Center for the Advancement of Natural Discoveries using Light Emission

CANDLE Project in Armenia

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Contents

• Introduction
• The Project Overview
• Laboratory Activity
• International Collaboration
• Summary
Why Synchrotron Light Source?

Electron source

X-Rays

Sample

Detector

• High Brightness
• Continues Spectrum
• Tunability
• High Coherency
User Demands - 3-10 times

Spectrum

0.01 0.1 1 10 100 keV

Cell Virus Protein Molecule Atom

Science

• Biology
• Physics
• Material Science
• Medicine
• Chemistry
• Environments

Industry

• Biotechnology
• Electronics
• New material
• Pharmacy
• Nanotechnology
• Microfabrication
CANDLE will serve scientists of 3000 km radius region.

XXI century

<table>
<thead>
<tr>
<th>Synchrotron Light Source</th>
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<tbody>
<tr>
<td>SPEAR3</td>
</tr>
<tr>
<td>DIAMOND</td>
</tr>
<tr>
<td>SOLEIL</td>
</tr>
<tr>
<td>Boomerang</td>
</tr>
<tr>
<td>CLS</td>
</tr>
<tr>
<td>ALBA</td>
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<tr>
<td>CANDLE Armenia</td>
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CANDLE will serve scientists of 3000 km radius region.
Why in Armenia?

Construction of 6 GeV synchrotron (1967)

A.I. Alikhanian

A.I. Alikhanov

Burakan Observatory

Armenian Nuclear Plant
Why in Armenia?

The major achievements in HEP include:

- The study of pion photoproduction, eta-meson generation.
- X-ray transition radiation and XTR detectors.
- Development of Quasi-Cherenkov radiation.
- Exper. observation of particle channeling radiation in crystals.
- Development of track spark chambers.

1971-1975 – Three Synchrotron Radiation Beamlines

Lab. of Radiation Solid State Physics
Lab. of Radiation Biophysics
Solid State Dept of Yerevan State Univ.
3 GeV CANDLE Light Source

Energy: 3 GeV
Current: 350 mA
Circumference: 216 m
Frequency: 499.65 MHz
Harm. Number: 360
Periods No: 16
Straight section: 4.8 m
Lattice type: DBA
Emittance: 8.4 nm
Beam lifetime: 18.4 hours

Time structure

beam: 2 nsec
bunch: 40 psec
Storage Ring – Figure of Merit

- High Brightness & Stable Beams

\[ \eta = 0.18 \text{ m}, \quad \beta_{x,y} = 7.9 / 4.8 \text{ m} \]

V. Tsakanov et al, Rev. Sci Instr., 2002
M. Ivanian et al, NIM (A) 2004

Tunes

\[ Q_x = 13.22 \]
\[ Q_y = 4.26 \]

Emittance

\[ \varepsilon_x = 8.4 \text{ nm} \cdot \text{rad} \]
Radiation Characteristics

**Dipole beamline**

- Dipole field $B$ (T) 1.354
- Critical ph. energy (keV) 8.1

**Wiggler type I**

- Magnetic field (T) 1.98
- Period length (cm) 17
- Critical ph. energy (keV) 11.97

**Undulator**

- Magnetic field (T) 0.3
- Period Length (cm) 5
- Photon energy $n=1,3,5$ (keV) 0.85/2.6/4.3
Storage Ring – Dynamics

Dynamical Aperture

Large oscillations
Ion Trapping & Beam Lifetime

Non-stable ions

<table>
<thead>
<tr>
<th>Stable ion mass</th>
<th>Residual gas species</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>2, H₂</td>
</tr>
<tr>
<td>-</td>
<td>16, CH₄</td>
</tr>
<tr>
<td>17</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>28, N₂, CO</td>
</tr>
<tr>
<td>32</td>
<td>-</td>
</tr>
<tr>
<td>33</td>
<td>-</td>
</tr>
<tr>
<td>37</td>
<td>-</td>
</tr>
<tr>
<td>42</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>44, CO₂</td>
</tr>
</tbody>
</table>

Trapped ions

Touschek Lifetime –39.4 hours

<table>
<thead>
<tr>
<th>Coupling</th>
<th>1%</th>
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</thead>
<tbody>
<tr>
<td>Gap Voltage</td>
<td>3.3 MV</td>
</tr>
<tr>
<td>Energy Accept.</td>
<td>2.4%</td>
</tr>
<tr>
<td>Vacuum</td>
<td>1 nTorr</td>
</tr>
<tr>
<td>Beam lifetime</td>
<td>- 18.4 hours</td>
</tr>
</tbody>
</table>
Ring impedance & Instabilities

Longit. Imped. - $0.3 \, \Omega$

Trans. Imped. - $12.5 \, k\Omega/m$

M. Ivanian et al, Phys. Rev STAB-2004

Undulator Imped.

Single bunch Instability

Multi-bunch Instability
Beam Physics Activity –2009-2010

Multi-Layer Tube Impedance

$Q_n$ – Field Transformation Matrix of 1 layer
$T=(E_z, E_\theta, B_z, B_\theta)$ - vector of tang. Comp.

$T_{in} = Q T_{out}$, $Q = Q_1 \cdot Q_2 \cdots Q_N$

$T_{in}$ – tangential E&M fields in inner surface
$T_{out}$ - tangential E&M fields in outer surface
$Q$ (4x4) – Field Transformation Matrix

wiggler

Kicker
Decoherence of Kicked Beam

Tune Shift:

- Amplitude dependence
- 1st order chromaticity
- 2nd order chromaticity

Beam centroid

\[
\langle x(N) \rangle = \beta \Delta x' A(N) H(N) e^{-M(N)} \sin[P(N) + Q(N) + 2\pi v_0 N]
\]

Tracking Simulation and Analytical Predictions
Storage Ring – Magnets

B=1.354 T, G=3.3T/m
aperture=44mm

G=20 T/m
aperture=50mm

Dipole

Quadrupole

Magnet supports
Storage ring – Vacuum system

**Mater. – Stainless Steel**

**Vacuum – 1 nTorr**

**Fore-vacuum** - 2

**Turbo-molecular** – 16

**Titan-sublimation** – 80

**Ion pumps** - 64

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Storage Ring – RF

**Energy loss/turn** 0.97 MeV 1.39 MeV

**Shunt Impedance** 6x3.4 MΩ

**Total RF power** 660 kW 830 kW

**Gap Voltage** 3.3 MV 3.3 MV

**Energy acceptance** 2.4% 2%

**Energy Spread** 0.1% 0.1%

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**ELETTRA type cavity**
Booster synchrotron

Energy: 3 GeV
Pulse current: 10 mA
Repetition: 2 Hz
Circumference: 192 m
Emittance: 75 nm-rad

Dipole: $B = 0.024 - 0.72 T$

Quadrupole: $G = 10^{-13} T/m$

Sextupole: $S = 90/110 T/m^2$
Energy ramp and Injection

Dipole ramping rate and energy gain

Emittance vs energy

75 nm

Dynamic aperture

Injection bump

Injected beam: 1 and 3 turns
Linac

- **90 kV Gun**
- **SPB 500 MHz**
- **SWB 1 GHz**
- **TWB 3 GHz**
- **ACC Section 3 GHz**

- Energy: 100 MeV
- Current: 1-20 mA
- Pulse length: 2-600 nsec
- Frequency: 3 GHz
- Energy Spread: < 1%
- Emittance: < 1 mm-mrad

Graphs showing:
- Longitudinal beam position Z [cm]
- ~90% efficiency
- Phase spectrum
- Horizontal profile
- Vertical profile
**Beamlines**

- Dipoles – 28
- Wigglers – 8
- Undulators – 4
- Exp. Stations ~40

1st Stage

1. Diffraction & scattering (dipole)
2. XAS Beamline (dipole)
3. LIGA (dipole)
4. Imaging Beamline (wiggler)
5. SAXS Beamline (wiggler)
6. Soft X-ray microscopy and spectroscopy (undulator)
**Structural Biology**

- Protein Structure
- Drug design

**Protein Structures deposited**

- 1992:
- 1996:
- 2000:
- 2004:

**Medicine**

- Angiography
- Bronchography
- Mammography
- Computed Tomography
- Photon Activ. Therapy
- Microbeam Rad. Therapy

**Physics**

- Macro-molecular physics
- High-Temp superconductivity
- Physics of nano-particles
- Surface physics

**Chemistry**

- Chemical Dynamics
- Polymers
- Nanoscale chemistry
- Biochemistry
- Catalytic Interfaces
Material Science

3D structure of new material

Crystal growth
New Crystals

- Nano-structures
- Nano-tubes

Micro-fabrication

X-Ray Lithography - LIGA

Diffraction & Scattering Beamline

Initial beam
After mirror M1
After DCM
Focused Beam
“CANDLE is a world-class project enabling frontier research in a whole spectrum of basic and applied sciences. This is an excellent investment from a scientific-technical point of view.”

From Panel Report

Washington, 14-15 Aug 2002
First Magnet

From Design

Simulation

To Fabrication

ArmElectroMash

May 27, 2003

MADE IN ARMENIA
Proposals

• Total number of proposals – 82
• Number of Scientists - 284
• Number of Institutes - 41
• Countries - 7
  Armenia, England, Germany, Georgia, France, Russia, USA

Fields:
  Physics, Biology, Medicine, Chemistry, Environment, Material science,

“From a review of the 69 experimental proposals, it is clear that strong Armenian user community will emerge as the facility is readied”

From Panel review
International Collaboration

Armenia, Germany, France, Italy, USA, Russia, Bulgaria, Greece, Georgia

European Laboratories

European Round Table for SR and FEL

- Letter of Supports
- Memor. of Understanding
- Collaboration Agreements
CANDLE Review

- CANDLE is a place where investment might lead to a major improvement in S&T infrastructure in Armenia.
  
  US Commission on S&T in Armenia, Nov 2004

“An Involvement of the Union in the Armenian CANDLE project would be a sign of encouragement to this project which concerned chiefly the European scientific teams “

Amendment 102, European Parliament, 26 Feb 2004

Sub Panel recommends to international and local organizations

- to include CANDLE in the priority list of projects conducted in Armenia
- start the pre-construction stage

18 May 2006
DESY Contribution
RF Components for 100 MeV Linac

Jan –Mar 2007

Establishment of RF laboratory and RF Test Stand
Memorandum Of Understanding

• National Academy of Science
• Yerevan State University
• Armenian Physical Society
• CANDLE

22 March 2007

Research Institute of

YEREVAN STATE UNIVERSITY
18 Dec 2008 - GOVERNMENT OF THE RA RESOLUTION on the Creation of 3GeV Light Source in Armenia

- CANDLE – strategic project for long term development
- The priority program for international cooperation
- Land Allocation
- Financial Commitment
- Organizational structure
Cost & Schedule

Dec., 2009

Commitments of Government of RA

- 25% funding for construction and operation
- Land Allocation Free of Charge
- TAX exemptions according to world standards

Operation Cost 5 mln/year

Euro58 mln

- 4 millions (2011)
- 18 millions (2012)
- 16 millions (2013)
- 14 millions (2014)
- 6 millions (2015)
Site Consideration

Main Building

Potential Users
Yerevan State University
Yerevan Medical University
Yerevan Engineering Univ.
Inst. Of. Molecular Biology
Inst. Of BioChemistry
Inst. Of PhysChemistry
Inst. Of Biotechnology
Inst. Of Microbiology
Inst. Of Fine Org. Chemistry

Abovyan

Yerevan
CANDLE Organization (vision)

- International Laboratory
- User Friendly Environment
- World Class Research