STATUS OF 3 GEV INTERMEDIATE ENERGY LIGHT SOURCE PROJECT CANDLE IN REPUBLIC OF ARMENIA

V. Tsakanov*, G. Amatuni, V. Avagyan, H. Gagiyan, A.Grigoryan, B. Grigoryan, A.Davtyan, V. Harutiunyan,V. Khachatryan, A. Vardanyan, M. Ivanian, V.Jalalyan, E. Laziev, Y. Martirosyan, A. Melkonyan, R.Mikaelyan, S.Minasyan, S.Nagdalyan, A. Petrosyan, A.Rstakyan, K. Sanosyan, S.Tatikian, A. Yayloyan, CANDLE, Yerevan, Armenia
A. Abashian, Virginia Tech., Blacksburg, USA
M. Aghasyan, CAMD, Baton Rouge, USA
V.Vartanian, Stanford University, USA
V. Ayvazyan, S.N. Simrock, K. Rehlich, DESY, Hamburg, Germany

Abstract

The status report on the 3 GeV intermediate energy third generation light source project CANDLE is presented. The storage ring design is based on 16 periods of double-bend achromatic magnet system that provide an equilibrium beam emittance of 8.4 nm–rad in horizontal plane. The design aims to produce a high spectral flux and brightness in the photon energy range of 0.1- 30 keV using the conventional undulators and wigglers.

1 INTRODUCTION

The research highlights, based on the usage of synchrotron radiation in biology, medicine, chemistry, materials and environmental sciences, the broadband application field of the results in pharmacy, electronics and nano-technology, promoted the design and construction of a number of third generation light sources worldwide at the intermediate energies 2.5-3.5 GeV [1]. Since 1967 the 6 GeV electron synchrotron in Yerevan Physics Institute was in operation. Number of unique results obtained on this facility include the study of pion photoproduction, eta-meson generation, transition and channelling radiations. Even in 80's it was well understood that the next accelerator facility in Armenia should be a life science and new technology oriented project [2].

The new synchrotron light source project named CANDLE (Center for the Advancement of Natural Discoveries using Light Emission) [3]–is a 3 GeV nominal energy electron facility, the spectrum of synchrotron radiation from bends, wigglers and undulators of which covers the most essential region of photons energy 0.1- 50 keV suitable for investigations at the cell, virus, protein, molecule and atomic levels. This paper presents the status report on the project development.

2 DESIGN OVERVIEW

The CANDLE general design is based on a 3 GeV electron energy storage ring, full energy booster synchrotron and 100 MeV S-Band injector linac (Fig.1).
The full energy booster synchrotron operating with the repetition rate of 2 Hz and the nominal pulse current of 10 mA provides the storage of 350 mA current in less than 1 min. The storage ring circumference of 216m gives the harmonic number h=360 for the accelerating mode frequency 499.654 MHz. The design of the machine is based on conventional technology operating at normal conducting conditions. However, if the demand of the user community requires the extension of the photon spectral range to hard X-ray region, superconducting wigglers may be installed. Table 1 presents the main parameters of the storage ring.

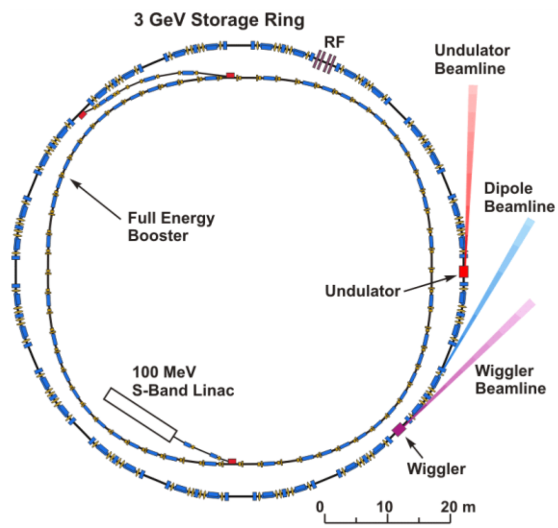

Figure 1: The general layout of CANDLE facility.

Table1. Main parameters of CANDLE.

Parameter	Value
Energy E (GeV)	3
Circumference (m)	216
Current I (mA)	350
RF frequency (MHz)	499.654
Harmonic number	360
Number of lattice periods	16
Straight section length (m)	4.8
Lattice type	DBA
Bending radius ρ (m)	7.385

*tsakanov@asls.candle.am

The optimisation of the facility performance has been made based on the following criteria:

- Photon beams from the bending magnets and the insertion devices need to cover the energy range of 0.1-50 keV with high spectral flux and brightness.
- The machine should have sufficient dynamical aperture to provide stable operation and long beam lifetime;
- For time dependent processes flexible operation with reproducible electron beam positioning is required.

The radiation characteristics of CANDLE photon beams- flux and brightness- drive the main features of the facility design. The *flux* is the appropriate figure of merit for the applications where little beam collimation is required and the sample transverse size is sufficiently large so that as to intercept the entire photon beam.

High *brightness* is required for experiments that involve samples or optics with very small phase space acceptance or techniques that exploit beam coherence. Fig. 2 presents CANDLE photon beams spectral flux and brightness for the dipole, undulator and two types of wiggler. The parameters of the source are given in Table 2.

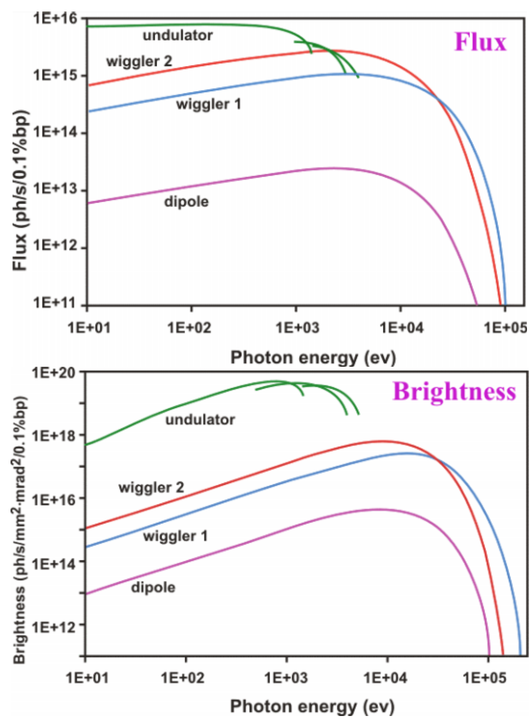

Figure 2: CANDLE spectral flux and brightness.

Table 2. CANDLE source characteristics.

Source	Field (T)	Period (cm)	Length (m)	Critical energy ε_c (keV)
Dipole	1.354	-	1.45	8.1
Undulator	0.3	5	4	0.85/2.6/4.3*
Wiggler 1	2	17	4	11.85
Wiggler 2	1.3	7	4	7.8

* the first three harmonics.

For time resolved experiments, the ability to accommodate many different bunch patterns (single and multi-bunch operation) is incorporated into the design.

3 STORAGE RING

The storage ring of the accelerator complex is the major facility that provides high brilliance X-Ray beams from the bends and insertion devices. The ring has a circumference of 216m that is divided into 16 Double-Bend Achromatic (DBA) type sections with a single cell length of 13.5 m. Each cell contains a 4.8 m long straight section for installation of insertion devices, injection system and RF cavities. The nominal magnetic field 1.354T of combined function dipole magnets provide the bending radius of $\rho = 7.385m$. The dipoles are vertically focusing to increase the horizontal damping partition number thus providing the small horizontal beam emittance of $\varepsilon_x = 8.4$ nm-rad with the dispersion in the straight $\eta = 0.18m$.

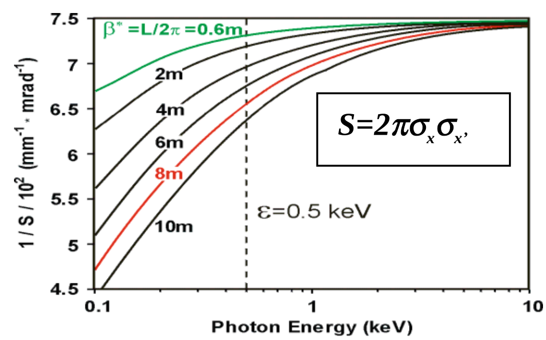

Figure 3. Brightness vs photon energy and local beta.

The optimisation of the optical parameters of the lattice to obtain a high spectral brightness of the photon beams from insertion devices keeping large the dynamical aperture of the ring [4] was an important issue of the R&D research. Fig. 3 presents the dependence of the spectral brightness of CANDLE insertion device on the horizontal betatron function at the source point. The decrease of the betatron function at the source point of CANDLE by one order of magnitude (from 10m to 1 m) results in the brightness gain less than 10% in a soft and hard X-ray region (over 0.5 keV). Significant improvement of the dynamical aperture and injection process with large horizontal beta value lead to lattice design with 7.9 m horizontal beta in the middle of insertion (Fig.4).

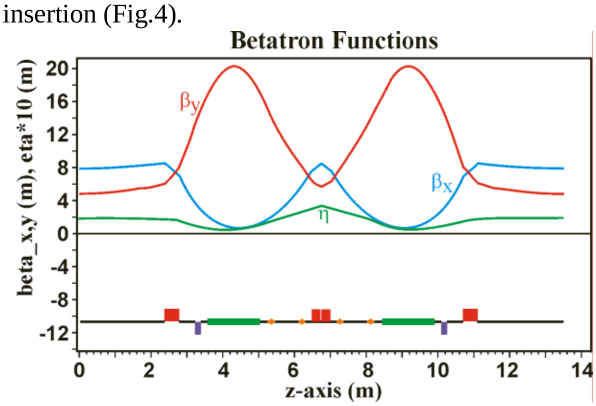

Figure 4: CANDLE lattice and amplitude functions.

In vertical plane, a low vertical beta $\beta_y = 4.85m$ is required to reduce the linear and non-linear focusing effects of the wiggler. The main parameters of the electron beam are given in Table 3.

Table 3. Beam parameters in storage ring

Parameter	Value
Betatron tunes Q_x / Q_y	13.22 / 4.26
Energy loss per turn (MeV)	0.97
Hor./vert emittance (nm)	8.4 / 0.084
Relative energy spread (%)	0.104
Hor./vert. beta at ID (m)	7.9/4.85
Dispersion (m)	0.18
Dynamic aperture (mm, $\pm 3\% \Delta E / E$)	15
Damping times τ_x, τ_y, τ_z (ms)	3.8, 4.5, 2.5
Total beam lifetime (hours)	19.6

The vacuum chamber of the ring is based on the stainless steel antechamber geometry design [5]. The total broadband impedance of the ring is at the level of 0.35 Ω that gives the single bunch instability threshold current per bunch of 7.8 mA [6].

The preliminary RF system for the storage ring is based on the ELLETRA type cavities. With the fully populated insertion devices, the gap voltage of 3.3 MV across 6 cavities provides the Touschek lifetime of 38 hours. Together with 1 nTorr vacuum pressure in chamber the total beam lifetime is at the level of 19.6 hours.

4 BOOSTER SYNCHROTRON

The first impact of the machine regular study is the new approach to the full energy booster design that has a larger circumference of 192 m [7]. The modified booster has a dimension close to the main storage ring and is located at the same tunnel, along the inner radius similar to SLS design [8]. That significantly improved the emittance of accelerated beam in the booster that is reduced to 75 nm-rad at 3 GeV final energy (Fig.5).

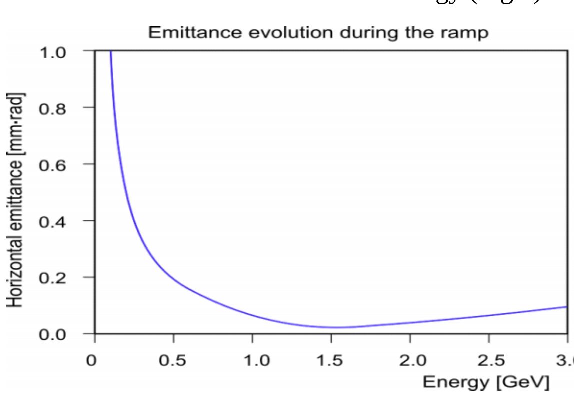

Figure 5. Beam emittance during the energy ramp.

In addition, the new design simplified a general facility construction, made it light and cost effective. The implementation of the top-up injection mode of storage ring operation also became more straightforward.

5 INJECTOR LINAC

The specifications for the 100 MeV injector linac are dictated by the high stable operation requirements with minimum beam losses and ability to operate in single and multi-bunch modes [9]. The gun is a standard thermionic gun modulated by 500 MHz amplifier. The bunching system is based on sequentially located 500 MHz, 1 GHz sub-harmonic cavities and the 3 GHz four cells traveling wave structure. The main accelerating section is a 6m long, 3 GHz frequency constant gradient type structure that accelerates the beam up to 100 MeV with gradient of 17MV/m. The optimization of the entire injection system parameters resulted in the transmission of more than 95% of particles along the linac with 90% of particles captured in 18 degree of the 3 GHz pulse structure (Fig.6).

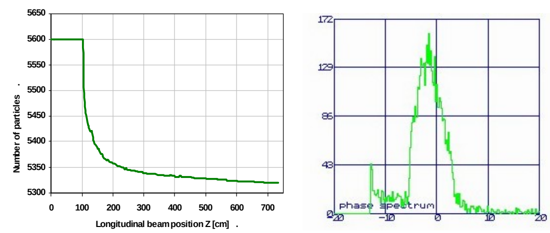

Figure 6. Number of transmitted particles (left) and longitudinal distribution in the 3GHz linac (right).

6 SUMMARY

CANDLE project has turned to the technical design stage. After the completion of Technical Design Report and experts review an extensive prototyping program will start. Taking into account the site decision is made, CANDLE is scheduled for operating in 2006-2007. CANDLE facility will be operate as an international laboratory, open to all qualified scientists in a diverse set of fields such as biology, materials science, chemistry and medicine.

7 ACKNOWLEDGEMENTS

CANDLE team expresses gratitude to all our colleagues for their invaluable support and help. Special thanks to Helmut Wiedemann, Guss Voss, Hermann Winick, Jeff Corbett and Ernst Weihreter for many helpful discussions.

8 REFERENCES

[1] J.Corbett, T.Rabedeau, Synch. Rad. News 12,22,1999.
[2] A. Amatuni et al, Report YERPHI 1322-17-91, 1991.
[3] V.Tsakanov et al, SSRC 02-01, March 2002.
[4] V. Tsakanov et al, Rev. Sci. Instr. 73:1411-1413,2002.
[5] V. Avagyan et al, This proceeding.
[6] M. Ivanian et al, This proceeding
[7] Y. Martirosyan et al, SSRC 02-01, March 2002.
[8] C. Gough et al, EPAC 98,623-625, 1998.
[9] B. Grigoryan et al, this proceeding