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OPTIMIZATION OF THE LATTICE REPLACEMENT OPTIONS FOR THE NEXT GENERATION AUSTRALIAN SYNCHROTRON

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Abstract

The design of a next generation Australian Synchrotron replacement lattice is a multi-objective and multi-constrained problem. Our group was tasked to produce a low emittance design while re-using the existing tunnel infrastructure and injector system. Our objectives coupled with the set infrastructure constraints are not straightforward to achieve with manual design. Several variables act at cross-purposes to one-another, leading to a conflicting trade-off between objectives. Recently we have investigated replacement options for the Australian Synchrotron containing longitudinal gradient and reverse bends in the form of a 4BA (4-bend achromat) lattice. In this work, optimise the lattice design for a potential fourth generation Australian Synchrotron facility. We outline the baseline 4BA solution to the lowest emittance lattice that can reuse the existing tunnels and injector system.

INTRODUCTION

The Accelerator Physics group at the ANSTO Australian Synchrotron (AS) was recently tasked with the goal of designing a baseline lattice for a potential upgraded facility at the Australian Synchrotron in Clayton, Victoria, Australia. The current storage ring is a 216 m circumference, 3.03 GeV electron storage ring which provides users with an emittance (ϵ_x) of 10.51 nm. With recent developments in the field and facilities around the world moving into the next generation of light source facilities, we aimed to develop a collection of potential designs for a new lattice with ultra-low emittance, while maintaining the tunnel infrastructure.

BASELINE LATTICE

General Layout

The lattice replacement design (AS-U) presented here is a symmetric fourth-order multi-bend achromat which achieves a extremely low emittance of 0.308 nm (308 pm). The design (shown in Fig. 1) comprises of 14 4BA cells with 14 long straight sections of 3.52 m. Each sector (see Fig. 2) comprises of a matching cell and dispersion suppressor section at either end of the unit cells (see Fig. 3). The beta-functions, dispersion function and $\mathscr{H}$ function of one sector is shown in Figs. 4, 5 and 6, respectively.

This lattice is based on the SLS-2 lattice design by Streun *et al.* [1]. We employ reverse bend (RB), longitudinal gradient bend (LGB) and vertical bend (VB) magnets. Longitudinal Gradient Bends [2] vary the magnetic field to compensate for dispersion and the $\mathscr{H}$ function. Reverse bend magnets at the end of the cells control and reduce the dispersion at center of the LGB magnet through variation of the dispersion [3].

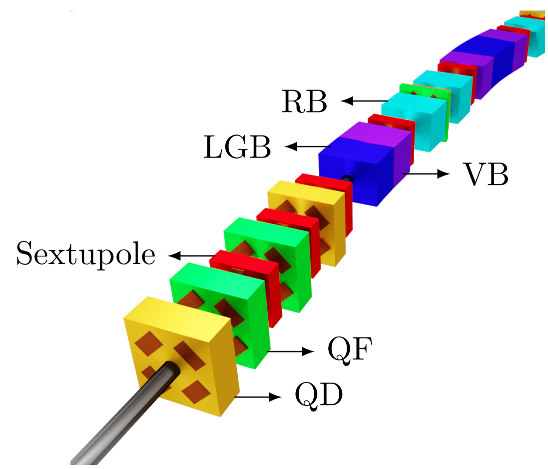

Figure 1: Baseline AS-U 4BA Lattice Matching Section.

Magnet fields were optimised to minimise the dispersion function (Fig. 5) and invariant $\mathscr{H}$ function (shown in Fig. 6) at the centre of the main bending magnets and maintain a zero dispersion straight section for insertion devices.

Parameters

The baseline lattice parameters are shown in Table 1 with comparison to the existing DBA storage ring. It is inevitable that such a compact sector length (15.42 m) coupled with such an aggressive 4BA design will require many magnets close together with high strengths resulting in large beam loading.

Table 1: Main Parameters of the New 4BA AS-U Upgrade Lattice and the Existing AS Lattice.

Parameter	**DBA**	**New AS-U**
Emittance ϵ_x	10 349 pm	308 pm
Circumference	216 m	216 m
Energy	3 GeV	3 GeV
Momentum Compaction α_c	0.002 1	−0.001 4
Energy Loss Per Turn U_0	0.93 MeV	1.95 MeV
Energy Spread	0.103 %	0.162 %
Linear Energy Acceptance	1.47 %	6.60 %
Natural Bunch Length σ_z	29.37 ps	9.19 ps
Peak Current	40.99 A	131.09 A
Touschek Lifetime	20 hours	16.75 hours
Coupling	1 %	5 %

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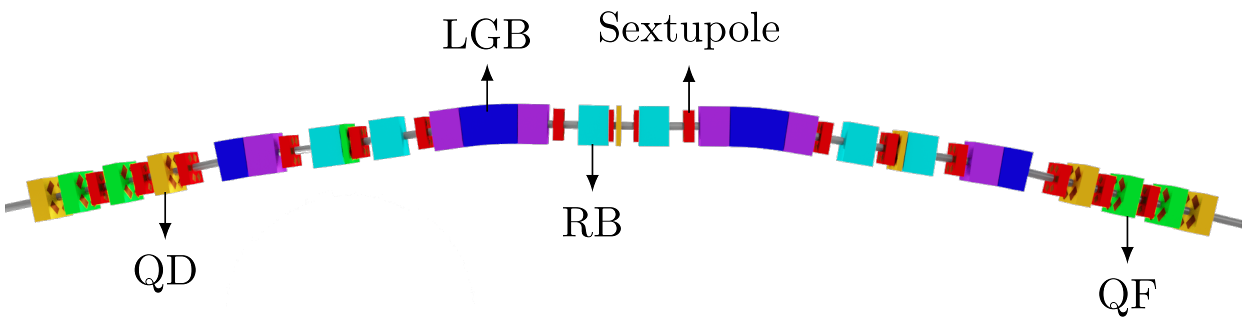

Figure 2: Baseline 4BA lattice geometry.

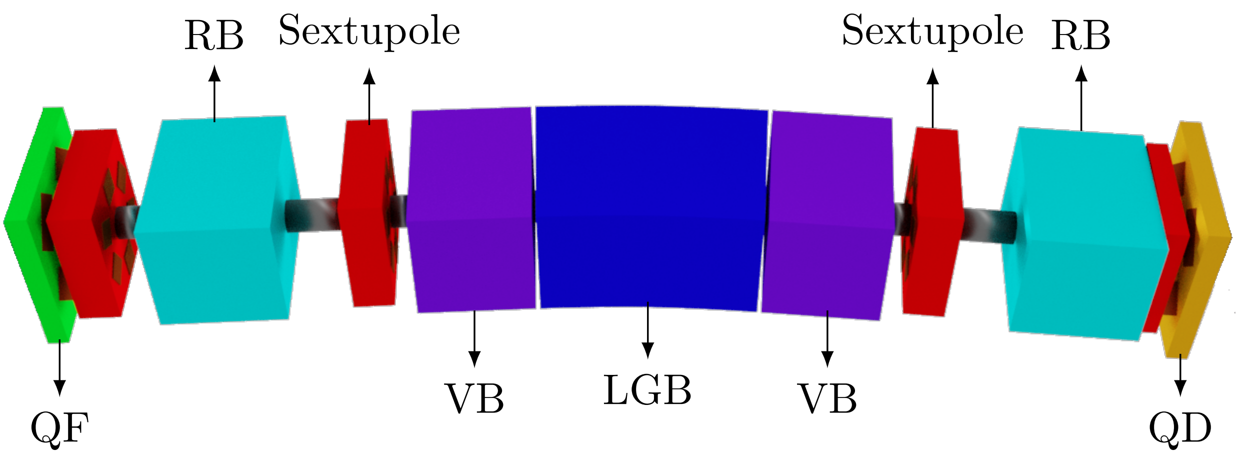

Figure 3: Baseline AS-U 4BA Lattice Unit Cell with Reverse Bends (RB), Longitudinal Gradient Bends (LGB), Vertical Bends (VB), Focusing Quadrupoles (QF) and Defocusing Quadrupoles (QD) as indicated.

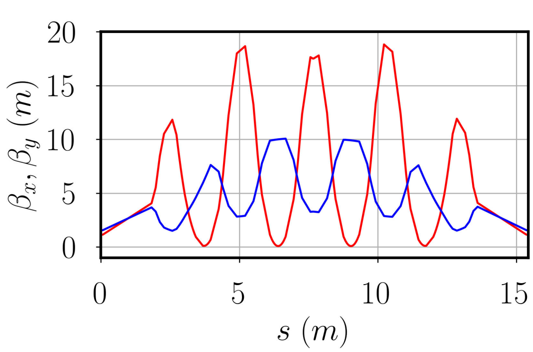

Figure 4: β_x (red) and β_y (blue) optical functions for the baseline 4BA AS-U lattice.

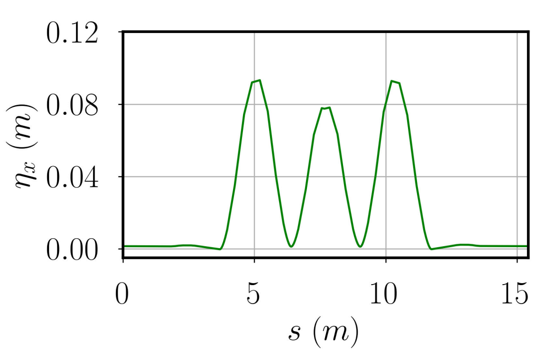

Figure 5: Dispersion η_x function (green) for the baseline 4BA AS-U lattice.

CONCLUSION

Our biggest constraint in the development of this design is the requirement to keep the existing storage ring tunnels and 216 m circumference. As the emittance is inversely proportional to the Circumference^3, the 216 m storage ring severely limits the achievable emittance. The low limit of circumference also reduces the number of unit cells we can insert in the sector. Our sectors are 15.43 m long, which means the maximum number of unit cells we can insert when taking into account the straight sections required is 4 to 5. The overwhelming majority of facility upgrades

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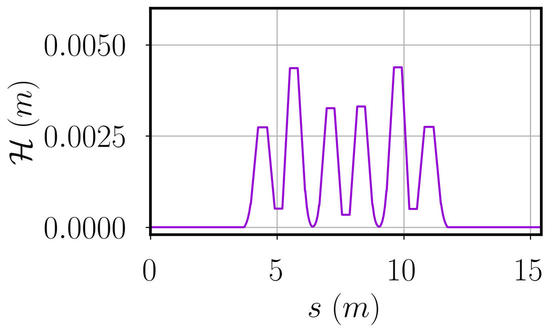

Figure 6: Curly-$\mathscr{H}$ invariant function for the baseline AS-U 4BA lattice.

have sectors ~25 m long and are able to reach emittance values of less than 150 pm. Despite these concerns, using the existing 216 m circumference storage ring at 3.03 GeV, we have designed a competitive 308 pm upgrade lattice. We note that the energy loss per turn (U_0) for the baseline AS-U upgraded 216 m design is high at 1.95 MeV per turn. A larger design concept for a 600 m circumference ring would relax the RF requirements which are one of the most expensive cost considerations for a an accelerator installation. A larger upgrade ring concept for the AS with extremely low emittance is described by Dowd et al. [4] in this proceedings.

REFERENCES

[1] A. Streun, "The anti-bend cell for ultralow emittance storage ring lattices", *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 737, p. 148, 2014. doi:10.1016/j.nima.2013.11.064

[2] B. Riemann and A. Streun, "Low emittance lattice design from first principles: Reverse bending and longitudinal gradient bends", *Phys. Rev. ST Accel. Beams*, vol 22, p. 21601, 2019. doi:10.1103/PhysRevAccelBeams.22.021601

[3] A. Streun and A. Wrulich, "Compact low emittance light sources based on longitudinal gradient bending magnets", *Nuclear Instruments and Methods in Physics Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 770, p. 98, 2015. doi:10.1016/j.nima.2014.10.002

[4] R. Dowd, M. Atkinson, R. Auchettl, J. Chi, Y-R.E. Tan, D. Zhu and K. Zingre, "Design Options for a Future Upgrade of the Australian Synchrotron Light Source", presented at the 12th Int. Particle Accelerator Conf. (IPAC'21), Campinas, Brazil, May 2021, paper TUPAB043.