

XAL Online Model Requirement Document

P. Chu
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This document only identifies what XAL can provide for LCLS online modeling environment. It does not provide implementation details. Also, this document is limited to only online model related issues and any non-model related XAL features are left out here. In this document, both already existing (in black) and planned (in orange) features are listed.

XAL framework general support

General accelerator hierarchy

1. Sections (sequences) are defined by the Accelerator Physicists (e.g. Paul Emma, Rick Iverson...) and stored in relational database (RDB).
2. Supporting the following device types: XCOR, YCOR, SOLN, BPM, LCAV, TCAV (incomplete), RF Gap (as fine structure within a cavity), QUAD, BEND, WIRE (to be completed by wire application) and profile monitor (to be completed by profile monitor application).
3. In addition to the hardware device types mentioned in 2), Markers can be defined as needed.
4. For each device, the following properties are accessible:
 - Physics ID (aka, MAD name, assigned as the *default* ID)
 - Engineering ID (EPICS PV name without the signal extension part)
 - Local position (in meters) relative to the beginning of the section the device belonging to.
 - Device length
 - On/offline status
5. For electro-magnets, the following properties in addition to 4) are available:
 - Magnetic length (in meters) – this should be able to update dynamically.
 - Polarity (+1 or -1)
 - Default field strength (in MKS units)
 - Field readback channel name and scaling constant (e.g. kG-to-Tesla transformation)
 - Power supply ID for this magnet (the way to link to the field set channel)
 - (optional) aperture
6. For beam position monitors, the following properties in addition to 4) are available:
 - Horizontal position channel name.
 - Vertical position channel name.
 - Amplitude average channel name.
 - Default to 1Hz BSA channel for the above channels with option to change to others.
7. For RF cavities (including both LCAV and TCAV), the following properties in addition to 4) are available:
 - Default RF cavity field gradient (in MV)

- Default TTF (transit-time factor)
 - Default RF phase (in degree)
 - Default frequency
 - Channels:
 - Field gradient set
 - Phase set
 - Field gradient readback
 - Phase readback
 - Information for RF gaps within this cavity
 - Gap length
 - Relative phase (to the cavity)
 - Amplitude scaling (from cavity/klystron)
 - TTF
 - End cell indicator
 - WIRE (to be filled by WIRE application)
 - Profile monitor (to be filled by profile monitor application)
8. Beam-line devices in the database are completed up to LI30 (previously the “full machine” beamline) and 2 dump lines. As physics needed, we can extend the coverage (with proper RDB support).

Beamline/section

For details, see XAL [JavaDoc](#).

1. Consecutive sections can be connected and form a beamline (combo-sequence).
2. Devices within a beam-line/section can be filtered.
3. For each section, a set of pre-defined beam/Twiss parameters, i.e. initial condition, is provided for the “starting” point of physics modeling.
 - The default initial condition for each section assumes no coupling terms.
 - Optionally, coupling terms can be provided in a 7x7 correlation matrix form in a separated probe file.
 - The initial condition for each section should be saved in RDB.
 - A GUI or easy access method for user to enter customized initial conditions (prototyped).
 - Information such as magnet focus lengths and K values should be available outside XAL.

Other support

1. Application data/configuration can be saved as *documents* and reloaded at a later time.
2. Add unit support to XAL and display unit next to a number in applications.

XAL online model support

Available algorithms

1. Single particle tracking algorithm – a simple algorithm for trajectory only calculation. This algorithm provides only trajectory calculation.

2. Envelope tracking algorithm – space charge included envelope code based on Trace-3D.
 - The step size along the beamline is determined at run-time according to space charge (adaptive algorithm).
 - This algorithm provides Twiss and possibly dispersion, chromaticity, B_{mag} .
3. Transfer Map tracking algorithm – algorithm for ring-like (closed orbit) beamline. *Transfer matrix* calculation is recommended to use this algorithm. This algorithm is based on particle tracking algorithm.
4. Model validation: will benchmark against MAD and ensure the match is reasonable.

Available modeling modes

1. Design (from MAD Deck) – model lattice is constructed from machine design configuration.
2. Live – model lattice is constructed from present machine setup.
 - Currently XAL only supports Java Channel Access, i.e. EPICS control system.
 - RF readings will not be from live machine because the control system is not ready. Presently RF information is from *design energy gain for each cavity*. We plan to use LEM (Linac Energy Manager Application) to get a recent energy profile from the machine and cache this information somewhere for model use.
3. Test – user can overwrite either one of the above lattices with own ‘what-if’ test setting.

Valid energy range

For operation applications, the lowest energy point will be at the end of L0A. There will be R&D effort for modeling space charge effect at lower energy (see below).

Online model lattice generation

1. For design lattice, it is initialized from static information, i.e. RDB or XML file.
2. For live lattice, it should generate according to magnetic lengths which could be energy dependent.

Data availability

1. Machine configuration should be saved (whatever we provide from below, it will be accessible from scripting languages stated in next item):
 - Into RDB: such as PV Logger or SCORE (similar to archiver).
 - Into file: format will be the same as XAL initialization (.xdxf) file.
2. Model output should be saved.
 - Into RDB:
 - Into file: format can be XAL convention (XML or extended markup language) or Excel convention (CSV or comma-separated values).
 - The output data saved in either RDB or file will be able to retrieve programmatically.

3. All the model data (including both input and output parameters) should be available to external programs such as scripting tools.

Scripting/Application support

All the XAL functions will be accessible for Matlab and Jython scripts. The XAL initialization (XML) files are available as well.

Online model GUI application

An XAL application provides basic online model GUI functions:

1. Selecting an initialization file to load.
2. Selecting a section or beamline to work with.
3. Selecting a modeling mode (design, live, etc.)
4. Selecting between magnet set/readback to use.
5. Displaying detail input parameters (hardware settings, model initial parameters).
6. Displaying selected model output in tables.
7. Displaying selected model output in plot versus coordinate along the beamline.
8. Being able to save result to a file.

Energy scaling application

This application will scale magnets with energy. An existing XAL application has similar functionality.

Linac Energy Manager (LEM) application

1. Dynamically adjust the lattice according to present klystron settings.
2. Saving the calculated energy profile for other program to use.

Modeling initial condition for each section for live machine

Presently model initial parameters are from MAD Deck. This may not be good enough to reflect the live beam properties. We would like to take a recent emittance measurement and trace back/forward to the beginning point of each section, save this information somewhere for online model to use.

Undulator modeling

The model will provide a simple model for a series of quadrupole effect first. Diagnostic devices will also be included.

Transverse cavity (TCAV) and solenoid modeling

1. TCAV has been added to the XAL. However, the details have not been completed.
2. Solenoid has been added to the XAL but has not been tested yet.

Additional magnet functions (low priority)

1. Higher order component support.
2. Ramping curve or polynomial support (general XAL support, not for LCLS).

“L0A” cavity detail modeling

Presently, the online model starts at about 2/3 into the L0A cavity with kinetic energy of about 56 MeV. **We will change the starting point to the end of L0A for now.** Also, the cavity is sliced to 7 pieces for detail modeling inside it. It may require additional terms in the calculation as well as further slicing the cavity.

Beam-based alignment

~~TBD~~: This application will be handled by other program for near future.

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