SR workshop (R. Bartolini)

The goal of the workshop is to design synchrotron light source based on a DBA lattice. The beam energy is 2.5 GeV.

From the initial DBA cell from P. J. Bryant

- **assume 8 DBA cells with 3.2 m straight sections**
- **complete matching (achieve betay = 2m in SS, check tunes)**
- **play with optics to reduce the emittance (break the achromatic condition)**
- **compute critical frequency of bending, energy loss, total power radiated**
- **Install IDs to reach 8 keV**
- **compute tuning range, bandwidth, energy loss per turn, total power emitted by the IDs, brilliance, tuning curves**
- **compute the RF power needed for 300 mA**

Low emittance lattices

Low emittance and adequate space in straight sections to accommodate long Insertion Devices are obtained in

Double Bend Achromat (DBA)

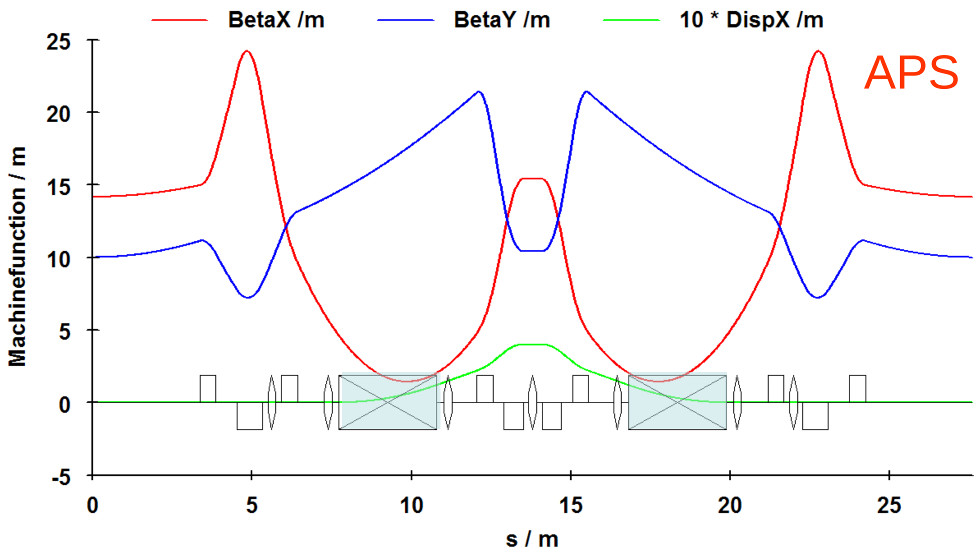
Triple Bend Achromat (TBA)

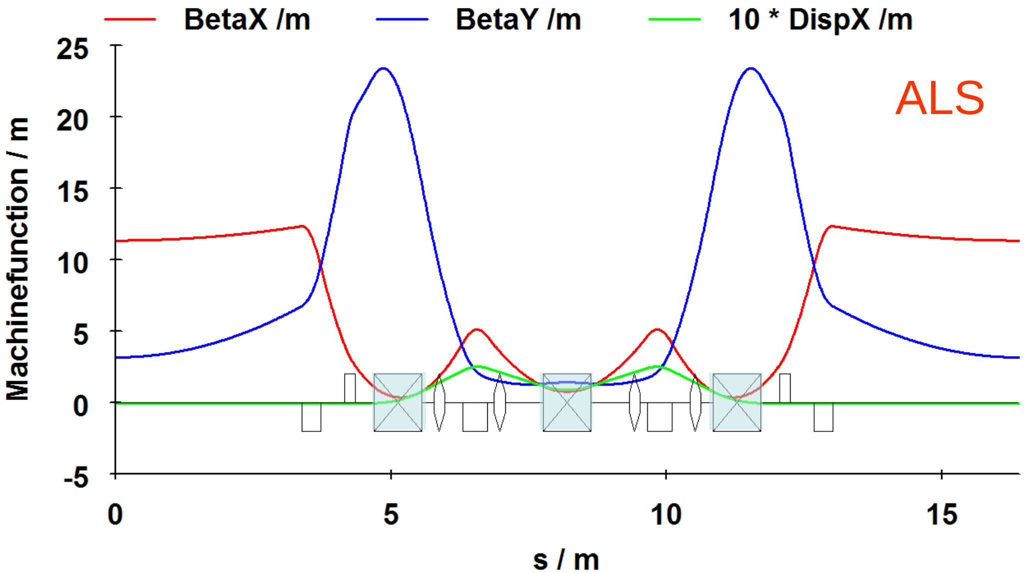
DBA used at:
ESRF,
ELETTRA,
APS,
SPring8,
Bessy-II,
Diamond,
SOLEIL,
SPEAR3
...

TBA used at
ALS,
SLS,
PLS,
TLS
…

$$\varepsilon_x = F \frac{C_q \gamma^2 \theta_b^3}{J_x} \propto \frac{1}{N_b^3}$$

$$F_{MEDBA} = \frac{1}{4\sqrt{15}} \qquad F_{MEDBA-disp} = \frac{1}{12\sqrt{15}}$$





Breaking the achromatic condition

Leaking dispersion in straight sections reduces the emittance

ESRF	7 nm $\rightarrow$ 3.8 nm
APS	7.5 nm $\rightarrow$ 2.5 nm
SPring8	4.8 nm $\rightarrow$ 3.0 nm
SPEAR3	18.0 nm $\rightarrow$ 9.8 nm
ALS (SB)	10.5 nm $\rightarrow$ 6.7 nm

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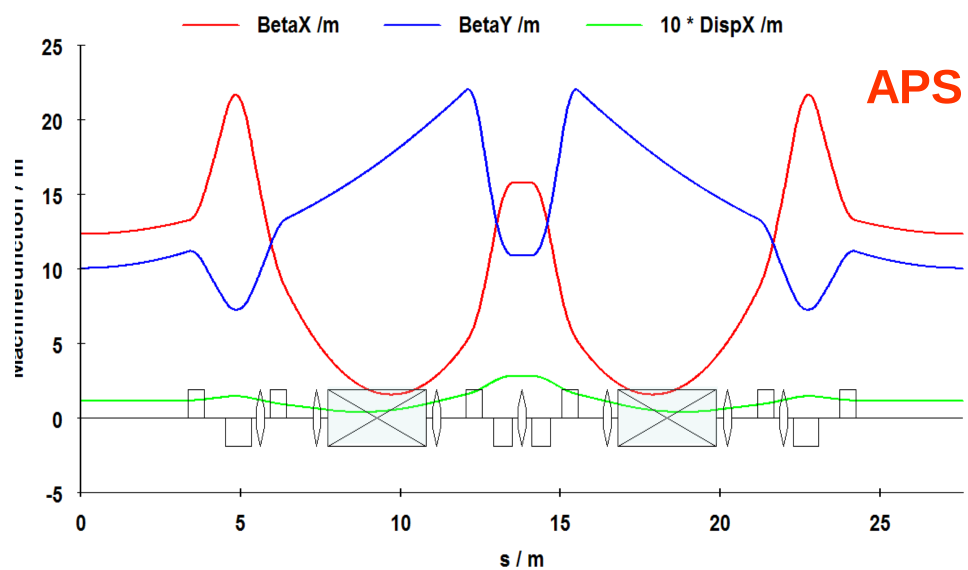
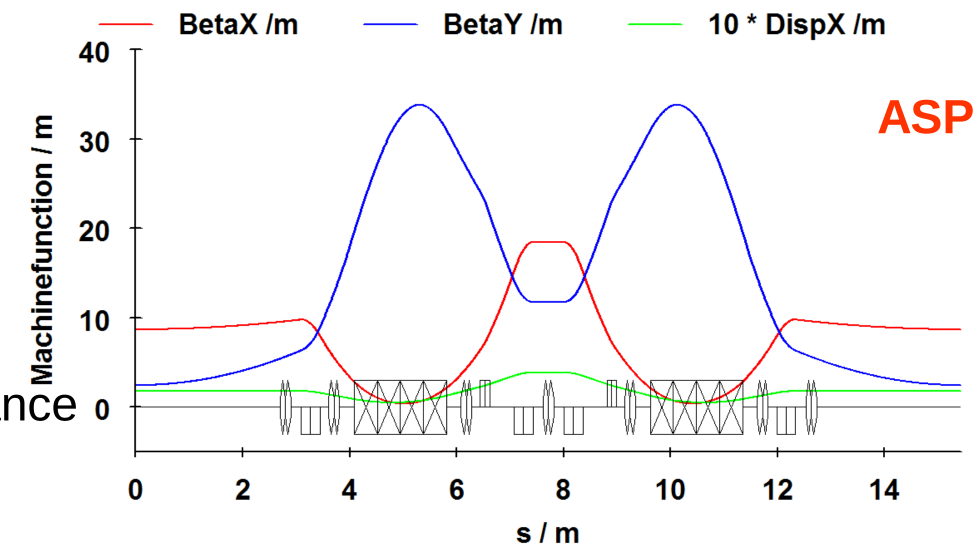


The emittance is reduced but the dispersion in the straight section increases the beam size

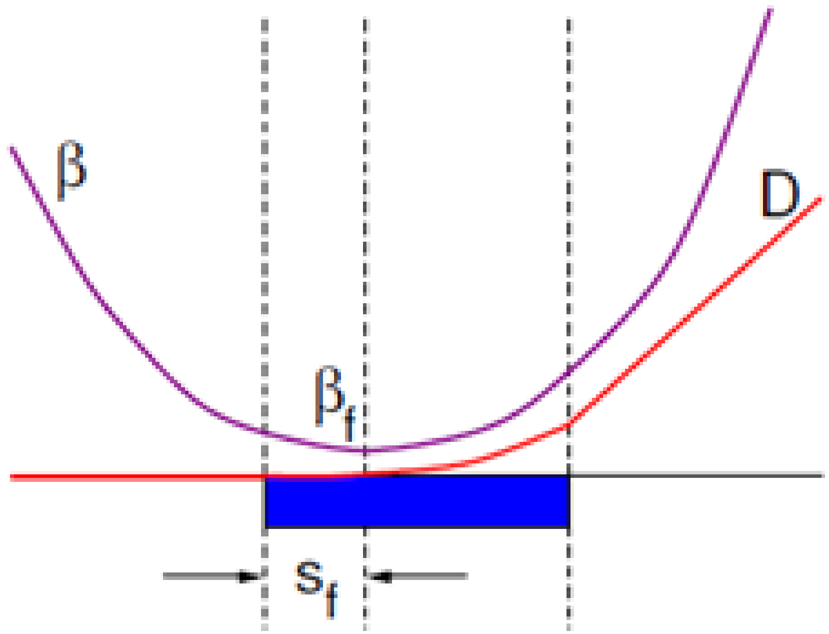
$$\sigma_x = \sqrt{\varepsilon_x \beta_x + (\sigma_E D_x)^2}$$



Need to make sure the effective emittance and ID effects are not made worse

Minimum emittance from a single dipole

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 from of a double bend achromat called **Chashman-Green** lattice

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

Minimum emittance from a single dipole

If we start with an achromatic condition at the beginning (or end) of the dipole we must find a minimum of <H> dipoles as a function of

(α_0, β_0) with $(D_0, D'_0) = (0, 0)$

The average of the dispersion invariant is

$$< H >_{\text{dipoles}} = \frac{1}{4\sqrt{15}} \rho\theta^3$$

this is three time larger than the TME

The condition for the minimum emittance and requires that the focus of the beta function ($\alpha_f = 0$), i.e. the minimum of β is reached in the first half of the dipole and occurs at

$$s_f = \frac{3}{8} L$$

and β reads

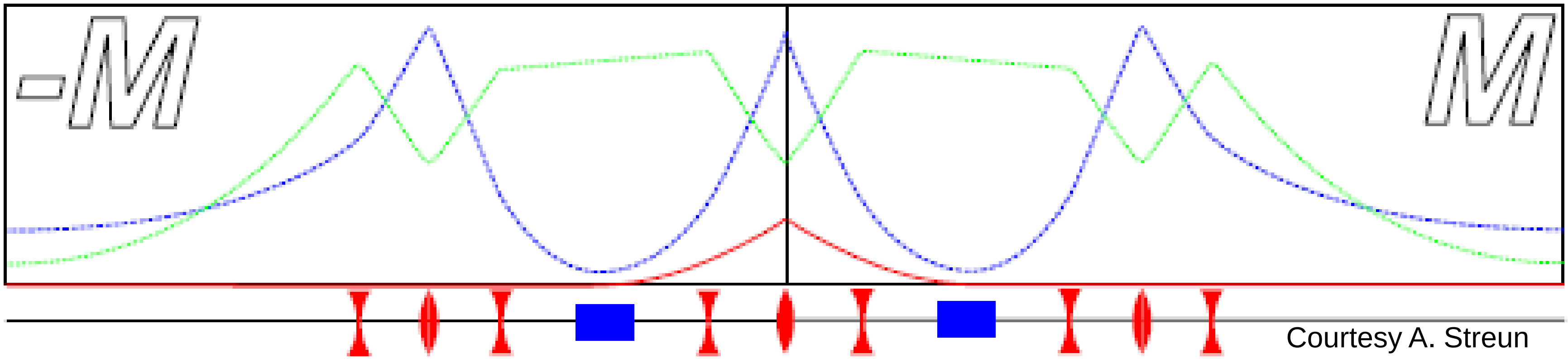
$$\beta_f = \frac{1}{8}\sqrt{\frac{3}{5}} L$$

In this case, the values of the optics functions at the entrance of the dipole are

$$\beta_0 = 2L\sqrt{\frac{3}{5}} \qquad \alpha_0 = \sqrt{15} \qquad D_0 = D'_0 = 0$$

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

$$\varepsilon_x = F \frac{C_q \gamma^2 \theta_b^3}{J_x} \qquad F_{MEDBA} = \frac{1}{4\sqrt{15}}$$