

Low Emittance lattices

Lattice design has to provide low emittance and adequate space in straight sections to accommodate long Insertion Devices

$$\varepsilon_x = \frac{\gamma^2}{J_x \rho} \langle H \rangle_{\text{dipole}} \quad H(s) = \gamma D^2 + 2\alpha DD' + \beta D'^2$$

Minimise β and D and be close to a waist in the dipole

Zero dispersion in the straight section was used especially in early machines

avoid increasing the beam size due to energy spread

hide energy fluctuation to the users

allow straight section with zero dispersion to place RF and injection

decouple chromatic and harmonic sextupoles

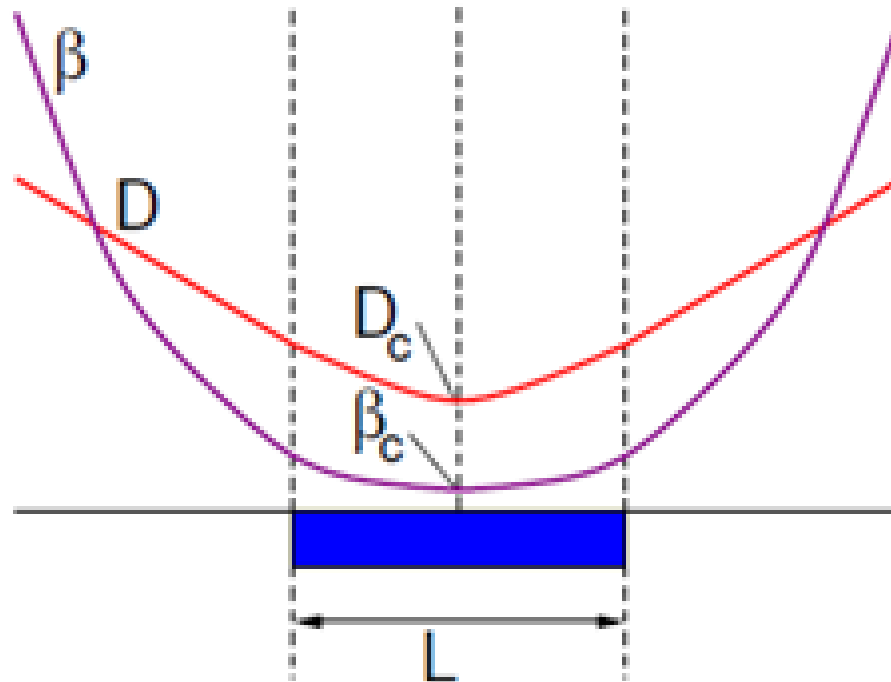
DBA and TBA lattices provide low emittance with large ratio between

$$\frac{\text{Length of straight sections}}{\text{Circumference}}$$

Flexibility for optic control for apertures (injection and lifetime)

Minimum emittance from a single dipole (V)

The optics through the dipole looks like



Courtesy A. Streun

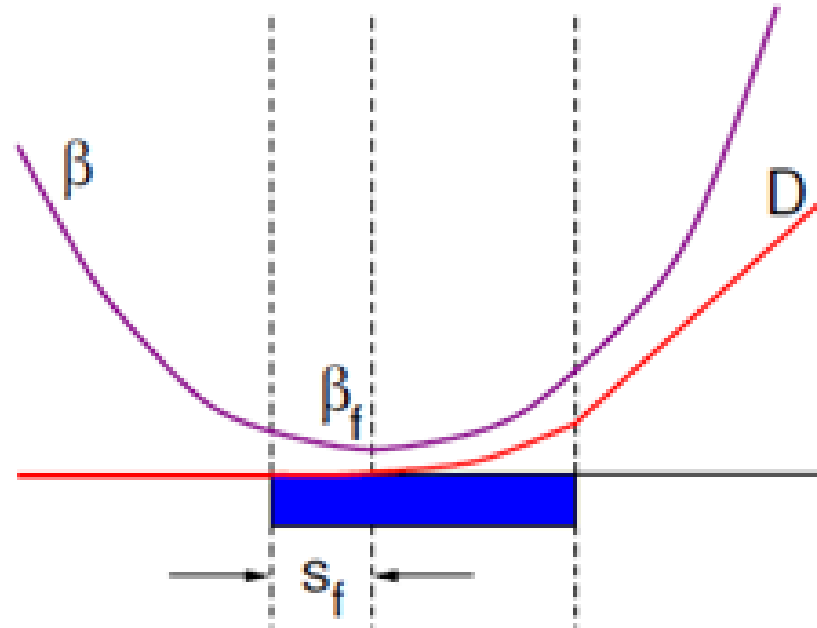
To build now a full lattice we can flank this dipole by matching sections to create a full ring, repeating periodically the TME-cell

Since $\varepsilon \propto \theta^3$ many small angle bending are favoured to reach smaller emittances

The dispersion is non zero in the straight section and it cannot be zeroed without further dipoles

Minimum emittance from a single dipole (VII)

The optics through the dipole looks like



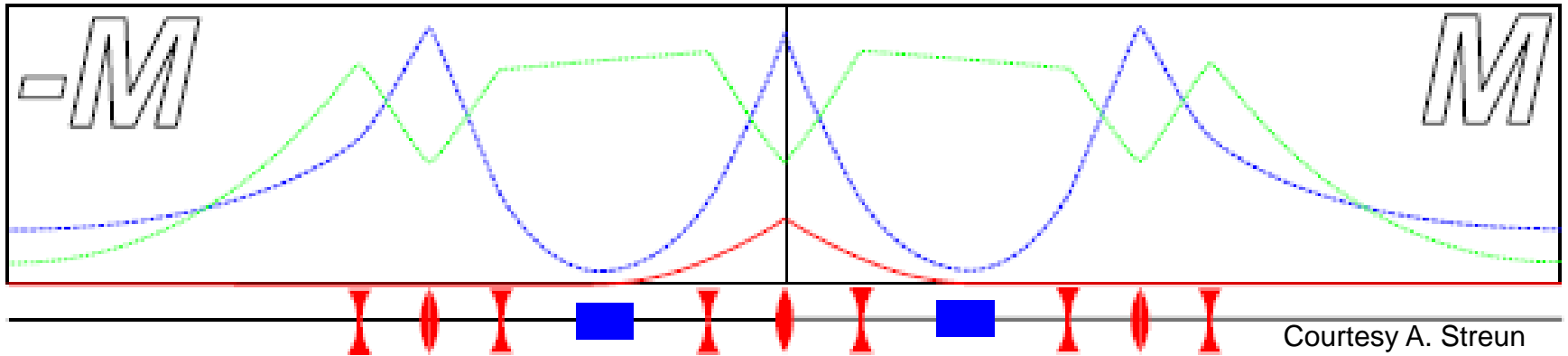
Courtesy A. Streun

To close the dispersion this cell can be repeated mirror symmetrically using a quadrupoles. This is the simplest form of a double bend achromat called Chashman-Green lattice

Since $\varepsilon \propto \theta^3$ many small angle bending are favoured to reach smaller emittances

Double bend achromat

A matching section can be added to tailor the optics for an insertion device as in

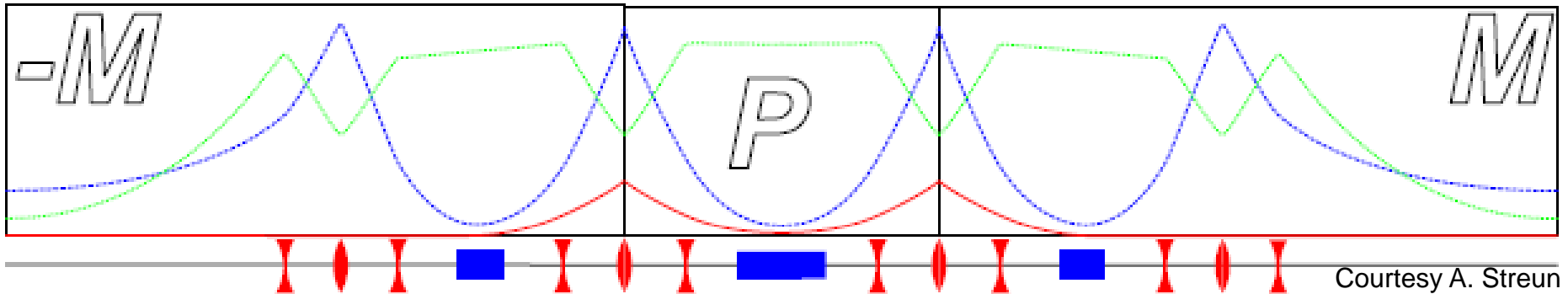


This is the basic structure of a DBA lattice used in many light sources

The horizontal emittance reached in medium size machines is in the order of few nm

Triple bend achromat

A TME cell can be added in between a DBA cell to generate a TBA cell



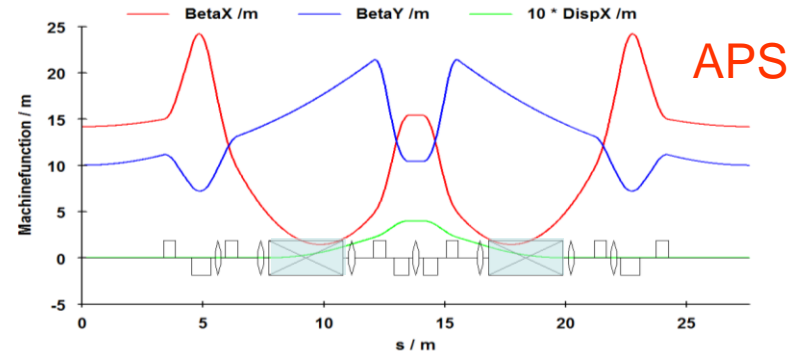
Notice that we cannot naively assume that the minimum emittance of the TBA is the average of the TME of a DBA and one TME cell.

We need to match the optics function between the two cells and this proves to be impossible if we use only quadrupoles and leave the same type of dipole, i.e. same strength and same length. In particular we cannot match the dispersion invariant at the dipole ends

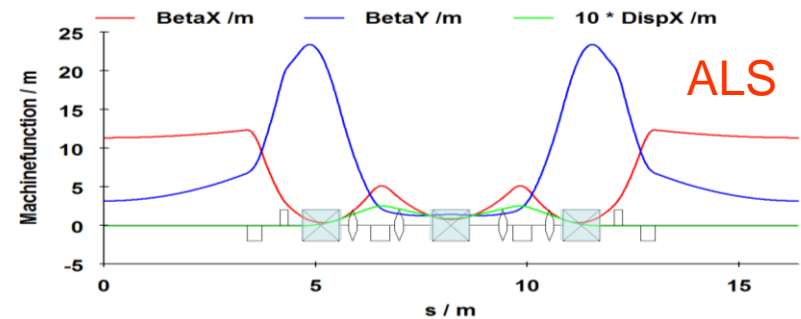
The condition for matching with minimum emittance require the external dipole to be shorter by $1/\sqrt{3}$.

Low emittance lattices

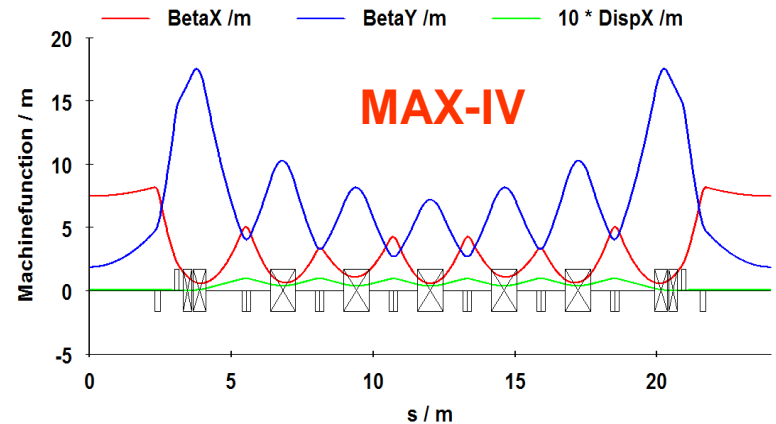
Double Bend Achromat (DBA)



Triple Bend Achromat (TBA)



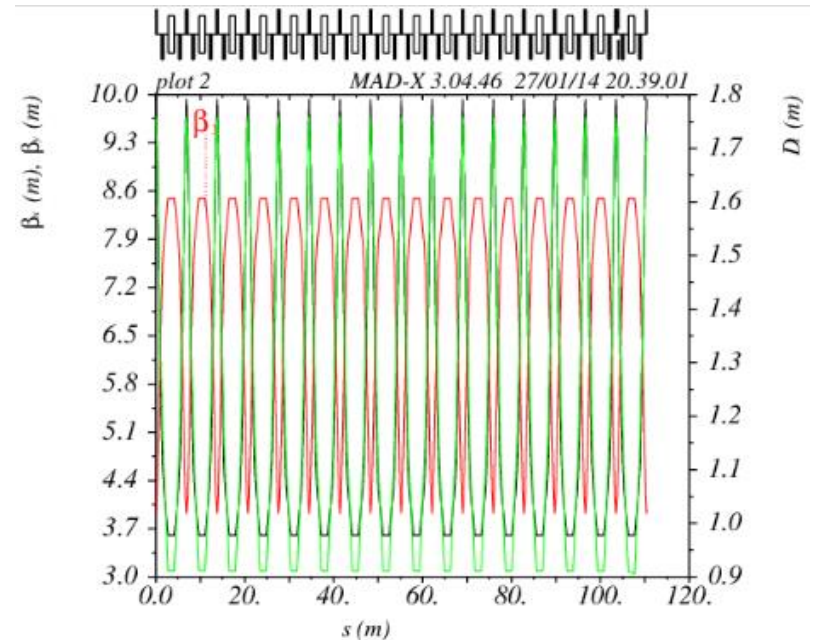
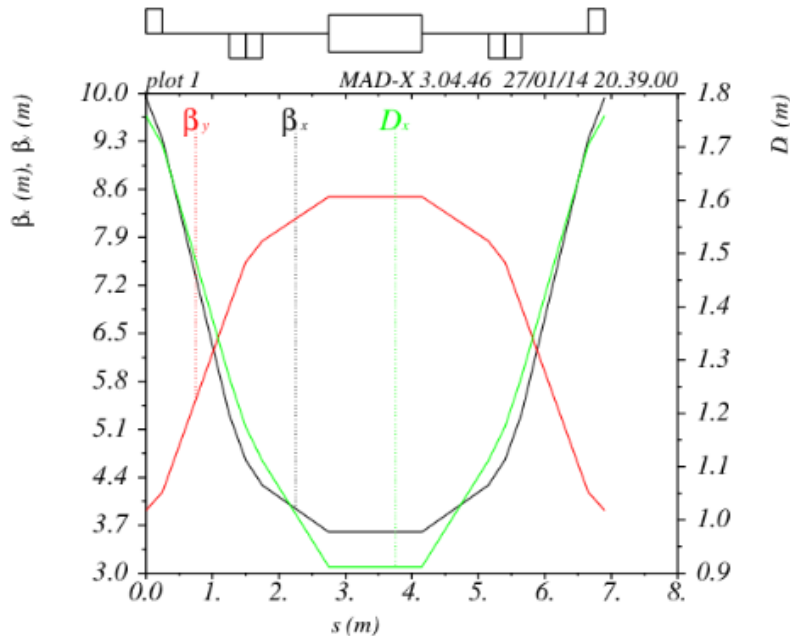
Multi bend achromats (MBA)



SR workshop (R. Bartolini)

The goal of the workshop is to design an upgrade of a second generation light source to a third generation light source. The beam energy is 2.5 GeV.

Assume the old lattice looks like



It uses only bending magnets (no long straight sections)
16 bends 1.4 m long. Compute the critical photon energy

SR workshop (R. Bartolini)

We want to create space for IDs and reduce the emittance

The new machine has to fit in the same tunnel, so the circumference is a fixed parameter, say

$$C = 110.4 \text{ m}$$

We want to have 8 long straight sections, say

long drifts 3.5 - 4 m (start with 4 m)

Use a double bend achromat and the previous geometric constraints

SR workshop (R. Bartolini)

What emittance can you achieve?

Can you maintain the same critical energy from the bending magnet?

Find the parameters for the following IDs

fundamental wavelength at 8 keV with a linewidth of 10^{-4} !

peak flux reaching 20 keV

What RF power is needed for running 400 mA?

Further comments:

Make it symmetric – 8 cells of length $110.4/8 = 13.8$ m

Keep the achromatic condition in the ID straights

Make betay small at the ID straight section (beta x can be larger...)

Use symmetry points for matching

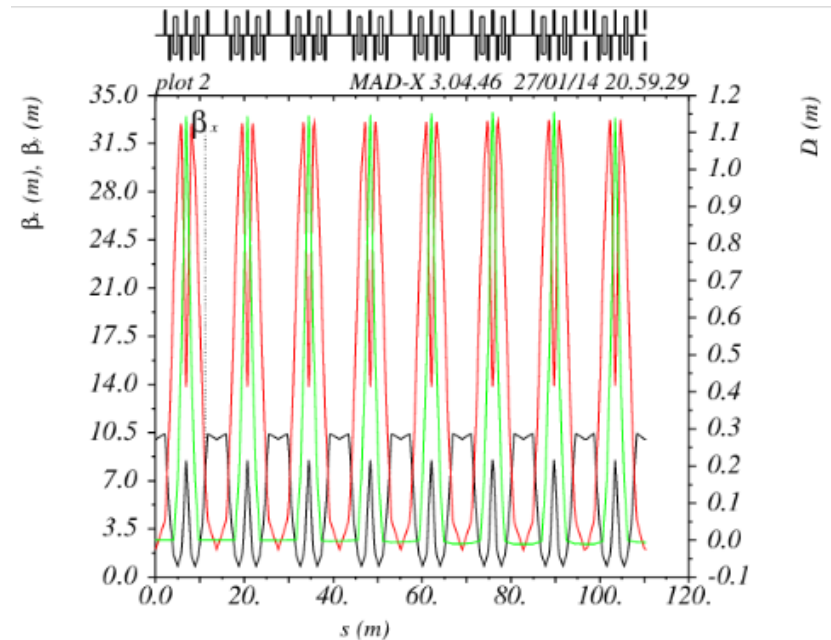
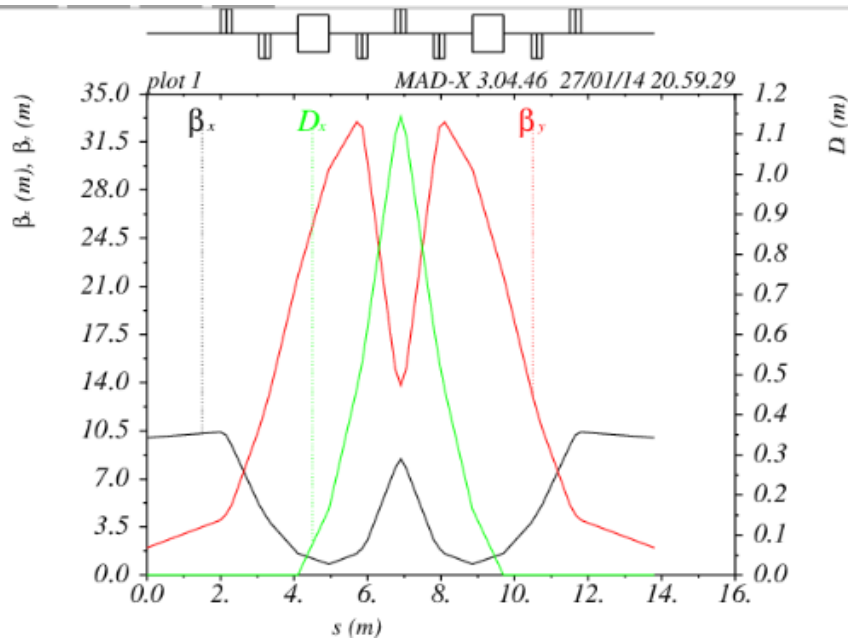
Plot (and minimise) the dispersion invariant

Did you compute the emittance correctly?

How would you modify this design to a MBA?

SR workshop (R. Bartolini)

A possible solution – by no means optimal



The emittance is expected to be in the 10s~ nm