MO Design and Status Review

XFEL MO concept, overview of system components

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Three Main Functionalities

1. Generation of ultra stable 1.3 GHz signal:
   - stability: \(5 \times 10^{-11}\) for >1s observation time, no aging – GPS stabilization
   - jitter: <170 fs RMS (1 Hz – 10 MHz)
   - output power: +40 dBm (32 outputs, min +15 dBm each)

2. Redundancy:
   - more than one unit
   - automatic failure detection
   - no interruption in signal delivery in case of one unit failure
     - small transition allowed

3. Diagnostics:
   - Built-in diagnostics in each device
   - DOOCS panels for monitoring
Concept Development - Single MO

- Simplicity
- Phase noise achievable
- Diagnostics easy to implement
- but..

No redundancy!
Concept Development – Two MO Channels

> Two units, but still no failure detection and no merging point.

Solution:

> **Failure detection** - low latency monitoring of amplitude and phase
  - no reference for phase measurement
  - slow drifts between Generation Channels

> **Channels isolation** – switching
  - no signal during switching
> Failure detection:
  - 3 Generation Channels allow to determine signal with wrong phase
  - Drifts between Channels are compensated by Vector Modulators (VM) to the SELECTED channel

> Channels isolation:
  - High-Q filter sustains signal for ~300 ns (time for detection and switching)

> COMPLEXITY
Each box is an individual 19'' module

Together 7 types of modules
- 3 types are ordered in external companies
- 4 types are designed and produced in DESY

Total number of modules: 13
**Generation Channel Devices**

- **GPSDO**: 100 MHz Synt., 1.3 GHz Synt.
- **REDUNDANCY BOX**: RF switch with Redundancy Controller, High-Q 1.3 GHz filter.
- **RF DISTRIBUTION BOX**: 32-way Power Splitter, Input and reflected power measurement.
- **PHASE NOISE ANALYZER**: 1.3 GHz +15 dBm.

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Generation Channel Devices

GPS Disciplined Rubidium Oscillator
- Provided by external company
- Consists of two units:
  - 2U: GPS receiver and Rb oscillator
  - 1U: ultra low noise OCXO and amplifier
- Features:
  - 10 MHz signal output
  - high signal stability
  - built-in diagnostics with LAN port
  - GPS antennas installed on XTIN roof

100 MHz Synthesizer
- Design and production in DESY
- 2U 19" module
- Features:
  - 100 MHz output
  - ultra low noise
  - built-in diagnostics
  - output protection against power reflection
- Components:
  - ultra low noise 100 MHz OCXO
  - locking unit
  - FRED
  - TMCB
  - isolator at the output

1.3 GHz Synthesizer
- Design and production in DESY
- 5U 19" module
- Features:
  - 1.3 GHz output
  - -170 dBC/Hz phase noise floor
  - High output power (+40 dBm)
  - unlimited phase control by VM
  - output protection against power reflection
- Components:
  - Dielectric Resonator Oscillator
  - High Power Amplifier
  - locking unit
  - 13x frequency multiplier
  - uVM
  - isolator at the output
Redundancy Box

POWER SUPPLY MODULE

GPSDO → 100 MHz Synt. → 1.3 GHz Synt.

GPSDO → 100 MHz Synt. → 1.3 GHz Synt.

GPSDO → 100 MHz Synt. → 1.3 GHz Synt.

REDUNDANCY BOX

RF switch with Redundancy Controller

High-Q 1.3 GHz filter

µC

RF DISTRIBUTION BOX

32-way Power Splitter

Input and reflected power measurement

PHASE NOISE ANALYZER

1.3 GHz

+15 dBm
Redundancy Box

Design and production in DESY

- 5U 19" module
- Features will be covered in B. Gąsowski talk

Components:
- RF switch with built-in low latency phase and amplitude measurement
- High-Q filter
- Redundancy controller
- TMCB

Redundancy Box

RF Switch PCB with built-in diagnostics

High-Q 1.3 GHz filter
Remaining Components

- **Power Supply Module**
  - Provided by external company
  - Provides power to:
    - GPSDO
    - 100 MHz Synthesizer
    - 1.3 GHz Synthesizer
    - Redundancy Box
    - RF Distribution Box

- **Redundant**
  - the same type as for LLRF

- **RF Distribution Box**
  - Design and production in DESY
  - 5U 19" module
  - Features:
    - 32 outputs
    - measurement of input and reflected power
    - LAN connection
  - Components:
    - power splitters
    - Bi-directional couplers and power meters
    - FRED
    - TMCB

- **Phase Noise Analyzer**
  - Provided by external company
  - 3U 19" module
  - Features:
    - Phase noise measurement
    - communication over LAN port
    - input for external references
Diagnostics in DESY modules

- Each DESY 19" module has built-in diagnostics and TMCB onboard
- TMCB collects data and communicates with DOOCS

- FRED provides the power to submodules
MO Rack Layout

1. MO Channel #1
2. MO Channel #2
   - Redundancy Box
   - Distribution Box
3. MO Channel #3
   - Interferometer Boxes
   - Interferometer for KLM

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Task Assignment

- Project leader – Łukasz Zembala
- Redundancy and RF Switch – Bartosz Gąsowski
- Tests and assembly – Stanisław Hanasz
- Orders, schematics, reviews – Henning Weddig
- Mechanics designer – Maciek Woźniczko
- Support boards – Marcin Sosnowski
- Redundancy Controller – Tomasz Owczarek
- Software – Adam Dworzański
- ...

Specifications, production files, failure reports and all the other project files are placed on the N: drive in the folder: N:\4all\public\MSK_Projekte\RFSyn\XFEL_MasterOscillator

MO project in Redmine is started
Thank you for your attention!
# Requirements from the users (backup slide)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value [unit]</th>
<th>Feasibility (comment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1.3 GHz</td>
<td>✓</td>
</tr>
<tr>
<td>Harmonics</td>
<td>&lt; -60 dBC</td>
<td>✓</td>
</tr>
<tr>
<td>Subharmonics</td>
<td>&lt; -60 dBC</td>
<td>✓</td>
</tr>
<tr>
<td>Spurious</td>
<td>&lt; -60 dBC</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Long term frequency stability:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1s – 1 day</td>
<td>≤ 5x10^{-11}</td>
<td>✓</td>
</tr>
<tr>
<td>&gt;1 day</td>
<td>&lt; 5x10^{-11}</td>
<td>✓</td>
</tr>
<tr>
<td>Aging</td>
<td>&gt; 1 month</td>
<td>GPS</td>
</tr>
<tr>
<td><strong>Short term frequency stability:</strong></td>
<td></td>
<td></td>
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<tr>
<td>Offset frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Hz</td>
<td>&lt; -60 dBC/Hz</td>
<td>✓</td>
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<tr>
<td>10 Hz</td>
<td>&lt; -80 dBC/Hz</td>
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<td>100 Hz</td>
<td>&lt; -115 dBC/Hz</td>
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<tr>
<td>1 kHz</td>
<td>&lt; -140 dBC/Hz</td>
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<tr>
<td>10 kHz</td>
<td>&lt; -145 dBC/Hz</td>
<td>✓</td>
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<tr>
<td>100 kHz</td>
<td>&lt; -163 dBC/Hz</td>
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<tr>
<td>1 MHz</td>
<td>&lt; -170 dBC/Hz</td>
<td>✓</td>
</tr>
<tr>
<td>10 MHz</td>
<td>&lt; -170 dBC/Hz</td>
<td>✓</td>
</tr>
<tr>
<td>floor</td>
<td>&lt; -170 dBC/Hz</td>
<td>✓</td>
</tr>
<tr>
<td>Connector type</td>
<td>SMA</td>
<td>✓</td>
</tr>
<tr>
<td>Number of outputs</td>
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<td>✓</td>
</tr>
<tr>
<td>Impedance</td>
<td>50 Ω</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Power at each output</strong></td>
<td>+15 dBm</td>
<td>✓</td>
</tr>
<tr>
<td>Amplitude stability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 Hz &lt; f &lt; 10 Hz</td>
<td>±0.088 dB</td>
<td>✓</td>
</tr>
<tr>
<td>f &gt; 10 Hz</td>
<td>±0.0080 dB</td>
<td>✓</td>
</tr>
<tr>
<td>Acceptable period of signal's interruption (case of redundant source switching)</td>
<td>no interruption allowed</td>
<td>✓</td>
</tr>
</tbody>
</table>

8 extra general purpose outputs of 10 MHz (1.3 GHz division of frequency by 130); min 0dBm each.
8 extra general purpose outputs of 216 MHz (1.3 GHz division of frequency by 8); min 0dBm each.
Functional block diagramme of the 1.3 GHz Synthesizer