PROPOSAL FOR A 3rd GENERATION NATIONAL IRANIAN SYNCHROTRON LIGHT SOURCE

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Abstract

The Institute for Research in Fundamental Sciences, IPM, has been given the go ahead to establish a major center in Iran for multi disciplinary research. The facility will include a 3rd generation light source for promoting science and technology in the field of accelerators and applications of synchrotron radiation. The preparation of the conceptual design report has been funded by the Iranian government and will be executed under the authority of the president of the Institute for Research in Fundamental Sciences, IPM, Tehran, Iran. The location of the facility will be close to the Iranian capital city, Tehran. Site selection for a few different locations is underway .The conceptual design report has to be finished by the end of 2011. The present draft design is a 3GeV, 3rd generation light source with a circumference of about 300 m and an emittance of 3.6 nm-rad providing light for research from the infra-red to X-rays region up to 10 keV and beyond. As initial beamlines, we plan for a protein crystallography beam line as well as SAXS and WAXS beamlines for material science research, UV/VUV/SXR, photoelectron spectroscopy and photon absorption spectroscopy, IR spectroscopy and EXAFS. Various technical groups which include Beam Optics, Power Supply, Radio Frequency, Mechanics, Vacuum, Magnets, Beam Diagnostics, Control, Radiation Safety, Cooling and Civil engineering have been formed. Initial steps towards completing a conceptual design of the project are taken. Major decision making are performed by the interim council consisting of many Iranian scientists and authorities.

INTRODUCTION

There are roughly 50 synchrotron light sources around the world, most of them are located in Europe, East Asia and North America. There isn't any Light Source in Iran and in the neighbouring countries. In order to improve the scientific conditions Iran is a member state of SESAME. Furthermore the number of students in Iran increases every year. For the improvement of the scientific conditions and the up to date education of the students the Iranian government has decided to build a synchrotron light source which provides an up to date research tool for the Iranian scientific community. Through this project Iran seeks a world's wide collaboration. For the design of this facility as well the operation Iran looks for international collaborations. For the design of the machine only a limited expertise exists in Iran and Iran will be relying on the support of SESAME for the preparation of the conceptual design report. Most of the sophisticated components for the accelerator complex as well the beam lines are not available in Iran and Iran is willing to purchase these components from abroad. The conceptual design report has to be finished within the next two years and it takes roughly 6 to 8 years to finish this project.

THE ACCELERATOR COMPLEX

The accelerator complex for a synchrotron light source consists of a pre injector, a booster synchrotron and the storage ring. In addition there are the transfer lines between the linac and the booster synchrotron as well the booster and the storage ring. The size of the synchrotron light source is given by the circumference of the storage ring. For the design of the storage ring one has to take into account that this is the source for the users and everything has to be optimized so that the users are getting a high quality beam. The circumference of the storage ring determines the emittance of the stored beam as well the overall length of the insertion devices which can be installed in the storage ring. In modern synchrotron light sources like DIAMOND, SOLEIL and ALBA with energy of 3 GeV, the emittance is in the range of 3 to 5 nm-rad and around 40% of the circumference is available for straight sections. This should also be the case for the Iranian Light Source. For the injection straight a length of roughly 8 m is required for the installation of the septum and the 4 kickers. For beam dynamic reasons the periodicity of the storage ring should be between 4 and 6 or higher. At the injection straight a relatively high horizontal beta function is needed (roughly 10 to 15 m). All the other straight sections should be devoted to the installation of the insertion devices. The length of these straight sections should be in the range of about 4 m in order to have enough space for the installation of 2 to 2.5 m long insertion devices. Most of the users are looking for a high flux density at the source point, which means at the middle of the straight sections. A high flux density means a small cross section for the stored beam. The cross section of the stored beam is given by the square root of the emittance multiplied by the beta functions. According to this relation a small emittance as well as small beta functions is required within the straight sections. This means a so called "mini beta section" should be designed for the straight sections. The horizontal as well vertical beta functions should be in the range of 1.5 to 2.5 m. With these conditions a draft version of a lattice for the Iranian light source has be designed, which is given in the Fig.1.

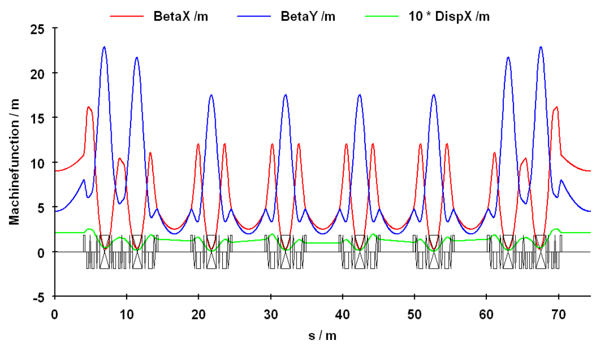

Figure 1: The first design of a lattice for the Iranian Light Source.

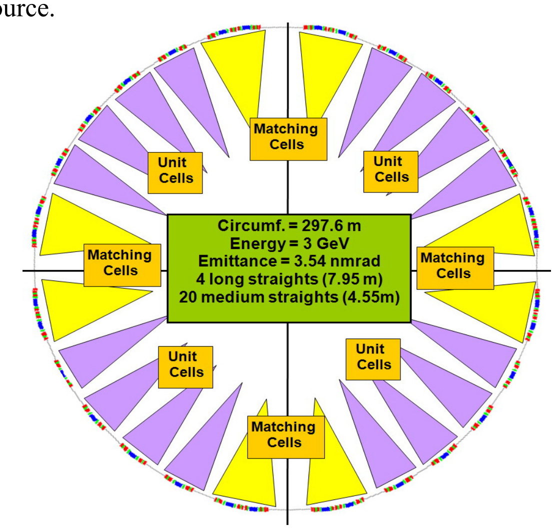

Figure 2: Principle layout of the storage ring.

Given in Fig.1 is one quadrant of the machine, which means a periodicity of 4 has been chosen. The lattice consists of the two matching sections at the beginning and the end as well the 4 unit cells in the middle of the quadrant (see Fig.2). The length of the straight section (required for the injection) is 7.95 m and the length of the 5 straights in a quadrant is 4.55 m. This means the overall length of the straights is 104.5 m which results in 35 % of the circumference. This lattice design results in an emittance of 3.5 nmrad. In order to have a compact arrangements of the magnets a combined function magnets will be used, which makes most of the vertical focusing. Within the straights there is a mini beta section with the beta functions $\beta(x) = 2.51$ m and $\beta(y) = 1.98$ m. With these values and the above mentioned emittance the cross section of the beam in the middle of the straights is $\sigma(x) = 94.3$ µm and $\sigma(y) = 8.4$ µm. All this features can compete with other modern 3rd generation light sources. The arrangements of the magnets for the unit cell as well in the matching section are given in Fig.3 and 4. The general parameters of the lattice are given in table 1. This is the first draft version for a lattice of the Iranian Synchrotron Light Source. This lattice has to be optimized and the beam dynamic calculations have to be performed for a good sextuple setting resulting in a sufficient dynamic aperture.

Table 1: The General Parameters of the Lattice

Beam energy	3	GeV
Beam current	400	mA
Circumference	297	m
Bending radius	7.047	m
Beam emittance, horizontal	3.57	nm-rad
Energy spread (%)	0.104	
Energy loss per turn	1.030	MeV
Tune Q_x/ Q_y	19.81/10.43	
Chromaticity, ζ_x/ζ_y	-42.86/-24.15	
RF-frequency	500	MHz
Bending magnet field	1.42	T
Bending magnet gradient	6.07	T/m
Critical energy (bend)	8.50	keV
Long straight sections	4×7.95	m
Short straight sections	20×4.55	m
Beam sizes, short straight section	94.3×8.4	µm
Beam sizes, long straight section	178×12.6	µm

For the layout of the booster synchrotron two solutions could be considered: The first solution is to build booster and storage ring in separate tunnels or to build booster and the storage ring in a shared tunnel as the second solution. There are of course advantages and disadvantages to each solution. At this stage the first solution will be adapted because in this case one can build up both accelerators separately.

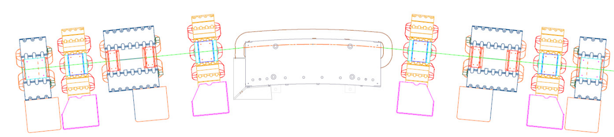

Figure 3: Arrangement of magnets within the unit cell of the lattice, in the middle us the combined bending magent. (blue: quadrupoles, red: sextupoles).

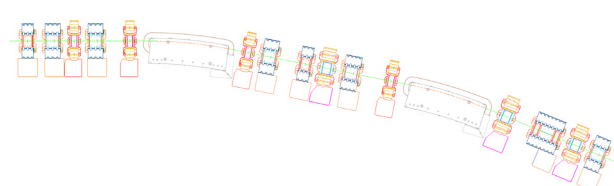

Figure 4: Arrangement of magnets within the matching section of the lattice. In the middle are the bending magnets (blue: quadrupoles, red: sextupoles).

BOOSTER SYNCHROTRON

A first draft design of the lattice of the booster synchrotron is given in Fig.5(a,b), it is the lattice of one quadrant. The lattice consists of 7 unit cells and two matching sections. Also in this case the vertical focusing is made by the bending magnets which makes the booster very compact and results in a small emittance. The small emittance is in favour of the injection process and should minimize the electron losses for the topping up modes. The general parameters of the lattice are given in Table 2.

Table 2: The General Garameters of the Lattice

Beam energy	3	GeV
Beam current	4	mA
Circumference	158.4	m
Bending radius	8.339	m
Beam emittance, horizontal	11.1	nm*rad
Energy spread (%)	1.16	
Energy loss per turn	0.860	MeV
Tune (Q_x/ Q_y)	11.2/5.3	
Chromaticity, (ζ_x/ζ_y)	-14.2/-9.44	
RF-frequency	500	MHz
Bending magnet field	1.2	T
Bending magnet gradient	4.354	T/m

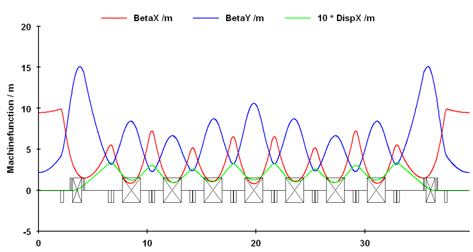

Figure 5(a): The optical functions for the booster synchrotron.

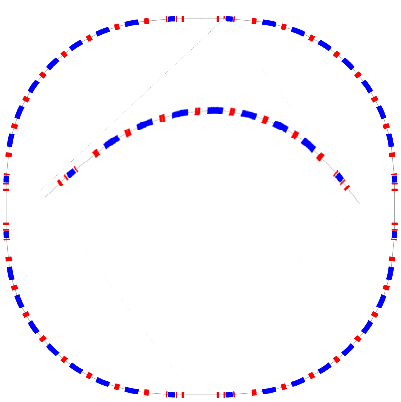

Figure 5(b): The first design of a lattice for the booster synchrotron.

BRILLIANCES OF THE DIFFERENT LIGHT SOURCES

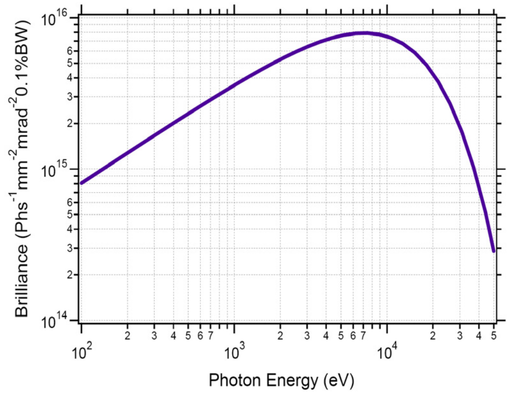

Figure 6: Brilliance of the radiation coming from the bending magnet.

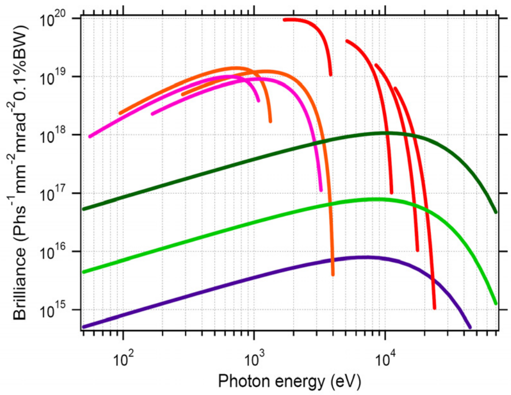

Figure 7: Brilliance of the Insertion devices at 400 mA (Blue: bending magnet, light green: multiple wiggler MPW80 (length 1m), dark green: superconducting wiggler SCW 30 (length 1.8m), red: IVU 21 (length 2 m), pink: EU71 (length 1.7m), orange:EU62 (length 1.7m).