Recent Activity on Coherent Light Source Development in UVSOR-II

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Heishun Zen (ByungJoon Chun, 전 병준, 全 炳俊)
Contents

• Introduction of UVSOR-II

• THz Coherent Synchrotron Generation

• VUV Coherent Harmonic Generation

• Future Prospects and Application
Where is UVSOR-II??

From Google Map
Introduction of UVSOR-II
Introduction of UVSOR-II

Low energy, low emittance synchrotron light source

<table>
<thead>
<tr>
<th></th>
<th>750 MeV</th>
<th>600 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>750 MeV</td>
<td>600 MeV</td>
</tr>
<tr>
<td>Emittance</td>
<td>27 nm-rad</td>
<td>17 nm-rad</td>
</tr>
<tr>
<td>Natural Energy Spread</td>
<td>4.3E-4</td>
<td>3.4E-4</td>
</tr>
<tr>
<td>Circumference</td>
<td>53.2 m</td>
<td></td>
</tr>
<tr>
<td>RF Frequency</td>
<td>90.1 MHz</td>
<td></td>
</tr>
<tr>
<td>Harmonic Number</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Bending Radius</td>
<td>2.2 m</td>
<td></td>
</tr>
<tr>
<td>RF Frequency</td>
<td>90.1 MHz</td>
<td></td>
</tr>
</tbody>
</table>

Bunch Length > 100 ps (RMS)

750 MeV ➔ User operation and high power FEL lasing

600 MeV ➔ Laser Driven Coherent Light Source Development
<table>
<thead>
<tr>
<th><strong>Beam Current</strong></th>
<th>301.8 mA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Life Time</strong></td>
<td>966 min</td>
</tr>
<tr>
<td><strong>Next Injection Time</strong></td>
<td>---:---</td>
</tr>
<tr>
<td><strong>Beam Dump Time</strong></td>
<td>---:---</td>
</tr>
</tbody>
</table>

**Operation Mode**

Multi Bunch Top Up

**Entrance Permitted**
High Power Laser System in UVSOR-II

Ti : Sapphire Laser System (800 nm) made by COHERENT
One 90 MHz oscillator, three amplifiers
Coherent Light Sources in UVSOR-II

- Storage Ring FEL
- THz Coherent Synchrotron Radiation
- VUV Coherent Harmonic Generation

This talk is focused on Laser Driven Coherent Light Sources in UVSOR-II
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Laser Bunch Slicing


Electron Bunch Length > 100 ps
Laser Pulse Duration ~ 130 fs

FEL interaction in an undulator
- Local energy modulation in electron beam
- Density modulation after passing through dispersive section
- Emit coherent synchrotron radiation in THz regime
Formation of Dip Structure

@Entrance of Undulator
@Exit of Undulator
After 1st Bend
After 2nd Bend

$\Delta E/E$

Density, $\tilde{Q}(z)$
Laser Bunch Slicing @UVSOR-II

IR Beam-line

- Bending magnet #6
- FEL port
- Plane mirror (M1)
- Plane mirror (M2)
- Magic mirror (M0)
- BL6U (Undulator BL)

Monitor Station

Electron beam

Laser System

(b) Undulator (a)

Femtosec Pulse Laser

fs-Laser
800 nm
Max. 50 mJ
150 fs – 1 ps

THz-IR Beam-line

(c), (d) Electron Bunch

Dip

THz Detector
General Property of THz-CSR


Generation timing is synchronized with laser injection timing.

\[ P_{\text{THz}} \propto I^2 \]
Monochromatic THz CSR

Laser pulse with sinusoidal amplitude modulation induces sinusoidal modulation to electron bunch
⇒ monochromatic coherent radiation
Recent Progress
Detection of THz E-field by EO sampling

Electro Optic sampling

Field induced birefringence is detected using the polarization rotation of short optical pulses.


Collaboration with
I. Katayama (Yokohama Nat. Univ.)
M. Ashida (Osaka Univ.)
THz-CSR
Focus Mirror
ZnTe
$\lambda/4$
Lens
Wollaston Prism (Polarizer)
Balanced Detector
Chopper for Lock-in Detection
Si Plate
Prove Laser
Prove Laser
THz-CS
Experimental Result

- We can measure the CSR electric field.
  ➔ Phase of CSR is stable.

- The oscillation period became slightly long when the laser was chirped.
  ➔ Change of the electron micro structure can be detected.

- Detected electric field has more than two cycle.
  (not mono- or half-cycle)

Application:
- THz Time Domain Spectroscopy
- THz Imaging
- Beam Diagnostics
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Coherent Harmonic Generation (CHG) = Coherent Spontaneous Radiation from Micro-bunched Beam

FEL interaction in Modulator
- Sinusoidal energy modulation in bunch
- Micro-bunching of e-beam in Buncher
- Coherent Spontaneous Emission in Radiator
Motivation of CHG

• Short Pulse (< 1 ps, depends on drive laser)

• Short Wavelength (< 100 nm)

• Narrower Spectrum than Normal UR

Time Resolved Photo Electron Spectroscopy
VUV Spectrum Measurement Station

- Radiation from Optical Klystron
- Pre-focusing Mirror System
- Electron Multiplier Tube
- VUV Spectrometer

Optical Klystron
λ_u = 110 mm
Nu = 9 + 9
Nd = 45 @800 nm
K = 6.18

fs-Laser
800 nm
Max. 2.5 mJ
150 fs – 1 ps
General Properties of CHG

General properties were measured with 3rd harmonics CHG at 266 nm.

\[
H_{3\text{with CHG}} = H_{3\text{SE}} \times 5
\]

Narrower Spectrum

\[\text{CHG} \propto I_{\text{peak}}^2: \text{signature of coherence}\]

Construction of VUV spectrometer and measurement of higher harmonics
Measured Spectrum with VUV Spectrometer

CHG pulse was successfully observed up to 9th harmonics (88.9 nm).

Macro-pulse power of CHG was small but peak powers were more than 100 times stronger than SR.

pulse duration SR > 100 ps, CHG < 1 ps
Saturation of CHG Intensity

With high peak power drive laser, CHG intensity saturates. And shows negative peak and increase again.
Origin of Negative Peak and Revival

With high laser power, over-bunching of micro-bunch occurs. → Double peak is created in longitudinal bunch distribution.

Cancel Out → Negative Peak

Additive Interference → Revival
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THz pump – PES probe beamline at UVSOR-II

S. Kimura et al., presented at SR109 and WIRMS2009

VUV-CHG [6-th CHG ($h\nu \sim 9$ eV) is expected, $\Delta h\nu \leq 10$ meV]

Ti:Sapphire laser
(1 kHz, 10 mJ/pulse)

Delay line

Radiation shield wall

Radiator

Modulator

PES analyzer

UHV chamber

Sample

FTIR

THz-CSR
(244 x 80 mrad²)

3D-magic mirror

Quasi-monochromatic CSR.
(Monochromator is not needed.)

Power spectral density (arb. units)

Frequency (cm⁻¹)

$[ \text{S. Kimura et al., NIMA 467-468, 437 (2001).} ]$
Construction of Dedicated Undulator Section

Present Experiment Area

New Experiment Area
Next year, two undulators will be installed in new straight section.
Summary

• **THz CSR**
  – EO sampling detection of CSR pulse was succeeded.

• **VUV CHG**
  – Up to 9th harmonics was observed.
  – Saturation of CHG intensity was observed.

• **Future Prospects and Application**
  – Dedicated Undulator line is under construction.
  – Coherent lights will be used for THz-pump – PES probe application.
Thank You

Coworkers
M. Katoh, M. Adachi, S. Kimura,
T. Tanikawa, Y. Taira,
M. Hosaka, N. Yamamoto, Y. Takashima,
T. Takahashi, T. Hara, A. Mochihashi, M. Shimada,
S. Bielawski, C. Szwaj, C. Evain, M. Le-Parquier
J. Yamazaki, H. Hayashi, E. Nakamura

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