The Perspective and Application of Extreme-UV FEL at Dalian

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FEL13, 2013.08.29
Dalian

Shanghai

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Dalian Coherent Light Source Site

Main DICP Campus

EUV FEL

New DICP Campus

~100 km

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Outline

Proposed FEL Machine
(Dalian Coherent Light Source)

Perspective and application of DCLS

Schedule
Major Technical Specifications of DCLS

- Targeted Wavelength Range: 50-150nm, completely tunable
- Pulse Energy: \( \sim 100 \, \mu \text{J} \)
- Repetition Rate: up to 50 Hz
- Pulse Width: 100 fs/1ps
- Two FEL Lines
The Layout of DCLS

- Laser for Photoelectrons
- LINAC
- Seeding Laser System
- EUV FEL2
- Photocathode
- EUV FEL1
- Facilities
- Beamlines/Endstations

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Photo cathode (BNL type)

Key parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode material</td>
<td>Cu</td>
</tr>
<tr>
<td>Gun gradient (MV/m)</td>
<td>100</td>
</tr>
<tr>
<td>Laser power (uJ)</td>
<td>250</td>
</tr>
<tr>
<td>Laser longitudinal length (ps)</td>
<td>7</td>
</tr>
<tr>
<td>Emittance (mm-mrad, rms)</td>
<td>1</td>
</tr>
<tr>
<td>Quantum efficiency</td>
<td>$3 \times 10^{-5}$</td>
</tr>
</tbody>
</table>
Double the flux of optical beam

Alternative of the second arm of undulator

Kicker of electron beam

From PSI SwissFEL CDR
SLAC type S-band linac structure

- **Maxium e beam energy (MeV)**: 300
- **Energy spread (rms)**: <0.20%
- **Emittance (mm-mrad, rms)**: ≤2.0
- **Bunch length (ps, FWHM)**: ≤1.0
- **Charge per bunch (nC)**: 0.5
- **Repetition rate (Hz)**: 50

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DCLS: 50-150nm tunable

HGHG

Adjustment:
Wavelength of seed laser
Gap of modulator
Gap of radiator

Second arm of FEL undulator

B. Liu et al PRST 16(2013) 020704
Hybrid undulator

<table>
<thead>
<tr>
<th>Modulator parameter</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Period (mm)</td>
<td>50</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>10-60</td>
</tr>
<tr>
<td>Total length (m)</td>
<td>0.5</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiator parameter</th>
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<tbody>
<tr>
<td>Period (mm)</td>
<td>30</td>
</tr>
<tr>
<td>Gap (mm)</td>
<td>9-40</td>
</tr>
<tr>
<td>Total length (m)</td>
<td>12+6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seed laser parameter</th>
<th></th>
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<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>240-360</td>
</tr>
<tr>
<td>Pulse length (fs/ps)</td>
<td>100/1</td>
</tr>
<tr>
<td>Power (uJ)</td>
<td>10/100</td>
</tr>
</tbody>
</table>

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Major Opportunities in Research

- **High Brightness**
  - Sensitive Detections of Atomic and Molecular Species

- **Ultrafast Character (ps, fs)**
  - Probing ultrafast processes of molecules in gas phase and at surfaces
Perspective and application of DCLS
Case I: Combustion

( Direct EUV Ionization)

Science 308, 1887-1889 (2005)
Molecular ionization is very important for detection of atomic and molecular systems, while EUV is the most efficient tool for this.

Electron impact ionization can produce fragmentation, and has no species selectivity.

### Molecular Ionization Energies

<table>
<thead>
<tr>
<th>Molecule</th>
<th>IE (ev)</th>
</tr>
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<tbody>
<tr>
<td>CH₄</td>
<td>12.61</td>
</tr>
<tr>
<td>CH₃</td>
<td>9.84</td>
</tr>
<tr>
<td>CO</td>
<td>14.01</td>
</tr>
<tr>
<td>NO</td>
<td>9.26</td>
</tr>
<tr>
<td>H₂</td>
<td>15.43</td>
</tr>
<tr>
<td>OH</td>
<td>13.0</td>
</tr>
<tr>
<td>H</td>
<td>13.6</td>
</tr>
<tr>
<td>CH</td>
<td>10.64</td>
</tr>
<tr>
<td>CH₃F</td>
<td>12.5</td>
</tr>
<tr>
<td>CH₃O</td>
<td>10.88</td>
</tr>
<tr>
<td>CH₃Cl</td>
<td>11.26</td>
</tr>
</tbody>
</table>

10 eV ~ 120 nm

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Case II: Ion molecule reaction

H/D atom Rydberg tagging technique

\[ H_2^+ + HD \rightarrow H_3^+ + D \]

\[ H_2 \rightarrow H_2^+ \text{ cross section: } \sim 1.0 \times 10^{-17} \text{ cm}^2 \text{ @ 76nm} \]

*J. Chem. Phys. 126, 094306 (2007)*
Case III: Photochemistry

Absorption Spectrum of the Water Molecule
Case III: Photochemistry

Yuan et al, PNAS v105 19148 (2008)

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Case IV: Ultrafast Dynamics at Surfaces

Time Resolved UPS Probe (Pump-Probe)

Photo catalysis
Electron dynamics in Solar Cells
Electron Transport Processes

Chem. Rev. 95, 735 (1995)

Dynamics of Photo catalysis on Surfaces
Welcome more innovational proposals
Schedule

2012.03 Starting of DCLS
Formal collaboration with SINAP

2012.04 First version of CDR and discussion

2012.11 Second version of CDR
Technical design of DCLS construction

2013.06 Technical design report

2013.08 Review of TDR at Dalian

2013.09 China-Germany Workshop
“EUV FELs in Molecular, Cluster and Surface Science at DCLS”

2013.10 Construction Starts
Completion of technical design

2014.11 Installation and commissioning.

2015 First lasing, first User experiment on DCLS

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Thank you for attention

Welcome to Dalian