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A 4th GENERATION LIGHT SOURCE FOR SOUTH-EAST-EUROPE

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Abstract

In Europe, most of the Synchrotron Light Sources are located in the middle, west and northern regions while the south-east is still lacking any major project. Hence a new initiative has been set up to propose the construction of a 4th Generation Light Source in that region. Design requirements limit the beam energy between 2.5 GeV to 3 GeV, the circumference is limited to 350 m, the emittance should be smaller than 250 pm rad and at least 14 to 16 straights have to be available for the users. Several magnet configurations have been investigated and the results revealed that the HMBA lattice can fully meets the requirements and is therefore proposed for the Light Source in the SEE-region of Europe. These studies show that for a 4th Generation Light Source with energies up to 3 GeV a circumferences of 350 m will be adequate.

INTRODUCTION

The South East European Region is an integral part of Europe but needs the help of the other European countries to develop its sustainable economy and social cohesion. The creation of an international institute devoted to sustainable technologies would be an essential element in such endeavours. The scientific and technological cooperation, including knowledge transfer and training of the young generation would strengthen innovation, information exchange and the development of human capacity building. A large-scale scientific research facility permitting excellence and internationally competitive activities is a significant means of addressing such common challenges. Since it could not be realised by a single country it requires regional cooperation and in this way its primary mission of attaining scientific excellence would be complemented by peaceful collaboration in a Region with considerable political frictions. For this propose, eight countries of south east of Europe region (Albania, Croatia, Bosnia - Herzegovina, Bulgaria, Kosovo, the FYR Macedonia, Montenegro, Serbia and Slovenia) signed a corresponding declaration. In the Declaration it is stated that the institute shall operate with the mission of 'Science for Peace' and that the Parties have a common vision and encourage the cooperation of researchers from the Parties.

Two options are considered for this initiative. The first one is 4th Generation Synchrotron Light Source for Science and Technology (SEE-LS) and the second one is Facility for Tumour Hadron Therapy and Biomedical Research. For the preparation of a concept for the SEE-LS project, a committee was set up with C. Quitmann (MAX IV) A. Nadji (SOLEIL), R. Bartolini (Diamond), P. Fernandes-Tavares and D. Einfeld (ESRF) as Chair person.

The project was formally announced and presented at the FORUM meeting at the ICTP in Trieste [1].

LATTICE SELECTION

Well known lattices for the 4th Generation Light Sources are: a.) the 7MBA lattice used for MAX IV [2], b.) the 5MBA for SIRIUS [3], c.) the HMBA lattice used for the upgrade of the ESRF and other light sources [4],[5], d.) the DDBA and DTBA lattices for a possible upgrade of Diamond [6],[7], e.) the S6BA (also a DTBA) for the upgrade of ELETTRA [8] and f.) the 7MBA lattice with anti bends and longitudinal gradients in the magnets [9], proposed for the upgrade of SLS. Some month ago a possible lattice for the upgrade of Soleil was presented [10]. The specifications of these lattices are summarized in Table 1.

Table 1: The Main Specifications of Some of the 4th Generation Light Source Lattices

Lattice	MAX IV	HMBA	SIRIUS	DDBA	DTBA	S6BA	SLS-II	SOL-2
Circumf. (m)	528	506.28	518.4	561	561	259.2	290.4	354.7
Periods	20	22	20	24	24	12	12	20
Achr.-Length (m)	26.4	23.013	25.92	23.375	23.375	21.6	24.2	17.735
Energy (GeV)	3	3	3	3	3	2	2.4	2.75
Emittance (pmra	328	141	250	272	101	255	102	72
Tune_Qx	44.06	53.6	48.1	51.21	57.45	33.1	37.2	55.2
Tune_Qy	17.76	15.43	13.17	17.31	20.362	9.2	15.3	18.2
Chrom._ξx	-51.47	-87.86	-124.4	-129	-78.15	-75	-95	-134
Chrom._ξy	-51.37	-70.78	-79.9	-93.51	-109.7	-51	-35.2	-125

The DDBA, DTBA and the S6BA lattices have the advantage of having an additional straight section in the middle of the achromat. These straights can be used to install small insertion devices and all instrumentations needed for the machine operation; hence more space is available for the users. The HMBA lattice has the requirement that the phase advance between the dispersion regions have to be π (vertical) or 3π (horizontal). This limits the settings for the smallest emittance, reduces however the number of required sextupoles. The specifications, according to a matching for a conference of roughly 350 m, are given in Table 2.

Table 2: Parameters of the Lattices in Table 1 Matched to a

Circumference of around 350 m.

Lattice	MAX IV	HMBA	SIRIUS	DDBA	DTBA	S6BA	SLS-II	SOL.-2
Circumf. (m)	369.60	368.20	362.88	374.00	374.00	345.60	338.80	354.7
Periods	14	16	14	16	16	16	14	20
Achr.-Length (m	26.40	23.01	25.92	23.38	23.38	21.60	24.20	17.735
Energy (GeV)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Emitt. (pmrad)	664	255	506	638	237	168	70	72
Tune_Qx	30.84	38.98	33.67	34.14	38.30	44.13	43.40	55.2
Tune_Qy	12.43	11.22	9.22	11.54	13.57	12.27	17.85	18.2
Chrom._ξx	-36.03	-63.90	-87.08	-85.99	-52.10	-100.00	######	-134
Chrom._ξy	-35.96	-51.48	-55.93	-62.34	-73.13	-68.00	-41.07	-125

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According to the requirement in the circumference, emittance and the number of straights, only the HMBA, DTBA, S6BA and the SLS2 lattices can be considered as candidates for the SEE-LS. Nonlinear beam dynamics issues favored at the end the HMBA and the S6BA. According to the reduced numbers of sextupoles and the larger dynamic aperture the HMBA lattice was finally chosen as a candidate for the SEE-LS. However the S6BA lattice is also a promising candidate. For a final decision more calculations have to be done and it is not excluded that other lattice solution, like the proposed SOLEIL upgrade, could be extended to this case.

PROPOSED LATTICE FOR THE SEE-LS

The magnetic structure and the machine functions of the proposed HMBA lattice are presented in Fig. 1. This is the same as for the upgrade of the ESRF [4], [5], and the difference is in the technology of the long bending magnets in the dispersion region. The idea is to use a gradient in the horizontal and not in the vertical direction, but still produced with permanent magnets. One quadrant with the main machine parameters is reported in Fig. 2. For 2.5 GeV and a circumference of 348 m, an emittance of 178 pm rad can been reached. The periodicity is N = 16 and the length of the straights is 5.8 m. The cross section of the beam in the middle of the straights are σ(x) = 51.2 μm and σ(y) = 4.8 μm for a coupling of 3 % leading to a vertical emittance of 5 pmrad.

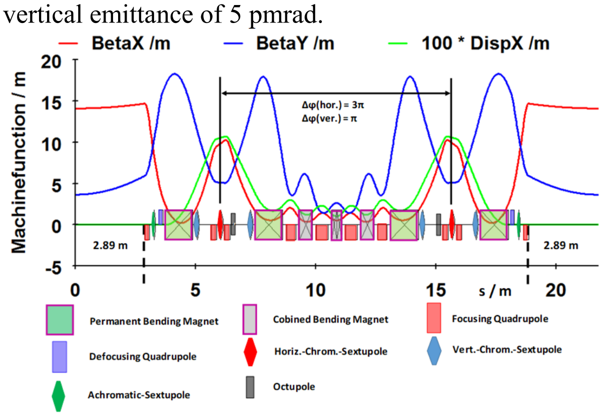

Figure 1: Magnetic structure and machine functions for the proposed SEE-LS lattice.

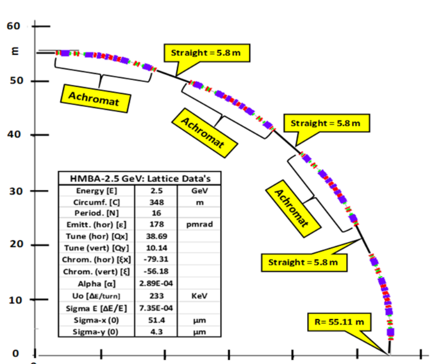

Figure 2: Layout of a quadrant with the specification of the storage ring.

The dynamic aperture, presented in Fig 3, is between ±7 to ±14 mm, values similar to other upgrade projects. Tune shift due to energy deviation is plotted Fig. 4. The relation between the proposed SEE-LS concept to other operating and proposed light sources is presented in Fig. 5 (see spot SEE-LS), a plot, which was created by R. Bartolini [6]. Within this graph the normalized emittance is given as a function upon the circumference. The spot of SEE-LS is below the red line which indicates that the specifications are well within those of 4^{th} Generation Light Sources.

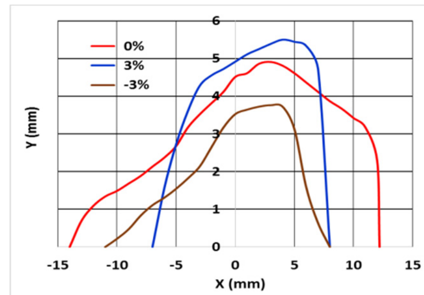

Figure 3: Dynamic aperture for on and ±3% off energy particles.

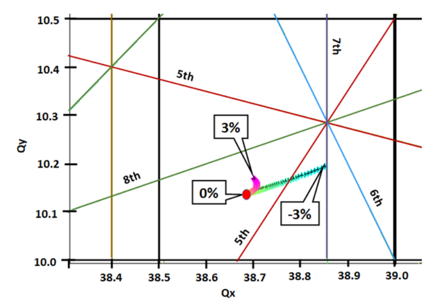

Figure 4: Tune movement with energy deviation up to ±3%.

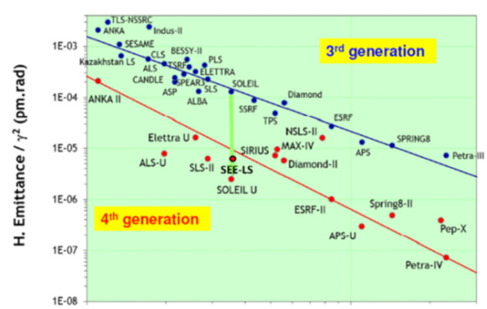

Figure 5: The normalized emittance vs circumference for the different light sources.

The brilliance achieved is presented in Fig. 6. In the soft-X-ray region brilliances region 10^{21} to 10^{22} ph/s/mm2/rad2/0.1%BW can be reached and a spectral region up to 20 keV can be covered. The intention is to build a 3 GeV machine and operate it at the beginning with 2.5 GeV in order to save some investment and operation costs. With 3 GeV, a spectrum up to 30 keV can be covered with insertion devices. Another argument for going later up to 3 GeV is that the nearest other light sources (ELETTRA and SOLARIS) operating only up to 1.5 or 2 GeV.

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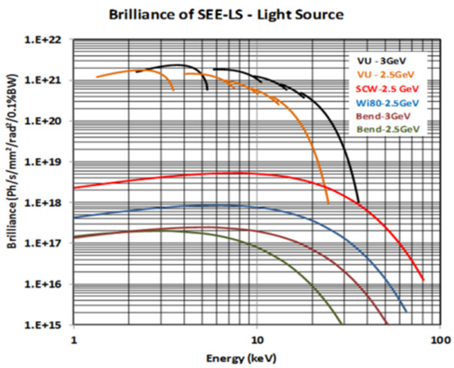

Figure 6: Brilliances of the proposed SEE-LS for different insertion devices and beam energies.

The fraction of coherent light as a function of the photon energy for different beam emittance is presented in Fig. 7. As shown, there is a big step between the 3rd and 4th generation light sources but not so much by reducing the emittance to values smaller as 0.2 nmrad.

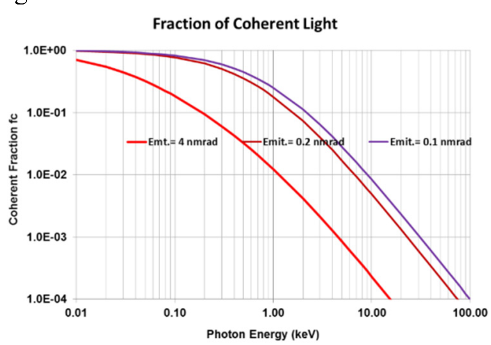

Figure 7: Fraction of coherent light source vs photon energy.

SPECIFICATIONS OF COMPONENTS

The parameters of the required magnets are roughly the same as for the ESRF-upgrade [11],[12] (see table 3). The magnets in the first part of the achromat (see Fig. 8) need a good field region of ± 12 mm and in the middle of the arc of +/- 6 mm.

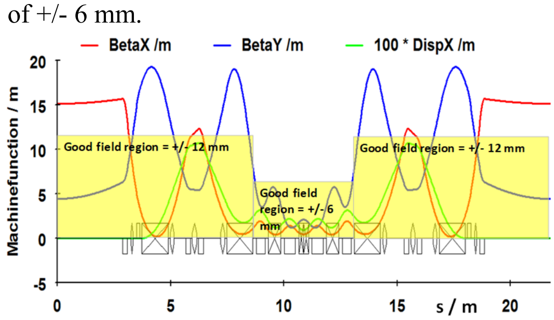

Figure 8: Good field region in quadrupoles and sextupoles.

Hence the intention is to use the ESRF-EBS ones with some modifications in the length. Also the type of girders used for the ESRF upgrade are proposed for the SEE-LS project. For the vacuum system, it is proposed to use a completely NEG-coating system as for MAX IV [13]. For the RF-system a 100 MHZ system should be used, it should also a copy of the Max IV system [14].

Table 3: The Main Specifications of the Magnets

Element	Length (m)	Defl.-Angle (degrees)	Radius (m)	Gradient (T/m)	B'' (T/m^2)	B(pole) (T)
M11	1.15	3.7	17.8081	4.3196	-91.462	0.468
M12	1.15	3.65	18.0521	9.14788	126.436	0.462
MQ1	0.55	2.6	12.1203	29.2115	-1805.9	
MQ2	0.44	2.6	9.69621	32.1468	1448.82	
		k-Value	(mm)			
QF1	0.2	4.4228	16.4	36.882		0.605
QD2	0.15	-2.7487	16.4	-22.921		-0.376
QF3	0.212	2.949	16.4	24.592		0.403
QF4	0.212	3.1092	16.4	25.928		0.425
QF5	0.388	6.6183	12.7	55.190		0.701
QF6	0.484	5.8611	12.7	48.876		0.621
		K-Value	(mm)			
SH1	0.1	43.448	19.2		724.631	0.1308
SD1	0.166	4.299	19.2		71.6993	0.01294
SF2	0.2	77.398	19.2		1290.85	0.233
SD3	0.166	-150.01	19.2		-2501.9	-0.4516

INJECTOR

The injector chain is given by the Linac, LTB transfer line, booster synchrotron and BTS transfer line, as for ALBA. A commercial 100 MeV Linac will be used as pre-injector. One quadrant of booster lattice is presented in Fig. 9. It includes of 12 unit cells with matching cells on each side of the straight sections. The circumference is 324 m, the periodicity is 4 and the emittance is 4.7 nmrad. The booster and the storage ring will share the same machine tunnel. With a RF-frequency of 100 MHZ both rings are separated by 3.8 m.

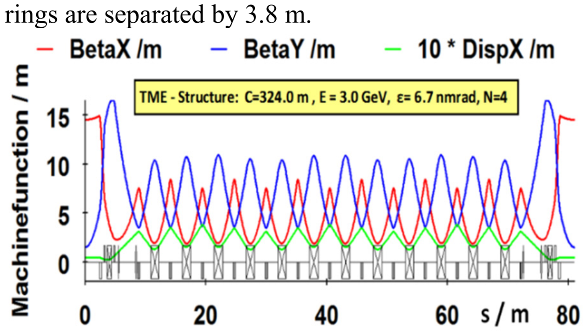

Figure 9: Layout of the proposed booster synchrotron.

CONCLUSION

A concept for a proposed synchrotron light source in the South-East-Europe region has been worked out. A comparison of the different lattice proposals for 4th generation light sources, shows that the HMBA-concept with horizontal gradient magnets fulfill the requirements. It could be shown that it is possible to get a 2.5 GeV 4th Generation Light Source with an emittance of less than 200 pmrad and circumferences of only 350 m. By giving up the phase requirements and introducing more sextupoles, the emittance can still be reduced to values smaller as 140 pmrad.

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REFERENCES

[1] *http://indico.ictp.it/event/8506/material/2/*

[2] S.C. Leemann, *Recent Improvements to the Lattices for the MAX IV Storage Rings*,IPAC11, 3029 (2011).

[3] L. Liu, et.al., *A New 5BA Low Emittance Lattice for Sirius*, IPAC13, 1874 (2013).

[4] J.L. Revol et al.,*ESRF Upgrade Phase II,* IPAC13,1140 (2013).

[5] S. Liuzzo et al., *Hybrid Multi Bend Achromat at 3 GeV for Future 4th Generation Light Sources,* IPAC16, 2822 92016).

[6] R. Bartolini, et al., *Novel Lattice Upgrade Studies for Diamond Light Source,* IPAC13, 240 (2013).

[7] R. Bartolini, *Design and Optimization Strategies of Nonlinear Dynamics in Diffraction-limited Synchrotron Light Sources,* IPAC16, 33 (2016).

[8] https://indicio.cern.ch/event/671745/timetable/

[9] A. Streun, *The anti-bend cell for ultralow emittance storage ring lattices,* NIMA, 737, p.148 (2014).

[10] *https://indicio.cern.ch/event/671745/timetable/*

[11] G. Le Bec, et al., "*Magnets for the ESRF diffraction limited light source project*," IEEE transactions on applied superconductivity, vol. 26, 2016.

[12] G. Le Bec, *et al.,* "*High gradient quadrupoles for low emittance storage rings,*" Physical Review Accelerators and Beams, vol. 19, p. 052401, 05/09/ 2016.

[13] E. Al-Dmour, et. al., *Diffraction limited storage ring vacuum technologies*, J. Synchrotron Radiation (2014), 21 (878-883).

[14] A. Andersson, et. al., *The 100 MHz RF System for MAX IV Storage Rings*, IPAC 2011 (193-198).