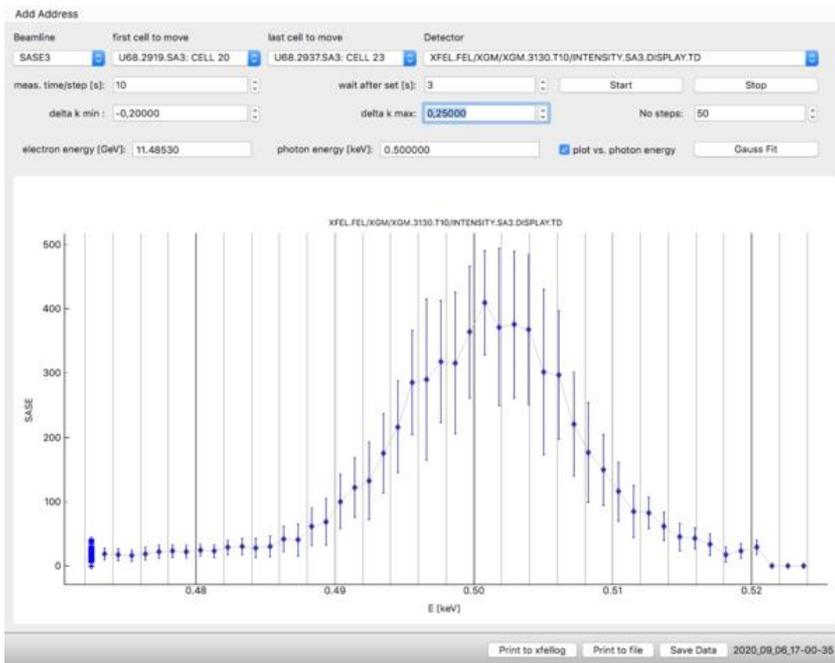
K-scan of the last 4 segments (radiator): resonant behaviour at 500 eV

Last 4 segments (radiator) at 530 eV

Last 4 segments (radiator) at 500 eV
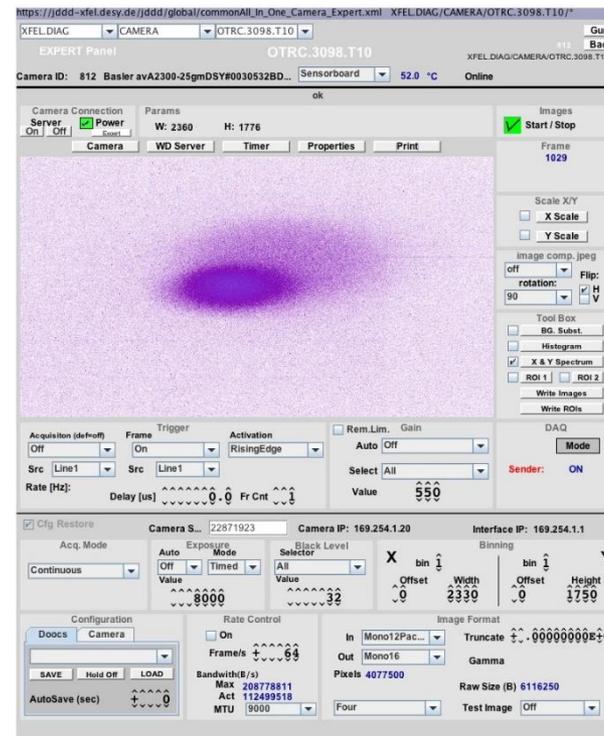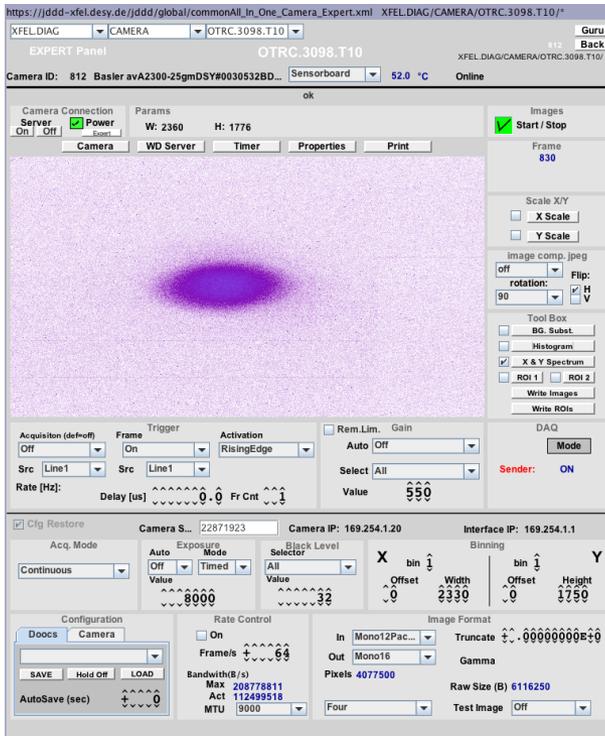
Conclusion: frequency mixing was demonstrated for the first time in a SASE FEL and in X-ray range. Futher studies and optimizations are needed to prepare for operation with APPLE afterburner next year.