

The Amsterdam Pulse Stretcher AmPS as a Photon Source

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Abstract

AmPS, an electron Pulse Stretcher/Storage Ring will start delivering nearly continuous electron beams of maximum 900 MeV in Spring 1992. The extracted beam (using the machine in Stretcher Mode) as well as the stored beam (in conjunction with an internal gas-jet target) will be used for nuclear physics purposes for about 2500 hours/year. For the remaining time of the year AmPS could be used as a dedicated Photon Source covering the spectrum from infrared up to soft X-rays. The synchrotron radiation properties of the actual machine are presented together with a design for a modified ring lattice. The modification only requires the addition of focussing elements to the actual machine so the characteristics in "nuclear physics" mode are not affected. The new lattice will allow AmPS to be operated in a low-emittance mode ($\epsilon = 4.5 \times 10^{-9}$ rad.m @ 900 MeV) providing a SR brilliance from its bending magnets of 2×10^{14} photons / s / mrad² / mm² / 100 mA / 0.1 % BW. Further enhancement of the brilliance can be achieved by the implementation of multipole undulators. The ring can accommodate such insertion devices in one of its 32 m long straights.

1. INTRODUCTION

AmPS operating in Storage Mode will store currents up to 200 mA. The AmPS ring has a "square" shape with a fourfold symmetric structure. Each quadrant comprises an achromatic curve ($l = 20.8$ m) with straights ($l = 16.1$ m) on either side; circumference is 212 m. The magnet lattice is of the FODO type and consists of 32 dipoles, 68 quadrupoles and 32 sextupoles. The project has been described in full detail in [1].

2. SYNCHROTRON RADIATION FROM THE PRESENT LATTICE

General: synchrotron radiation will be available from the 32 dipoles ($\rho = 3.3$ m) of AmPS. The ring has 4 straight sections of which two sections can accommodate insertion devices. Table 1 shows general SR parameters of AmPS.

Spectrum: the AmPS ring has been designed to operate from 300 MeV to 1.0 GeV. The characteristic energy of the SR from the bending magnets can therefore be shifted from 20 eV at 300 MeV to 665 eV at 1 GeV. A superconducting wavelength shifter with a strength of 8 T can extend the characteristic energy to about 5 keV.

Photon flux and brilliance: the photon flux from the dipoles is comparable with the flux from other SR sources. The present usage of AmPS (Stretcher + Internal Target Physics) doesn't require low emittances and small beam sizes. The SR brilliance of the source therefore is presently not competitive with the new generation of machines.

3. LOW EMITTANCE LATTICE

3.1. Basic concept

The transverse emittance ϵ_x can be expressed as

$$\epsilon_x = C_q \gamma^2 \frac{I_5}{I_2 - I_4} \quad (1)$$

C_q is a lattice-independent constant; I_n are the synchrotron integrals. $I_2 = 2\pi/\rho$; for a given set of dipoles, therefore, I_2 is a constant. For rectangular dipoles, see ref [2], $I_4/I_2 \approx -\pi^2/(3N_d^2) = -3.2 \times 10^{-3}$ (N_d is number of dipoles).

Table 1. General SR characteristics of the actual AmPS ring

SR from ring dipoles				
electron energy	[GeV]	0.3	0.6	0.9
circulating current	[A]	0.2	0.2	0.2
dipole field	[T]	0.3	0.6	0.9
characteristic energy (ϵ_c)	[keV]	0.02	0.14	0.49
energy loss/turn	[keV]	0.22	3.5	17.4
photon flux	[10^{12} *]	0.48	0.96	1.44

* photons/s/mrad/100 mA/0.1 % BW

A decrease of the value of ϵ_x , therefore, implies decreasing the value of I_5 . The value of I_5 strongly depends on the dispersion function inside the dipoles: in all low-emittance lattices the dispersion function inside the dipoles is small.

3.2. Possible low-emittance structures

Since we are dealing here with an adaption of an existing lattice, with the additional condition of retaining the functionality of the present lattice, the possibilities of modification are somewhat restricted.

Basically four structures have been considered:

- double focussing achromat (DFA): FD-[B]-F-[B]-DF
- triple achromat (TA): [B]-FDF-[B]
- triple bend achromat (TBA): FD-[B]-F-[B]-F-[B]-DF
- FODO structure: F-[B]-D-[B]

F and D indicate focusing and defocusing quads respectively; B is a dipole. The minimum emittance obtainable with these structures can be expressed as

$$(\epsilon_x)_{\min} = C_q \gamma^2 \theta^3 f \quad (2)$$

θ is the dipole bending angle (rad) and f is a structure-dependant factor (e.g. $f(\text{DFA}) = 6.45 \times 10^{-2}$; $f(\text{TBA}) = 5.02 \times 10^{-2}$). Comparing $\theta^3 f$ with the present value of I_5/I_2 indicates that theoretically the emittance can be reduced by a factor 350–250.

FODO structure

Each of the four cells comprising a Curve is basically a FODO cell; since such a cell contains two dipoles, the structure is **not** dispersion-free. In order to match the FODO cells to the dispersion-free straights, a *dispersion suppressor* is needed. The following structure, (Fig. 1), containing 4 dipoles, is composed from two regular (Curve) cells, and comprises one FODO cell + dispersion suppressor:

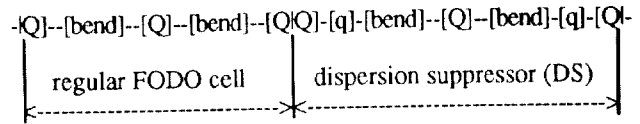


Fig. 1 Half a Curve; the structure of a full Curve is (DS)-(FODO)-(FODO)-(DS). The physical lengths of (FODO) and (DS) are equal. Four additional quads/Curve ([q]) are needed.

Since the dispersion function in a FODO cell is never very low (here it oscillates between 0.35 and 0.90 m), the equilibrium emittance will also not be very low:

$$\epsilon_x (@900 \text{ MeV}) = 32 \times 10^{-9} \text{ rad. m.}$$

(i.e. reduction by factor 5 w.r.t. present lattice)

$$\chi_x = -8.1 \quad \chi_y = -14.8$$

This relatively small reduction factor of the emittance makes this structure for our machine not very interesting.

TBA's

Each Curve comprises 8 dipoles (4 cells); $1 \frac{1}{2}$ cell (containing 3 dipoles) can be converted into a triple bend achromat (TBA). Two additional quads per TBA are needed. Using 6 out of a total of 8 dipoles (i.e. 3 cells) yields two TBA's. The remaining cell (containing two dipoles) should be used to 'connect' the two TBA's. Constructing the TBA's is not the problem; the problem is to construct from the one remaining cell (and within the space occupied by that cell) an (achromatic) match between the two TBA's:

$$[\text{TBA}] - [\text{achr. match of 2 dipoles}] - [\text{TBA}]$$

This problem has not been solved yet. Another possibility is to connect the two TBA's directly, and put one dipole on either end of the structure:

$$[\text{one dipole-match}] - [\text{TBA}] - [\text{TBA}] - [\text{one dipole-match}]$$

Table 2. SR source parameters at 0.9 GeV; present lattice and improved lattice ('mod(a)').

	lattice type		
	present	improved	
horiz. beam emittance (ϵ_x)	[10^{-9} rad.m]	160	4.8
horiz. beam size (σ_x) in dipole	[μm]	690	85
vert. beam size (σ_y) in dipole	[μm]	87	21
natural SR vert. divergence at ϵ_c	[μrad]	290	290
brilliance	[10^{12} **]	5.7	190

** photons/s/mrad²/mm²/100 mA/0.1 % BW

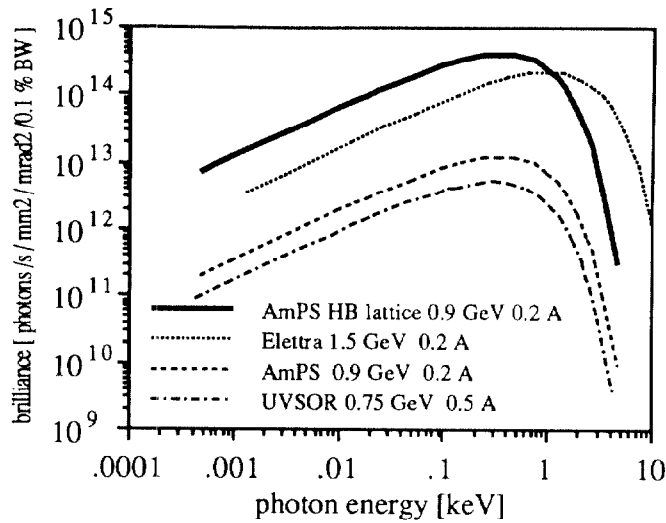


Fig.2 AmPS brilliance (present and modified lattice) compared to Elettra and UVSOR brilliance.

This match is not achromatic; therefore the TBA should already start with non-zero dispersion, thus increasing the dispersion function in *all* the TBA magnets: the structure will acquire FODO-like properties. This is probably not a fruitful approach.

3.3. AmPS lattice modification

Each of the 4 curves of AmPS comprises 4 cells of the following configuration:

$$F-[B]-D-[B]-F$$

Adding a quad either on the inside or outside of each dipole (and changing the polarity of the central quad) will result in a DFA-like structure, see Fig. 3:

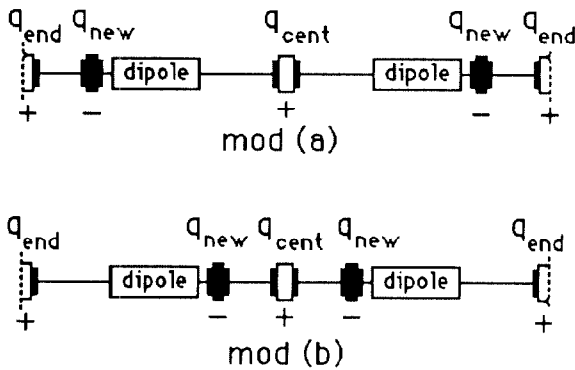


Fig. 3 Modification of cell structure (solid :added quadrupoles); each of the 4 Curves comprises 4 of these cells.

Each Curve contains two families of sextupoles (2 per cell) to control the chromaticity; these sextupoles are not shown in Fig. 3. In Table 3 some properties of the two configurations have been summarized. Configuration 'mod(b)' clearly reduces the emittance the most; however, this structure introduces much more chromatic aberrations than

configuration 'mod(a)'. Before a final decision will be made about the modification configuration, a more thorough analysis will be made about chromaticity control, dynamic aperture and sensitivity of the modified lattice.

Table 3. Quadrupole tipfields ($E = 0.9 \text{ GeV}$) and emittance-related data of configurations *mod(a)* and *mod(b)*, see Fig. 1. Dimensions of q_{new} : $l = 0.105 \text{ m}$; $\phi = 71 \text{ mm}$

	mod(a)	mod(b)
$B_{tip}(q_{end})$ [kG]	7.87	8.08
$B_{tip}(q_{cent})$ [kG]	8.28	9.60
$B_{tip}(q_{new})$ [kG]	-8.73	-8.95
$\epsilon_x(0.9 \text{ GeV})$ [rad.m]	4.8×10^{-9}	1.1×10^{-9}
χ_x	-18.0	-63.0
χ_y	-13.9	-34.1
$\epsilon_{present}/\epsilon_x$	33	149
I_5 / I_2	4.06×10^{-3}	0.91×10^{-3}

4. PROPERTIES IMPROVED LATTICE

The resulting SR brilliances from dipole radiation for the actual and the improved lattice ('mod(a)', Fig.3) are shown in Fig. 2. The graph clearly shows the competitive position of AmPS with respect to some of the new generation machines. In Table 2 important source parameters are summarized. A possible set-up for SR beamlines including insertion devices has been presented in [3].

5. CONCLUSIONS

It is possible to adapt the AmPS lattice to operate either in a high or a low emittance mode. In the low emittance mode the AmPS ring will provide a competitive photon flux and a high brilliance when compared to other synchrotron radiation sources. The ring will operate for nuclear physics experiments during 2500 hours/year. Therefore dedicated use of the ring for SR experiments would be feasible up to about 2000 hours/year provided funding is available.

6. REFERENCES

- [1] G. Luijckx e.a., "Status of the Amsterdam Pulse Stretcher Project " Proc. 2nd European Accelerator Conference (EPAC 1990), pp. 589-591.
- [2] J.A.Uythoven, J.I.M. Botman and H.L. Hagedoorn, "Analytical evaluation of synchrotron radiation integrals for isomagnetic lattices with rectangular dipole magnets". Proceedings EPAC (Rome, June 7-11, 1988), p.649
- [3] Guy Luijckx and Rob Maas, "Synchrotron Radiation from the Amsterdam Pulse Stretcher (AmPS)" Proc. 4th International Conference on Synchrotron Radiation Instrumentation [SRI-1991], Review of Scientific Instruments, Vol.63, No.1 (part II B) pp.1621-1622.