STATUS OF 3 GEV CANDLE SYNCHROTRON LIGHT FACILITY PROJECT

V. Tsakanov[*], M. Aghasyan, G. Amatuni, V. Avagyan, A.Grigoryan, B. Grigoryan, D. Kalantaryan, V. Khachatryan, A. Vardanyan, M. Ivanyan, V.Jalalyan, E. Laziev,
Y. Martirosyan, R.Mikaelyan, S.Minasyan, K. Sanosyan, S.Tatikian, S.Tunyan

CANDLE, Acharian 31, 375040 Yerevan, Armenia

Abstract

CANDLE- Center for the Advancement of Natural Discoveries using Light Emission – is a 3 GeV third generation synchrotron light facility project in Republic of Armenia. The report includes the main considerations that underlie the Conceptual Design Report of the project and the progress made after the last EPAC conference. An overview of the beam physics and the first group of beamlines study in future facility are given.

INTRODUCTION

An overview of the CANDLE synchrotron light facility project had been presented in EPAC2002 [1]. The design report of the project [2] had been conducted under the DOE contract and successfully passed the review panel in August 2002.

In this report the progress on machine and beam physics study, first group of beamlines consideration as well as the results of the first prototype magnet fabrication for the facility booster ring are given. The basic approaches that under lied the facility design and performance are: a brand new facility with the state-of-the-art infrastructure, the facility operation as an international laboratory, the competitive spectral flux and brightness, the stable and reproducible photon beams, the high level of the control with user-friendly environment.

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 of 216m in circumference has 16 DBA type periods. The harmonic number of the ring is 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. In total 13 straight sections of the storage ring are available for insertion devices (ID). Table 1 presents the main parameters of the storage ring.

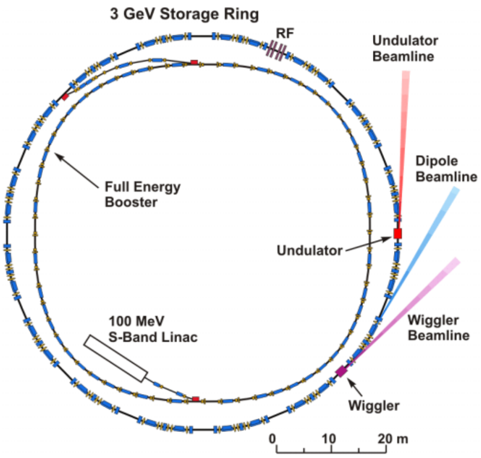

Figure1: The general layout of CANDLE facility.

Table1. Main parameters.

Energy E (GeV)	3
Circumference (m)	216
Current I (mA)	350
Number of lattice periods	16
Horiz. emittance (nm-rad)	8.4
Beam lifetime (hours)	18.4

The photon beams from the dipoles and the conventional ID's are covering the energy range of 0.01-50 keV with high spectral flux and brightness. However, if the users demand requires the extension of the photons energy to hard X-ray region, the superconducting wigglers may be installed. Fig. 2 presents the CANDLE spectral brightness for the dipole, undulator and wiggler sources.

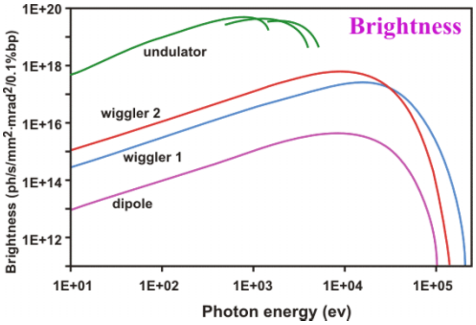

Figure 2: CANDLE spectral brightness.

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[*] tsakanov@asls.candle.am

BEAM PHYSICS

The CANDLE design has 16 identical Chasman-Green type cells with non-zero horizontal dispersion in the middle of the long straight section $\eta_x = 0.18m$ that provides 8.4 nm-rad horizontal emittance of the beam. The emittance by factor of about 2 is smaller with respect to achromatic lattice ($\eta_x = 0$) that provides 18 nm-rad of horizontal emittance. The rms energy spread in the beam is at the level of 0.1%.

The spectral brightness of the photon beam from undulators in third generation synchrotron light sources is one of the main figures of merits that define the advance of the facility design to utilize the whole capacity of the insertion devices. 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 was an important issues of the R&D. The results of the study for CANDLE show [3] that for a real electron beam the spectral brightness in short wavelength range is high for the lattice with large beta value in the middle of straight section. In longer wavelength range, the high brightness implies the small beta lattice.

Fig.3 shows the dependence of the normalized brightness on the emitted photon energy for different horizontal beta values at the source point. Dashed line corresponds to the theoretical optimal beta values associated with each photon energy [3]. The improvement of the brightness with small horizontal beta is visible only for the photon energies below 0.1 keV. Starting from 0.5 keV the brightness increases with larger betatron fuction, and in the energy range of higher than 5 keV the brightness actually reaches its maximum for the beta at the level of 8 m.

In vertical plane the beam emittance is given by the coupling of the horizontal and vertical oscillations. Fig.4 shows the normalized brightness versus of the vertical beta function for CANDLE nominal lattice and 1% coupling. The small vertical emittance of the beam shifts the characteristic regions of the brightness behaviour to harder X-ray region. The increasing of the spectral brightness with low beta is now visible in the photons energy range of 0.5-8 keV and starting from about 10 keV the brightness increases for high beta function. Due to the small vertical emittance of the electron beam, the achievement of the high brightness in whole spectrum range of emitted photon implyes the low vertical beta design in comparison with horizontal beta. The comparatevely low vertical beta function in undulators is improving the machine performance as well by means of reducing the linear and non-linear effects of insertion devices [4]. Taking into account the requirement to have sufficient dynamical aperture of the CANDLE storage ring, the horizontal and vertical betatron functions in the middle of the straigth sections are optimized to $\boldsymbol{\beta_x = 8.1m, \beta_y = 4.85m}$.

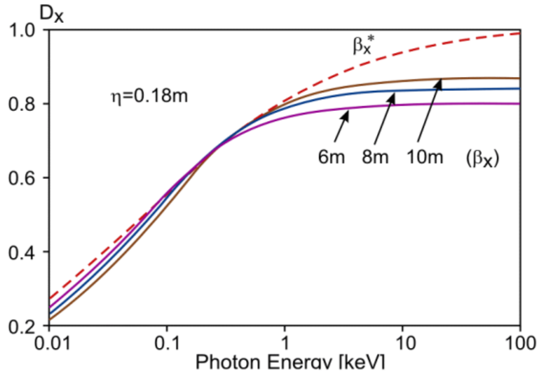

Figure 3. The normalized CANDLE brigthess versus photon energy for various horizontal beta.

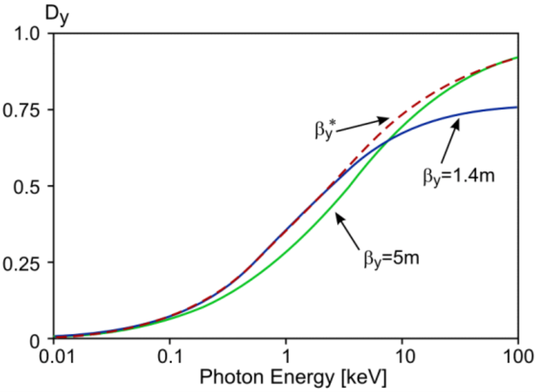

Figure 4. The normalized CANDLE brightness versus photon energy for various vertical beta.

The compratevely high beta values in middle of straight section are significantly improving the dynamical aperture of the ring. Fig.5 shows the CANDLE storage ring dynamic aperture with 3% energy spread which is sufficient for facility stable operation.

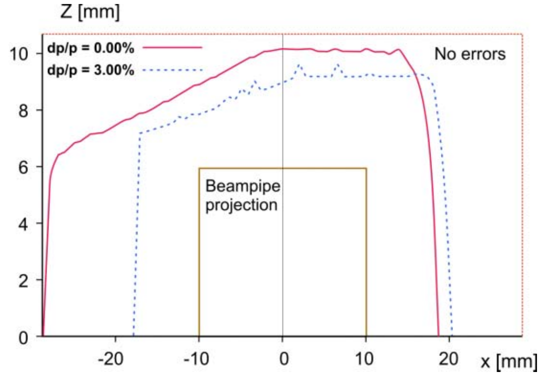

Figure 5: The CANDLE storage ring dynamic aperture in the middle of the straight section.

More elaborate study has been performed for evaluation of the fringe field and non-linear beam dynamics effects [5], space charge effects of the tilted bunch motion [6], the facility misalignment and correction procedure.

BEAMLINES

The increasing demand of synchrotron radiation usage worldwide drives the scenario for the first stage beamlines that are an integrated part of the facility construction. Based on the existing synchrotron radiation usage statistics, the following beamlines have been preliminary selected to build at the first phase of CANDLE construction [7]: LIGA (dipole), General Diffraction and Scattering Beamline (dipole), X-ray Absorption Spectroscopy Beamline (dipole), Soft X-ray Spectroscopy Beamline (Undulator), Imaging Beamline, Small Angle X-ray Scattering (Wiggler). The technical design of the proposed beamlines is based on the advanced instrumentation techniques developed for number of modern synchrotron light sources with reasonable freedom in optics to adjust the beamline with the user demanded requirements for a particular experiment.

LIGA beamlines. The designed LIGA beamlines will cover the experiments with three photon energy regions: 1-4 keV for fabrication of X-ray masks and thin microstructures up to 100 µm height (LIGA I), 3-8 keV for standard LIGA microstructures fabrication with resists height up to 500 µm (LIGA II) and 4-35 keV for deep lithography (LIGA III).

General Diffraction and Scattering Beamline. The general diffraction & scattering beamline is based on the dipole source and will produce a moderate flux of hard (5-30keV) focused or unfocused tunable monochromatic X-rays sequentially serving two experimental stations: EH1 for roentgenography routine or time resolved, low or high temperature structural studies of polycrystalline materials, for reflectivity investigations of thin films and multi-layers; EH2 for single crystal structure determination in chemistry and material science, for charge density studies and anomalous dispersion experiments.

XAS Beamline. The XAS capabilities using the CANDLE bending magnet radiation will cover a photon energy range up to about 35 keV (E_c =8.1 keV). Using a differential pumping system this beamline can be operated with no window before the monochromator and will produce outstanding intensity in soft X-ray region of the spectrum. This region covers the K edges of elements such as Si, S, P and Cl, which are of high technical interest. Using double crystal monochromator and gold coated total reflection mirror, with low expansion water-cooled substrate, the beamline will be able to operate in hard X-ray region, which will allow users to measure EXAFS of all elements either at K or L_3 edges. XAS data could be recorded in transmission, fluorescence and electron yield mode at normal and grazing incident angels.

Imaging Beamline. The Imaging beamline using 3 T permanent wiggler radiation will provide a high flux "white" or tunable monochromatic coherent radiation in 6-120 keV photon energy range at about 150m from the source (monochromator designed to be located at 145m from the source). The experimental program will include: phase contrast imaging; diffraction-enhanced imaging (DEI); hard x-ray microscopy; holographic imaging and tomography; micro-focusing techniques; high resolution X-ray topography and diffractometry; X-ray micro-fluorescence analysis including trace element analysis; high resolution X-ray inelastic scattering; research structure and properties of materials under the high pressure and high temperature conditions by the energy-dispersive X- ray diffractometry and R & D of the new X-ray optics elements.

SAXS Beamline. The small-angle scattering instrument at CANDLE is advanced Bonse-Hart camera [8]. The scientific applications include small and ultra small angle X-ray scattering and nuclear resonance. The primary optical elements of the beamline are vertically and horizontally adjustable slits, high heat load monochromator with liquid nitrogen cooled crystal (Si) cases, high resolution monochromator which limits the bandpass of the monochromatic photons from the first monochromator to meV range.

Soft X-ray Spectroscopy Beamline. The field of soft X-ray micro-spectroscopy is relatively new, but expanding rapidly, due to its unique capabilities to address complex problems in materials, environmental and biological sciences. By combining spectroscopic chemical information with high spatial resolution, X-ray micro-spectroscopy provides new research opportunities. These capabilities are achieved the best possible way by using high brightness photon beams provided by advanced undulators in third generation light sources. Two types of microscopes are proposed to be build on undulator source at CANDLE – a zone plate based scanning transmission X-ray microscope (STXM) and a photoelectron emission microscope (PEEM).

SUMMARY

The progress of the new facility project after EPAC2002 is summarized in the CANDLE laboratory activity report [9]. The next stage of the project development implies an extensive prototyping program, the RF, magnet and vacuum test stands establishment, number of machine and user international workshops. The international collaboration is highly appreciated and we express our gratitude to all colleagues for their interest, support and cooperation.

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