SANDWICH Scripts

Simulations with elegant and GENESIS 1.3

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SANDWICH Scripts
S2E Meeting, 27.03.2014
Motivation

- For most seeding simulations different programs have to be employed, because of their individual strengths and weaknesses.

- For our purposes (CHG, HGHG, Self-Seeding, EEHG): GENESIS 1.3 simulates electron-light-interaction (modulator and radiator).

- For high currents dispersive sections (chicanes) are more accurate computed by codes that include collective effects -> elegant (ASTRA, CSRTrack, …).

- For high harmonics one needs about 8000 particles per slice and harmonic in GENESIS to suppress numerical noise to a minimum.

- Normal SDDS Files can load up to 22E6 particles into GENESIS.

\[
22E6 \text{ particles} / (500 \text{ slices} \times 8000 \text{ particles/slice}) = 5.5
\]
The Challenge

Hierarchical Data Format (HDF)

- root
  - /datasets
    - /beamletsize,
    - /refposition,
    - /slicelength,
    - /slicespacing,
    - /slicecount
  - /current
  - List of particles
    - $x, p_x, y, p_y, \gamma, \theta$

Self-Describing Data Set (SDDS)

- Header
  - Description of all parameters within the body including name, unit and variable type.

- Body
  - Contains all parameter values. In our case:
    - datasets: beamletsize, refposition, slicelength, slicespacing, slicecount
    - charge
    - list of particles: $x, x', y, y', \gamma, t$
  - Attribution to slices is missing!

ASCII File
The Challenge

- Different charges per particle in different slices.
- Same number of particles per slice

- Same charge per particle
- Number of particles proportional to current.
- No slices!
First Tests
Transverse phase space distribution

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Transverse phase space distribution
Current distribution

GENESIS 1.3  HDF5_2_SDDS  SDDS_2_HDF5  GENESIS 1.3

![Graph showing current distribution with 'Original' and 'Processed' curves.](image)
Bunching (Fundamental)

GENESIS 1.3  HDF5_2_SDDS  SDDS_2_HDF5  GENESIS 1.3
Bunching (2\textsuperscript{nd} harmonic)

GENESIS 1.3 \rightarrow HDF5\_2\_SDDS \rightarrow SDDS\_2\_HDF5 \rightarrow GENESIS 1.3

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image.png}
\caption{Bunching (2\textsuperscript{nd} harmonic) graph showing the comparison between Original and Processed data.}
\end{figure}
CHG R56 Scan

GENESIS 1.3 → HDF5_2_SDDS → ELEGANT → SDDS_2_HDF5 → GENESIS 1.3

Change deflecting angle of dipoles within chicane. (50A, 20µJ Run)

![Graphs showing current and s[m] plots]
CHG R56 Scan

**GENESIS 1.3** → **HDF5_2_SDDS** → **ELEGANT** → **SDDS_2_HDF5** → **GENESIS 1.3**

Change deflecting angle of dipoles within chicane. (50A, 20µJ Run)

![Graphs showing current vs. s (m)](image-url)
CHG R56 Scan

<table>
<thead>
<tr>
<th>GENESIS 1.3</th>
<th>HDF5_2_SDDS</th>
<th>ELEGANT</th>
<th>SDDS_2_HDF5</th>
<th>GENESIS 1.3</th>
</tr>
</thead>
</table>

Change deflecting angle of dipoles within chicane. (50A, 20µJ Run)

<table>
<thead>
<tr>
<th>Bunching on different harmonics in *10^4</th>
<th>R56 [µm]</th>
<th>0</th>
<th>-10</th>
<th>-40</th>
<th>-110</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>5.0</td>
<td>10.4</td>
<td>28.3</td>
<td>28.2</td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>1.7</td>
<td>1.1</td>
<td>12.0</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>3rd</td>
<td>1.5</td>
<td>1.6</td>
<td>2.9</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>2.0</td>
<td>2.8</td>
<td>6.0</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>5th</td>
<td>2.2</td>
<td>1.3</td>
<td>4.8</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Challenges

> Particles that leave a slice due to their movement come back into the slide from the other side.

> Can this cause problems in GENESIS 1.3 calculations?
> Compare: beamfile input with particle input.
Conclusion

- We have a tool capable of the generation of HDF5 Particle Distribution Files from SDDS files and vice versa.
- GENESIS 1.3 and elegant accept these files and understand them correctly.
- Since the phase space distribution manipulation takes place in elegant (which does not know anything about harmonics), one can reach any harmonic.
Outlook

➢ Is GENESIS 1.3 suitable for seeding simulations?
➢ Substitute elegant with some other SDDS capable tracking code?
➢ Substitute modulator calculations by elegant module?
➢ Test the framework with physics runs for future CHG and HGHG experiments
First Tests

GENESIS 1.3 can handle the chicane by transfer matrices, too. What is the difference to elegant?

<table>
<thead>
<tr>
<th>Sim Parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>8192</td>
</tr>
<tr>
<td>Electron $\gamma$</td>
<td>1369</td>
</tr>
<tr>
<td>Energy Spread</td>
<td>$0.1\gamma$</td>
</tr>
<tr>
<td>Laser Power</td>
<td>100 $\mu$J</td>
</tr>
<tr>
<td>Laser Duration (FWHM)</td>
<td>30 fs</td>
</tr>
<tr>
<td>Laser Wavelength</td>
<td>270 nm</td>
</tr>
</tbody>
</table>
First Tests

1.5 kA Run:

- GENESIS 1.3
- HDF5_2_SDDS
- ELEGANT
- SDDS_2_HDF5
- GENESIS 1.3

![Graph showing current fluctuations](image)
First Tests

1.5 kA Run:

![Graph of 1.5 kA Run]
## Simulation Programs

<table>
<thead>
<tr>
<th></th>
<th>GENESIS</th>
<th>ELEGANT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version</strong></td>
<td>3.2.1, 22M7</td>
<td>25.2.2</td>
</tr>
<tr>
<td><strong>Architecture</strong></td>
<td>64 bit</td>
<td></td>
</tr>
<tr>
<td><strong>Parallel</strong></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum No. of Particles</strong></td>
<td>~ 22 M (parallel: (2^{63} - 1))</td>
<td></td>
</tr>
<tr>
<td><strong>Used number of Particles</strong></td>
<td>~ 150 k/slice ~ 75 M</td>
<td></td>
</tr>
<tr>
<td><strong>Highest Harmonic</strong></td>
<td>7th (in spectrum)</td>
<td></td>
</tr>
<tr>
<td><strong>Used for</strong></td>
<td>Undulator Simulations, Particle Tracking and Collective Effects</td>
<td></td>
</tr>
<tr>
<td><strong>File Format</strong></td>
<td>HDF5</td>
<td></td>
</tr>
<tr>
<td><strong>Longitudinal Coordinates</strong></td>
<td>(\gamma, \theta, k_{\text{slice}})</td>
<td>(\gamma, t)</td>
</tr>
<tr>
<td><strong>Transverse Coordinates</strong></td>
<td>(x, y, p_x, p_y)</td>
<td>(x, y, x', y')</td>
</tr>
<tr>
<td><strong>Charge per particle</strong></td>
<td>Constant in one slice</td>
<td>Constant for each particle</td>
</tr>
</tbody>
</table>

For experts:
- **NHARMMAX** during compilation limits the highest harmonic in the simulated spectra
- The radiator can lase on **ANY** harmonic of the modulator
- There are several options
  - Sort particles to narrower slices
  - Use **MULTCONV**, **CONVHARM**, and **ZSEP**
Requirements

- Remodel particle distribution according to current profile.
- Convert GENESIS slice structure with ponderomotive phases [-3.3;3.3] to intra bunch coordinate.
- Divide particle distribution into slices with the same number of particles.
- Each slice has to contain the same number of particles. This number has to be a multiple of 4*NBINS (128).

A huge amount of particles is lost in the conversion. Depending on current profile this can be up to the order of 50%.
Bunching (3rd harmonic)

GENESIS 1.3   HDF5_2_SDDS   SDDS_2_HDF5   GENESIS 1.3

![Graph showing b^2 as a function of s (m)](image_url)

- Original
- Processed
Longitudinal phase space distribution (tail)
Longitudinal phase space distribution (tail)
Longitudinal phase space distribution (at modulation)
Longitudinal phase space distribution (at modulation)
Longitudinal phase space distribution (at modulation)