The CESR/CHESS Upgrade at Cornell University

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Synchrotron SOLEIL, France
Upgrade of the Cornell Electron Storage Ring as an X-ray Source for the Cornell High-Energy Synchrotron Source

* Increase beam energy and decrease emittance from 100 nm-rad at 5.3 GeV to 30 nm-rad at 6.0 Gev

* New optics in 1/6 of ring around former e+e- collision point, including six double-bend achromats, each comprising two combined-function magnets and two horizontally focusing quadrupoles and accommodating a pair of 1.5-m canted undulators

* Operations with a single positron beam of 200 mA rather than e+/e- beams of 120 mA each. The choice of positrons necessitated by the orientation of one major CHESS beam-line. ==> Electron cloud buildup in the new, smaller vacuum chambers for the combined-function magnets and undulators should be estimated to see if mitigation strategies are needed.

A major effort in design, engineering, production, field measurement, girder development and alignment strategy for 12 new combined-function and 12 quadrupole magnets is now underway.

The project leader and contact is Alexander Temnykh of Cornell University.
Double-bend achromat

Baseline design omits any sextupoles in new achromats. New achromats will replace existing achromats where sextupoles are omitted. Diagram shows the layout of the achromats with the progression of the beam path.
The ring FODO lattice transports beam around the CESR tunnel to the new arc comprised of six double-bend achromats.
The vertical aperture is limited by the undulator vacuum chambers to ±2.3 mm. The horizontal aperture is defined by the vacuum chambers in the CESR tunnel arcs to be ±45 mm.
**BPM alignment error correction and dynamic aperture study**

BPM misalignment iterative correction procedure restores beta functions to <1%, emittance to 10 pm, and coupling to <1%.

Frequency map for misaligned and corrected lattice including guide field multipole errors. Physical aperture shown by dotted red line. Nonlinearities do not limit acceptance.
Injection efficiency found to be greater than 85% over a wide range of the tune plane in a model which includes field errors, misalignments and undulator multipoles.

This is a significant improvement over present CHESS two-beam operation.
Comparison of synchrotron radiation pattern in the south arc region

Present CESR layout

CESR/CHESS upgrade layout

There is a very high rate of synchrotron radiation photons on the combined-function magnet vacuum chamber walls.
**Element-averaged beam size, beta functions and photon rates**

**Present CHESS lattice**

<table>
<thead>
<tr>
<th>Element</th>
<th>Nr Seg</th>
<th>&lt;Length&gt;</th>
<th>Tot Length</th>
<th>Fraction</th>
<th>&lt;Beta X&gt;</th>
<th>&lt;Beta Y&gt;</th>
<th>&lt;Sig X&gt;</th>
<th>&lt;Sig Y&gt;</th>
<th>&lt;Phot/m/e&gt;</th>
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</thead>
<tbody>
<tr>
<td>Dipole</td>
<td>47577</td>
<td>0.010</td>
<td>475.5</td>
<td>61.6%</td>
<td>15.4</td>
<td>20.5</td>
<td>1.4443</td>
<td>0.1389</td>
<td>1.048</td>
</tr>
<tr>
<td>Drift</td>
<td>19478</td>
<td>0.010</td>
<td>188.5</td>
<td>24.4%</td>
<td>17.9</td>
<td>21.3</td>
<td>1.4934</td>
<td>0.1375</td>
<td>0.696</td>
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<tr>
<td>Wiggler</td>
<td>2171</td>
<td>0.010</td>
<td>21.6</td>
<td>2.8%</td>
<td>13.7</td>
<td>12.2</td>
<td>1.5101</td>
<td>0.1083</td>
<td>0.191</td>
</tr>
<tr>
<td>Quadrupole</td>
<td>6396</td>
<td>0.010</td>
<td>63.8</td>
<td>8.3%</td>
<td>18.5</td>
<td>22.6</td>
<td>1.5080</td>
<td>0.1402</td>
<td>0.790</td>
</tr>
<tr>
<td>Sextupole</td>
<td>2198</td>
<td>0.010</td>
<td>21.9</td>
<td>2.8%</td>
<td>18.5</td>
<td>22.5</td>
<td>1.5458</td>
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<td>0.739</td>
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<td>Solenoid</td>
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<td>0.000</td>
<td>0.0</td>
<td>0.0%</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
</tr>
<tr>
<td>Octupole</td>
<td>76</td>
<td>0.010</td>
<td>0.8</td>
<td>0.1%</td>
<td>21.7</td>
<td>15.8</td>
<td>1.8705</td>
<td>0.1256</td>
<td>0.281</td>
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<tr>
<td>Non-dipole</td>
<td>30319</td>
<td>0.010</td>
<td>296.6</td>
<td>38.4%</td>
<td>17.8</td>
<td>21.0</td>
<td>1.5027</td>
<td>0.1362</td>
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<tr>
<td>Non-drift</td>
<td>58418</td>
<td>0.010</td>
<td>583.7</td>
<td>75.6%</td>
<td>15.8</td>
<td>20.5</td>
<td>1.4578</td>
<td>0.1380</td>
<td>0.976</td>
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<tr>
<td><strong>Total</strong></td>
<td>77896</td>
<td>0.010</td>
<td>772.4</td>
<td>100.0%</td>
<td>16.3</td>
<td>20.7</td>
<td>1.4662</td>
<td>0.1378</td>
<td>0.907</td>
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</tbody>
</table>

**CESR/CHESS upgrade lattice**

<table>
<thead>
<tr>
<th>Element</th>
<th>Nr Seg</th>
<th>&lt;Length&gt;</th>
<th>Tot Length</th>
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<th>&lt;Beta X&gt;</th>
<th>&lt;Beta Y&gt;</th>
<th>&lt;Sig X&gt;</th>
<th>&lt;Sig Y&gt;</th>
<th>&lt;Phot/m/e&gt;</th>
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</thead>
<tbody>
<tr>
<td>Dipole</td>
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<td>440.0</td>
<td>57.1%</td>
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<td>21.2</td>
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<tr>
<td>Drift</td>
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<td>0.010</td>
<td>189.8</td>
<td>24.6%</td>
<td>16.4</td>
<td>19.3</td>
<td>0.8690</td>
<td>0.0701</td>
<td>0.734</td>
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<tr>
<td>Wiggler</td>
<td>970</td>
<td>0.010</td>
<td>9.6</td>
<td>1.2%</td>
<td>23.3</td>
<td>15.4</td>
<td>1.2779</td>
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<td>Quadrupole</td>
<td>6438</td>
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<td>8.3%</td>
<td>17.1</td>
<td>21.0</td>
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<td>Sextupole</td>
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<td>0.010</td>
<td>21.2</td>
<td>2.8%</td>
<td>18.2</td>
<td>24.5</td>
<td>0.9649</td>
<td>0.0801</td>
<td>0.861</td>
</tr>
<tr>
<td>Solenoid</td>
<td>0</td>
<td>0.000</td>
<td>0.0</td>
<td>0.0%</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.000</td>
</tr>
<tr>
<td>Octupole</td>
<td>78</td>
<td>0.010</td>
<td>0.8</td>
<td>0.1%</td>
<td>19.3</td>
<td>13.0</td>
<td>1.0158</td>
<td>0.0624</td>
<td>0.320</td>
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<td>28.2</td>
<td>3.7%</td>
<td>1.8</td>
<td>1.59</td>
<td>0.2182</td>
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<tr>
<td>CCU</td>
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<td>0.010</td>
<td>16.6</td>
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<td>Non-dipole</td>
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<td>18.7</td>
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<td>Non-drift</td>
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<td>0.010</td>
<td>580.9</td>
<td>75.4%</td>
<td>13.5</td>
<td>20.4</td>
<td>0.8410</td>
<td>0.0746</td>
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<tr>
<td><strong>Total</strong></td>
<td>77509</td>
<td>0.010</td>
<td>770.8</td>
<td>100.0%</td>
<td>14.2</td>
<td>20.1</td>
<td>0.8477</td>
<td>0.0735</td>
<td>1.023</td>
</tr>
</tbody>
</table>

Average synchrotron radiation rate incident in the combined-function magnets will be double that in the CESR dipole magnets.
Electron cloud simulation package
ECLOUD
* Originated at CERN in the late 1990's

* Widespread application for LHC, KEK, RHIC, ILC ...

* Under active development at Cornell since 2008

* Successful modeling of CESRTA tune shift measurements (2009-2016)

I. Generation of photoelectrons
A) Production energy, angle
B) Azimuthal distribution (v.c. reflectivity)
II. Time-sliced cloud dynamics
A) Cloud space charge force
B) Beam kick
C) Magnetic fields
III. Secondary yield model
A) True secondaries (yields > 1!)
B) Rediffused secondaries (high energy)
C) Elastic reflection (dominates at low energy)
IV. Additional magnetic field environments
A) Sextupole fields
The cloud density in the combined-function magnets is predicted to be a factor of four higher than in the CESR dipoles now.
Our calculations are based on the beam-processed aluminum vacuum chamber surface properties typical of the present CESR ring, so we can conclude that special cloud mitigation techniques such as grooves or coatings will not be necessary in the new south arc region of the ring.

**CLEO detector removal 2016**

- **July:** Final disassembly of 1000 tons of steel and crystal began
- **August 4:** CLEO steel stockpile
- **August 10:** Removal of crystal calorimeter
- **September 9:** CLEO is gone
- **August 4:** CLEO steel stockpile
- **September 16:** New bridge over CLEO pit
- **September 21:** Restoring CESR
Beam brightness comparisons

Pin-hole flux [photons/sec/0.1% bandwidth]. Red lines are CHESS 1.5-m compact undulator as of May 2016. Purple lines are CHESS post-upgrade with 1.5-m compact undulator.

With a 3.5-m undulator, the CESR/CHESS upgrade pin-hole flux can be expected to exceed that of the APS with undulator A.

Operation of the upgraded CESR ring for CHESS is scheduled to begin during the summer of 2018, providing 20- to 150-keV X-ray beams for about 1300 user visits per year.

26 October 2016