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Compact

Linear polarisation via a Delta Afterburner for the CompactLight Facility

H. M. Castañeda Cortés[1], N.R. Thompson, D.J. Dunning

ASTeC and Cockcroft Institute, STFC Daresbury Laboratory, Warrington, United Kingdom.

[1]hector.castaneda@stfc.ac.uk

Abstract

- *We studied a configuration comprising a helical Super Conductive Undulator (SCU) followed by a delta afterburner (configured to generate linearly polarised light), beam-diverted scheme [1, 2], using the layout of the CompactLight facility[3].*
- *The trade-offs between the SCU and afterburner length, degree of polarisation and pulse energy are discussed.*
- ***We found that a compromise between FEL performance, degree of polarisation and afterburner length must be done in order to fulfil the user requirements [4] by the H2020 CompactLight Project.***

Constraints on polarisation and CompactLight

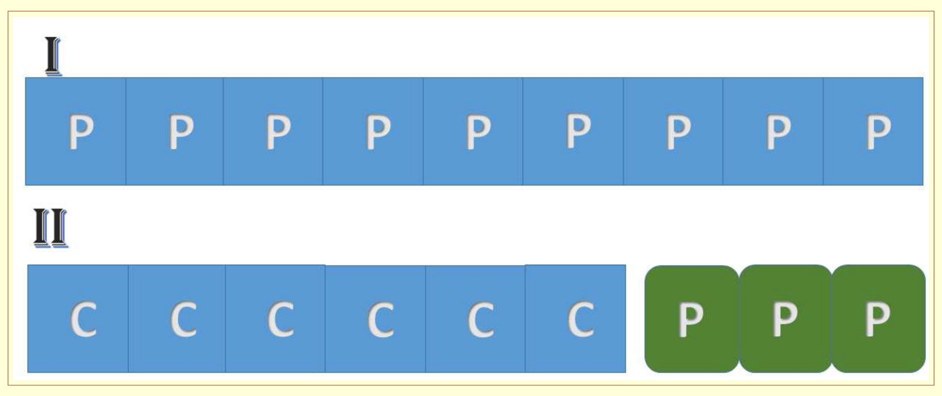

Figure 1: *Options to generate linearly polarised radiation.*

Options to generate linearly polarised radiation

I. Undulator as stand-alone (delta undulator in planar configuration).

II. **Linearly polarising afterburner**: **Helical SCU + delta afterburner (configured to generate linearly polarised light)**

Beam and Undulator parameters

Undulator and beam parameters

Table 1: *Undulator parameters (SCU and delta undulator).*

Undulator type	a_w	λ_u (mm)	$l_{section}$(m)	E_{ph}(keV)
SCU	0.907	9.85	2.27	16
Delta (AB)	0.546	13.83	2.28	16

Beam parameters

- E_{beam} = 5.5 GeV.
- Peak Current = 5 kA.
- $\bar{\epsilon} = 0.2$ mm − rad.
- RMS slice σ_E= 0.01%.
- $\bar{\beta}$ = 9 m .

FEL figures of merit for option I.

Undulator type	$L_{sat.}$ (m)	$P_{sat.}$ (GW)	$E_{sat.}$(μJ)
SCU	15.61	9.53	52.11
Delta	29.13	7.53	41.19

Delta afterburner and polarisation

Reduction in undulator line and FEL performance

AB length (m)	ΔL(m)	$E_{AB}/E_{delta-sat}$
2.28	10.9	17.2%
4.56	8.7	24.4%
6.84	6.4	31.3%
9.13	4.1	42.6%
11.4	1.8	68.4%

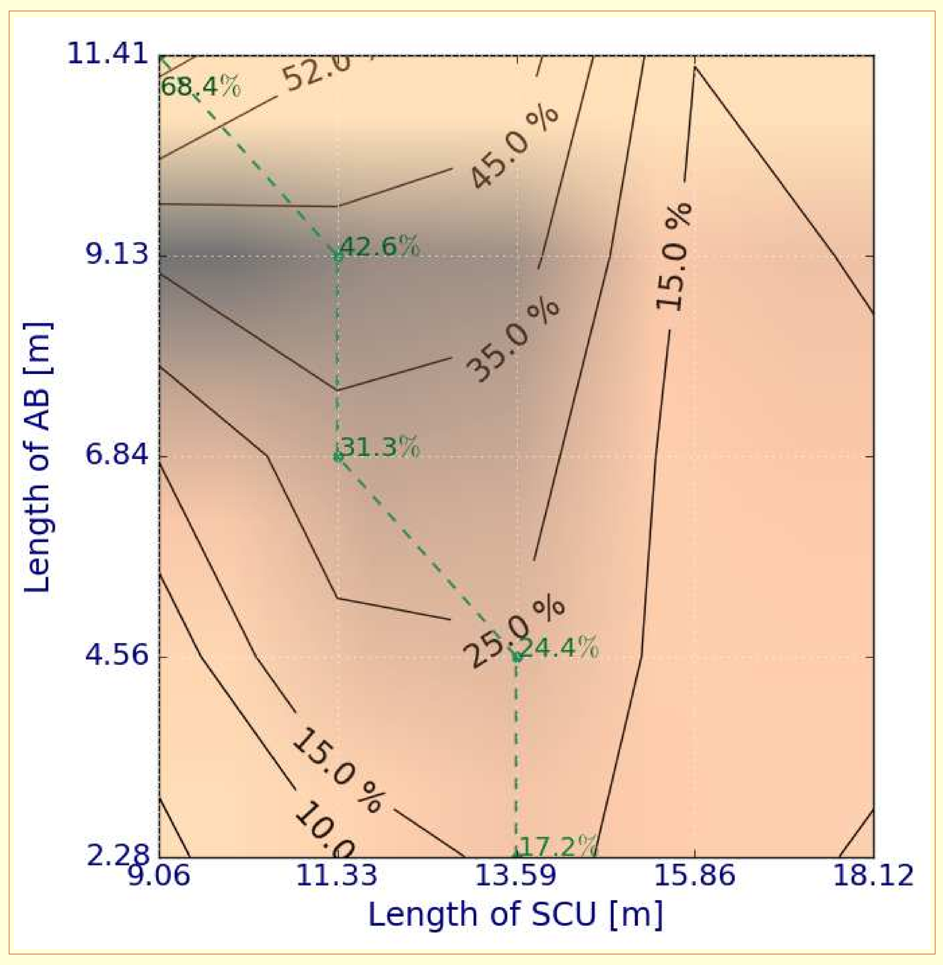

Figure 2: *Pulse energy ratio for different AB and SCU lengths.* ***Green dotted line*** *(maximum ratio per afterburner length).*

Compactness and FEL performance

- Option II is **more compact** as long as the length of the AB is less than 13 m. Afterburner length $\Rightarrow L_{AB} = L_{delta-sat} - L_{SCU-sat}$.
- E_{pulse} at the end of AB(- -) $\rightarrow 17\% - 68.4\% \times E_{delta-sat}$ (41.19 μJ).
- **A compromise must be made between compactness and FEL performance** $\Rightarrow$ A shorter undulator line gives linearly polarized radiation but at the cost of reduced pulse energy

Impact of inverse taper

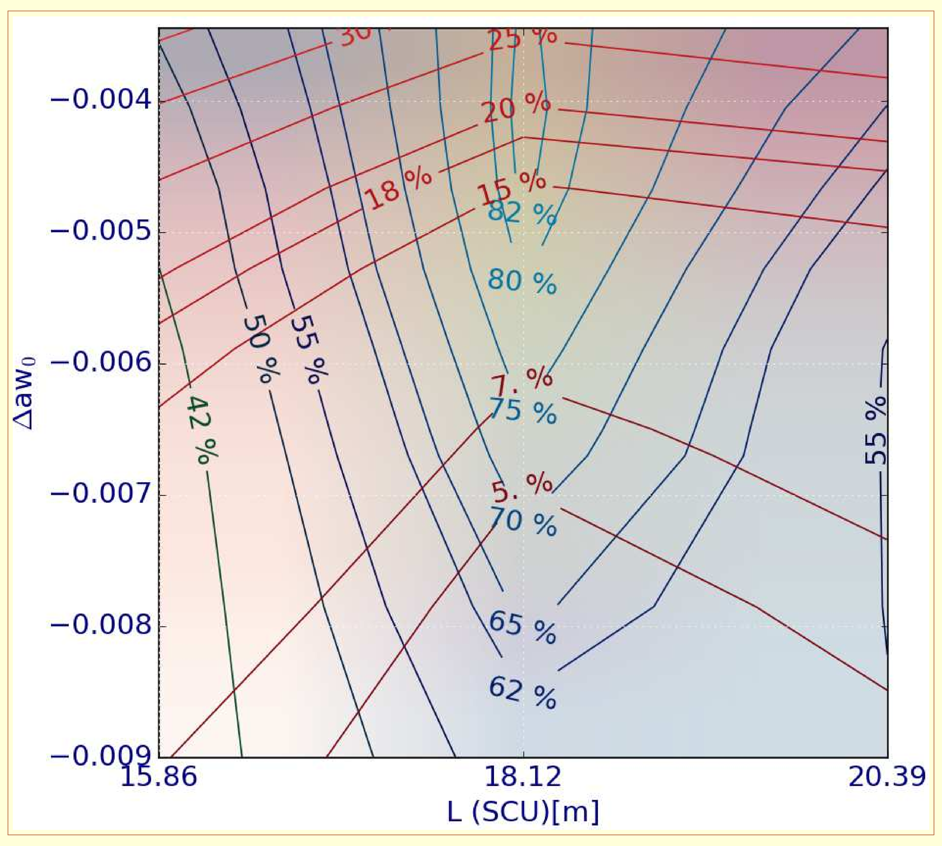

Figure 3: *Ratios of bunching and peak power at the end of the tapered SCU for different tapers and SCU lengths compared to untapered SCU at saturation.* ***Blue*** *contour lines (Bunching ratios),* ***Red*** *contour lines (Peak power ratios per SCU lengths).*

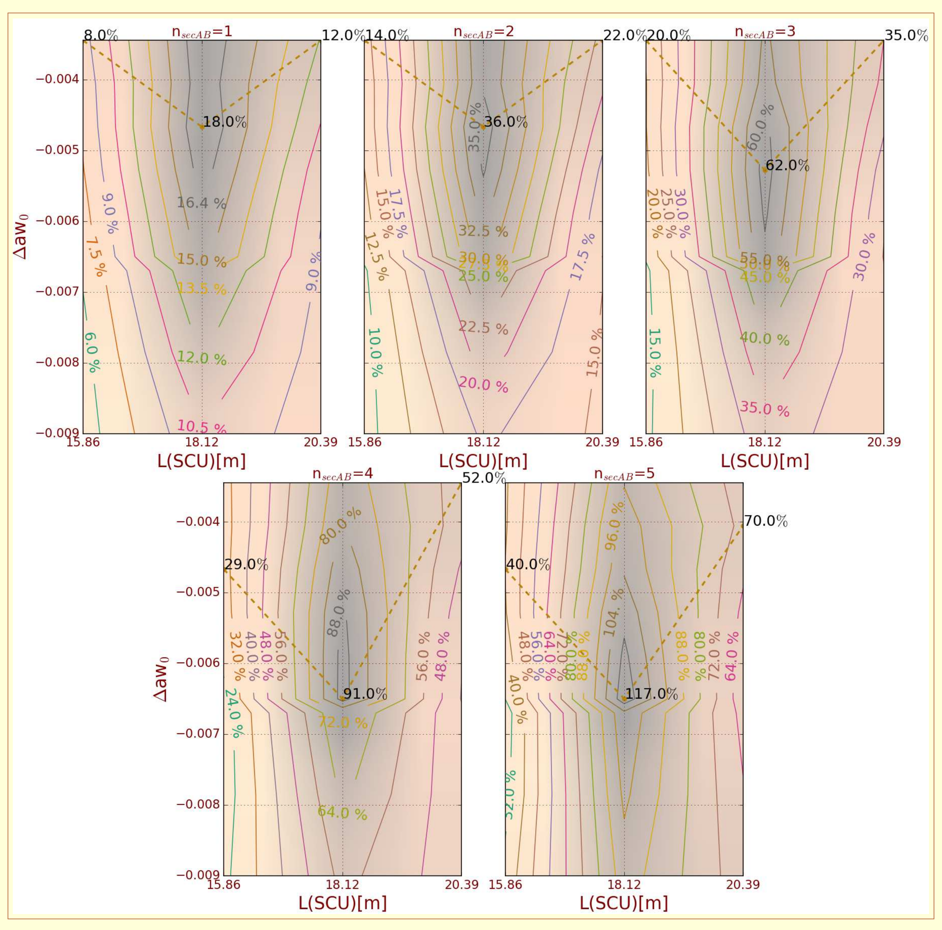

Figure 4: *Ratios of pulse energies at the end of the afterburner (option II) compared to the saturation pulse energy obtained for option I (**dotted black line**: maximum ratio of pulse energies ratio per SCU length).*

Inverse taper, bunching and peak power at the end of the SCU

- ★ Inverse taper scan for different SCU and afterburner lengths to assess FEL performance(scheme in [1] and experimentally proven in [2])
- ★ Optimal taper$\Rightarrow -0.004 \geq \Delta aw_0 \geq -0.006$ and $L_{SCU} = 18.12$ m
  - ▲ $P_{SCU-end}$ suppression between 7% and 15 % of $P_{SCU-sat}$.
  - ▲ Bunching at the end of the SCU around 80% bunching at saturation for the SCU.
- ★ Reduction of growth rate and increase in gain length due to optimal taper $\Rightarrow$ suppression of peak power whilst bunching still growing [1]
- ★ Shorter afterburners (1 to 3 sections) $\Rightarrow$ $18\% \leq \max(E_{end-AB}/E_{delta-sat}) \leq 62\%$
- ★ **A compromise must be made between compactness and FEL performance**

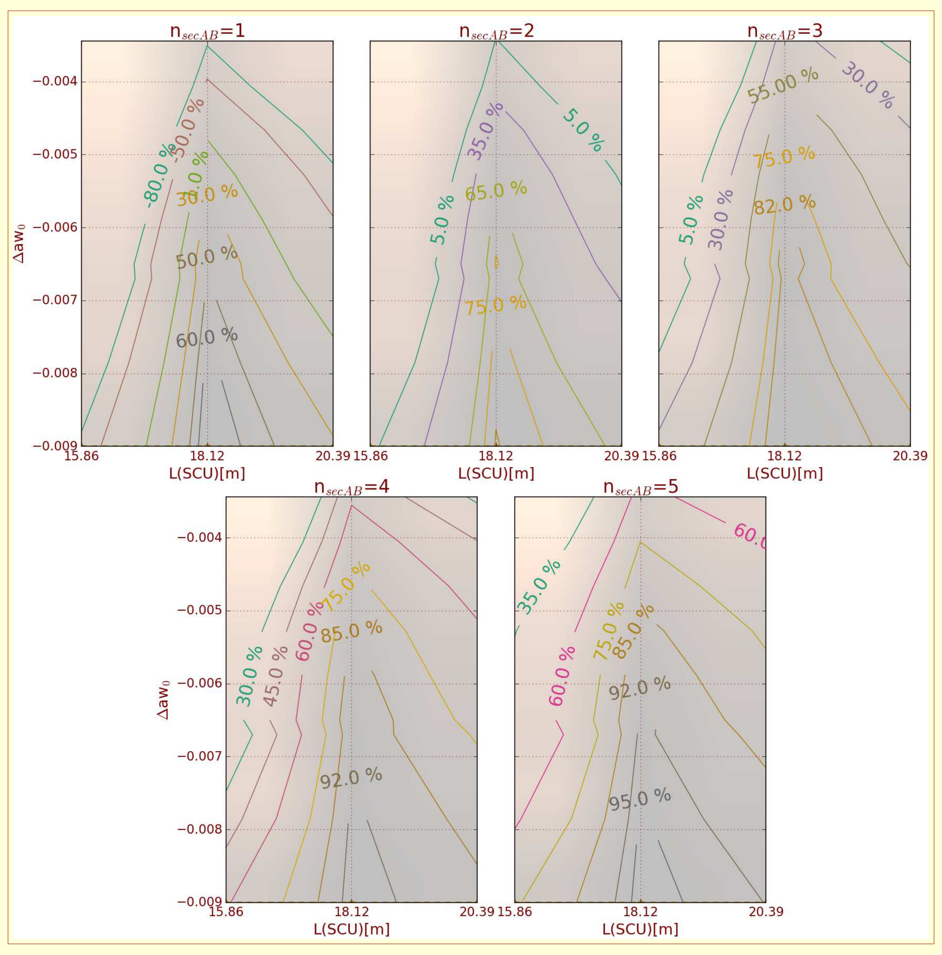

Figure 5: *Degree of polarisation for different number of afterburner sections.*

Degree of polarisation

- Deg. Pol. $= 1 - \frac{P_{SCU-end}}{P_{end-AB}}$, [1]
- Deg. Pol. < 0, optimal taper, 1 AB section (more circularly polarised radiation).
- 55% $\leq$ Deg. Pol. $\leq$ 82% for three sections AB, optimal taper (more linearly polarised radiation).
- **Larger afterburners will generate radiation with larger degree of polarisation, but undulator line won't be compact (compromise).**

Summary

- A study was carried out to show the feasibility of an afterburner generating linearly polarised light for the H2020 CompactLight Project.
- The afterburner option is more compact as long as the length of the afterburner is less than 13 m.
- A shorter afterburner makes the layout more compact (saving up to 11 m) but at the cost of reduced pulse energy (around 17% the pulse energy of the stand-alone delta at saturation) and a "more circular" degree of polarisation (optimal taper scenario).
- A compromise between the length of the afterburner to be designed, the FEL performance and degree of polarisation must be done.
- Variable polarisation (different configuration of afterburner) as a natural step forward to be done.

References

[1] E. A. Schneidmiller and M. V. Yurkov, *Phys. Rev. Spec. Top. - Accel. Beams*, vol. 16, 08 2013.

[2] A. Lutman *et al.*, *Nat. Photonics*, vol. 10, 05 2016.

[3] G. D'Auria *et al.*, in *Proc. Int. Part. Accel. Conf. 2019.* Melbourne, Australia: JACoW, 2019, p. TUPRB032.

[4] A. Mak, P. Salén, V. Goryashko, and J. A. Clarke, Tech. Rep., 2018. [Online]. Available: https://www.compactlight.eu/uploads/Main/D2.1_XLS_Specification.pdf

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