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ARIA, a VUV beamline for EuPRAXIA@SPARC_LAB

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Introduction

EuPRAXIA@SPARC_LAB [1,2] is the project of a compact facility based upon a high brightness X-band LINAC, a particle-driven plasma acceleration stage and a Free-Electron Laser (FEL).

ARIA [3] is a VUV FEL (~50-180 nm) recently included in the project baseline. In comparison with AQUA, the main beamline [4] aiming at the water window, ARIA requires more relaxed constrain for the electron beam and a shorter magnetic length; it is more flexible than AQUA and can provide user operation at an earlier stage of the EuPRAXIA project. ➜ Low cost High impact

It features the standard High-Gain Harmonic Generation configuration [5], seeded by a long wavelength seed (410-560 nm) realized with commercial OPA amplifiers: the choice of a long wavelength seed allows to cover the full wavelength range (after second harmonic generation) with harmonic orders 3–9 ➜ Flexibiliy

The electron beams can be accelerated in a low charge per bunch mode through the plasma module or at higher charge in the X-band RF LINAC.

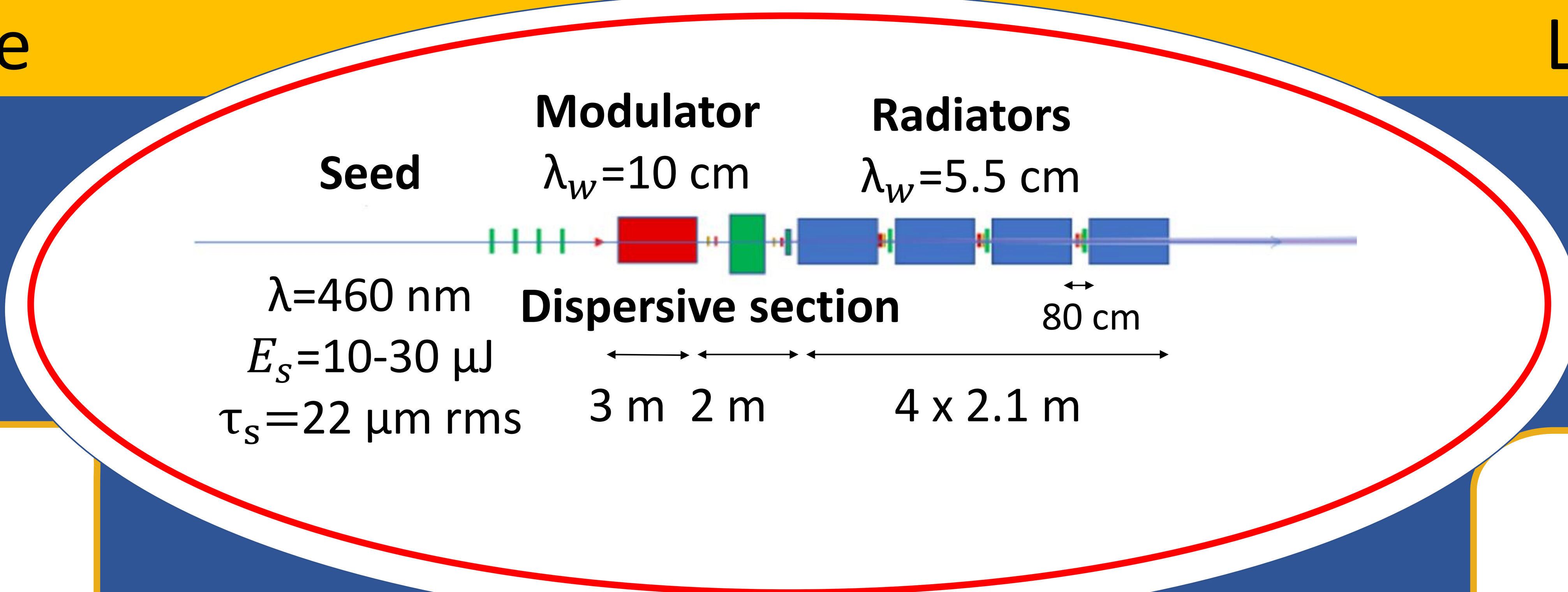
If starting from shot noise, this FEL operates in the single-spike SASE regime [6], with pulse lengths dominated by the bunch length and characterized by First order coherence & 100% intensity fluctuations

Tens to hundreds μJ pulse energies are achieved at saturation, after 6-8 undulator modules.

Here we present the ARIA beamline, including its preliminary layout, the possible operating modes and the expected performance. The reported simulation results are obtained using the 3D time-dependent FEL code GENESIS 1.3 [7].

Short beam mode

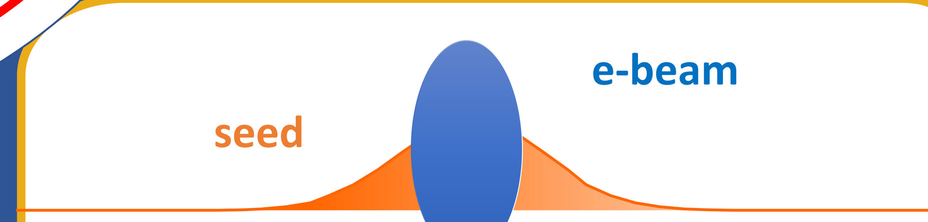
Short e-beam	From LINAC+PWA
Charge (pC)	30
Bunch length (rms, μm)	2
Energy (GeV)	1
Peak current (kA)	1.8
Slice energy spread (%)	0.05
Slice norm. emittance (mm mrad)	0.8



Long beam mode

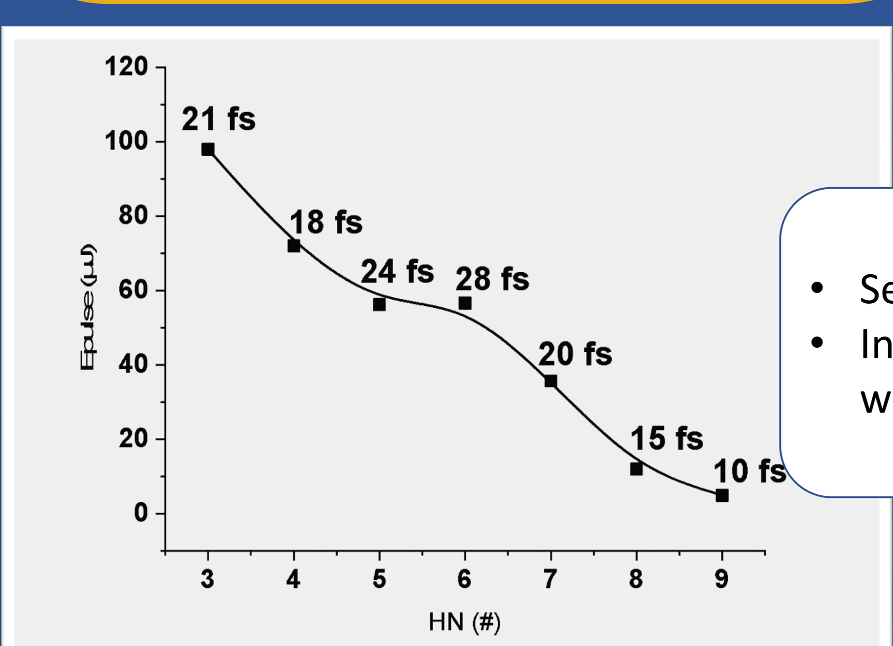
Long e-beam	From LINAC
Charge (pC)	200
Bunch length (rms, μm)	34
Energy (GeV)	0.8–1.2
Peak current (kA)	0.7
Slice energy spread (%)	0.01
Slice norm. emittance (mm mrad)	0.5

- Pulse duration limited by e-bunch length ($<\lambda_{coop}$) & large gain bandwidth ($\sim\rho_{3D} \approx 10^{-3}$)



- Pulse spectral width limited by e-bunch energy correlations.

Different & complementary to long e-bunch, low current – short seed (FERMI style)

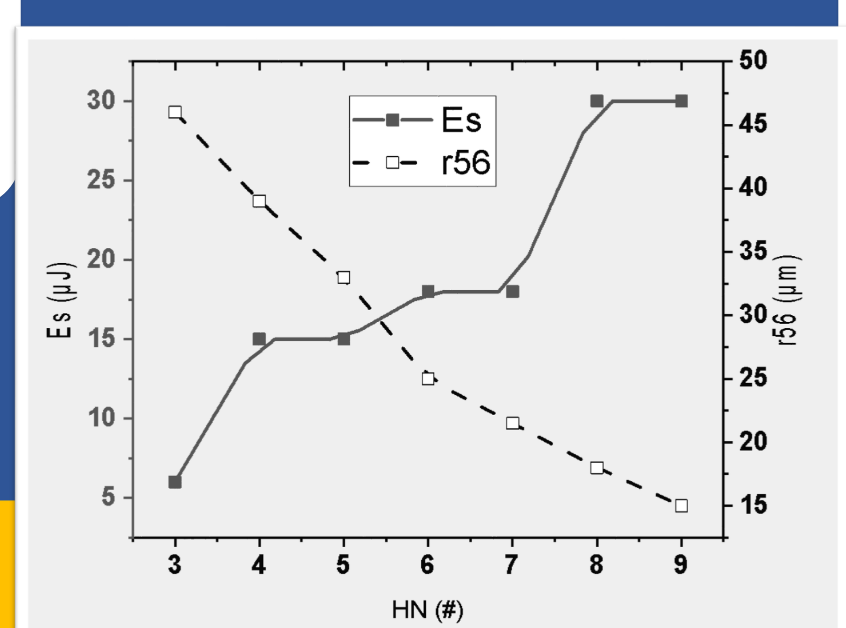


Output pulse energy vs harmonic number HN
(The achieved FWHM pulse durations are specified)

- Second order coherence
- Intensity and central wavelength stability

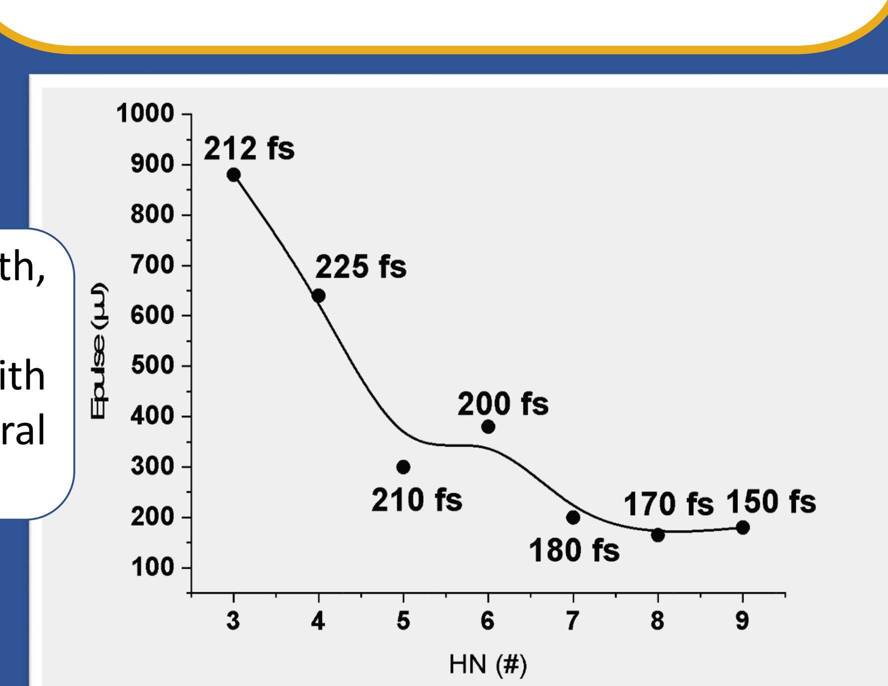
provided by the seed

Seed energy Es and R56 vs harmonic number HN



- Narrow linewidth, wavelength stability
- Max. coupling with monochromator spectral acceptance

by seed coherence & monochromatization



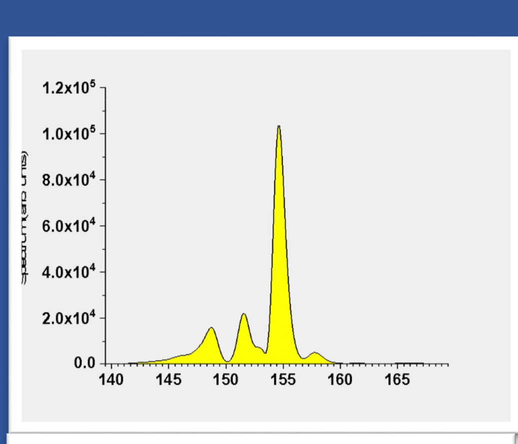
Output pulse energy vs harmonic number HN
(The achieved FWHM pulse durations are specified)

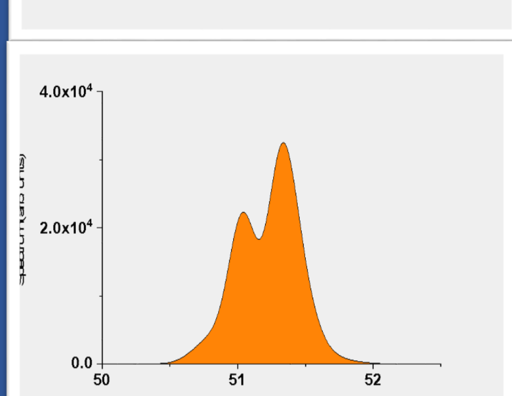
Two example cases of output pulses at saturation

Early saturation in the 30 pC e-bunch case from plasma for long wavelengths (HN ≤5)

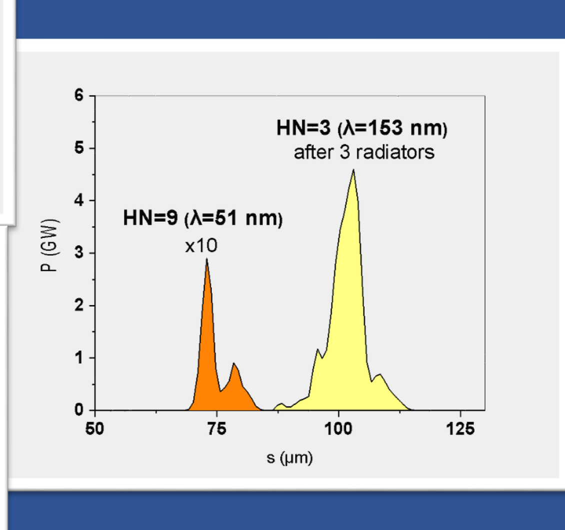
Output pulse	HN=3	HN=9
λ (nm)	153	51
τ (FWHM, fs)	21	10
E (μJ)	100	5
Size (mm)	0.74	0.43
Div. (mrad)	0.1	0.04
Time-BW product ()	2	0.69

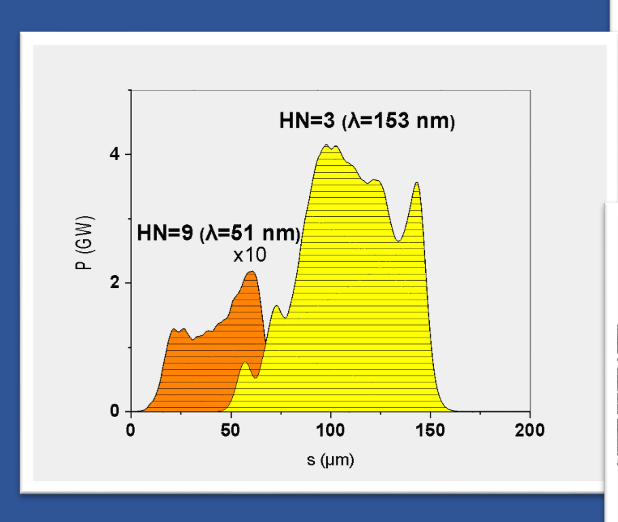
One radiator can be used for pulse gymnastics [8,9]



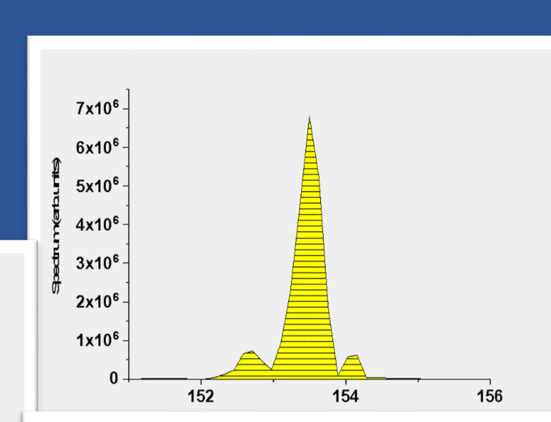


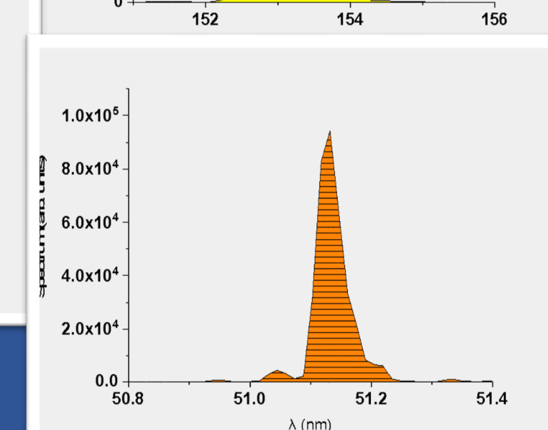
HN=3





HN=9





Output pulse	HN=3	HN=9
λ (nm)	153	51
τ (FWHM, fs)	212	150
E (μJ)	880	180
Size (mm)	0.85	0.35
Div. (mrad)	0.26	0.11
Time-BW product ()	2.7	3.8

Less demanding operation mode

Conclusions

The ARIA beamline has been presented at the EuPRAXIA@SPARC_LAB User Workshop [10]: its performances and spectral range of operation have raised interest for experimental applications.

⇨ Stable, 10 to 200 fs-long (FWHM) pulses with an energy from 5 to 800 μJ are achieved in the two beam modes in the whole spectral range

Tolerance analysis on the influence of phase space fluctuations in the plasma-driven 20 pC case are foreseen

References

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