Laser-to-RF Optics and Integration .

How to resynchronize the 1.3GHz main drive line to the Master Laser Oscillator?

Thorsten Lamb
on behalf of the
Laser-Based Synchronization Team

February 20, 2012

Deutsches Elektronen-Synchrotron

HELMHOLTZ ASSOCIATION

DESY

Outline

System Overview

- RF cables of 1.3 GHz main drive line drift in phase
  - one optical link can provide a drift free synchronization signal at one point in the accelerator
  - its a point to point connection so its expensive
- RF reflectometer sub-distribution for the main linac to reduce costs (Dominik)

System Overview

- RF cables of 1.3 GHz main drive line drift in phase
  - one optical link can provide a drift free synchronization signal at one point in the accelerator
  - its a point to point connection so its expensive
- RF reflectometer sub-distribution for the main linac to reduce costs (Dominik)
- L2RF is a phase detector between optical and RF domain
- the RF can be resynchronized and drifts are removed

System Overview

- RF cables of 1.3 GHz main drive line drift in phase
  - one optical link can provide a drift free synchronization signal at one point in the accelerator
  - its a point to point connection so its expensive
- RF reflectometer sub-distribution for the main linac to reduce costs (Dominik)
- L2RF is a phase detector between optical and RF domain
- the RF can be resynchronized and drifts are removed

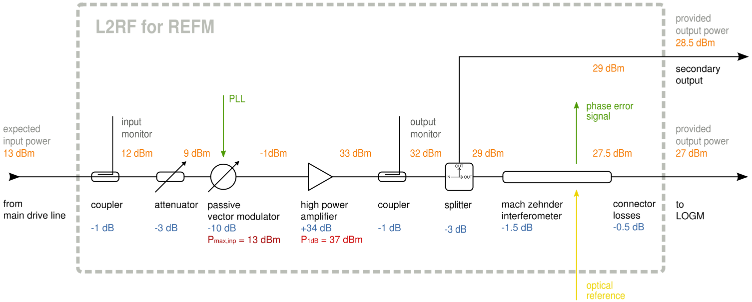
System Overview

- RF cables of 1.3 GHz main drive line drift in phase
  - one optical link can provide a drift free synchronization signal at one point in the accelerator
  - its a point to point connection so its expensive
- RF reflectometer sub-distribution for the main linac to reduce costs (Dominik)
- L2RF is a phase detector between optical and RF domain
- the RF can be resynchronized and drifts are removed
- REFM-OPT is a feed-through RF setup with the L2RF phase detector

System Overview

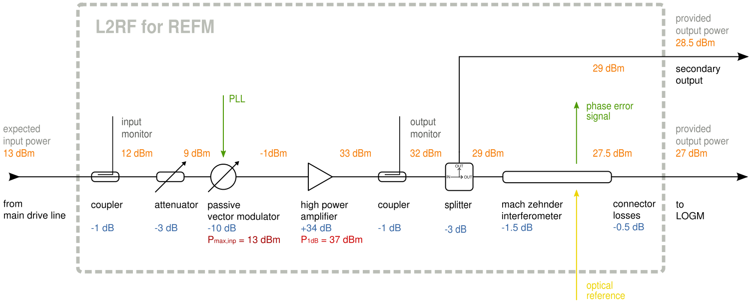
- RF cables of 1.3 GHz main drive line drift in phase
  - one optical link can provide a drift free synchronization signal at one point in the accelerator
  - its a point to point connection so its expensive
- RF reflectometer sub-distribution for the main linac to reduce costs (Dominik)
- L2RF is a phase detector between optical and RF domain
- the RF can be resynchronized and drifts are removed
- REFM-OPT is a feed-through RF setup with the L2RF phase detector
- for early startup its even possible to have modules just with RF components and add the optical part later

Layout of RF Components



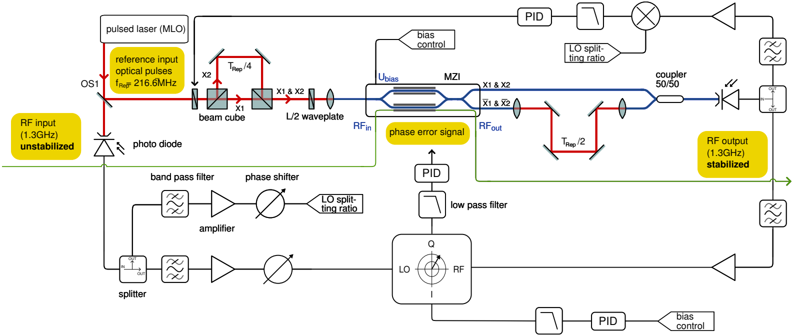
- setup can operate from lower RF input power if needed
  - will reduce SNR of output signal
- fixed attenuator and VM already foreseen to adjust and stabilize 1.3 GHz RF power

Layout of RF Components



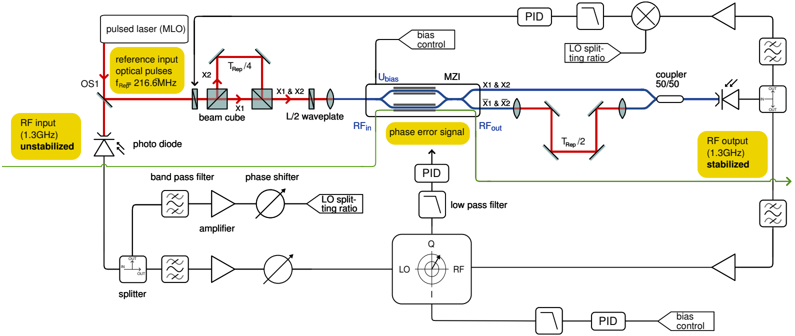
- setup can operate from lower RF input power if needed
  - will reduce SNR of output signal
- fixed attenuator and VM already foreseen to adjust and stabilize 1.3 GHz RF power
- output power fixed due to damage threshold of MZI
- more output ports can be generated by using internal 2, 4 or 8 way RF splitter
  - symmetrical splitter layout promises low drifts also at non stabilized outputs

Layout of L2RF Components



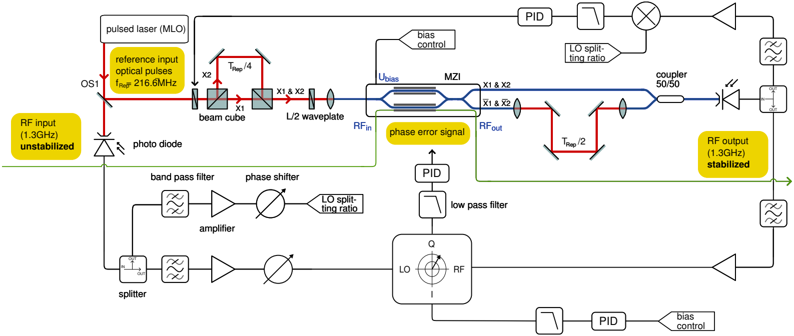
Layout of L2RF Components

> essentially this L2RF is a phase detector between optical and RF domain



Layout of L2RF Components

- essentially this L2RF is a phase detector between optical and RF domain
- L2RF detector electronics will be covered in the next talk by Ewa
- L2RF optical setup and components will be covered here

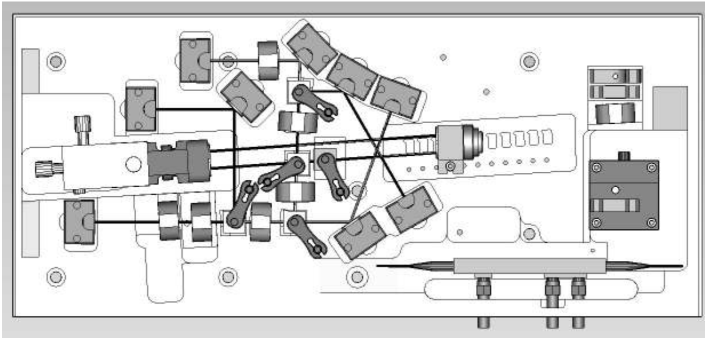


Layout of L2RF Components

- essentially this L2RF is a phase detector between optical and RF domain
- L2RF detector electronics will be covered in the next talk by Ewa
- L2RF optical setup and components will be covered here

Layout of L2RF Components

- essentially this L2RF is a phase detector between optical and RF domain
- L2RF detector electronics will be covered in the next talk by Ewa
- L2RF optical setup and components will be covered here



Stabilization Requirements

- demanding relative stability requirements
  - humidity influence on fiber 2.5 $\mathrm{fs/m}$ % RH
  - temperature influence on fibers 55 $\mathrm{fs/m}$ K
  - temperature influence on aluminum baseplate 77 $\mathrm{fs/m}$ K

Stabilization Requirements

- demanding relative stability requirements
  - humidity influence on fiber 2.5 $\frac{fs}{m\ \%\ RH}$
  - temperature influence on fibers 55 $\frac{fs}{m\ K}$
  - temperature influence on aluminum baseplate 77 $\frac{fs}{m\ K}$
- absolute requirements on the setpoint
  - MZI has zero temperature coefficient at around 27 deg C

Stabilization Requirements

- demanding relative stability requirements
  - humidity influence on fiber 2.5 $\frac{\mathrm{fs}}{\mathrm{m}\ \%\ \mathrm{RH}}$
  - temperature influence on fibers 55 $\frac{\mathrm{fs}}{\mathrm{m\ K}}$
  - temperature influence on aluminum baseplate 77 $\frac{\mathrm{fs}}{\mathrm{m\ K}}$
- absolute requirements on the setpoint
  - MZI has zero temperature coefficient at around 27 deg C
- rack climatization for LLRF will be $\pm$ 1 deg C

Stabilization Requirements

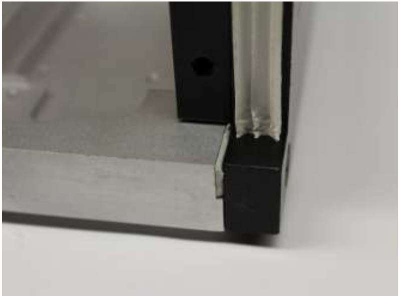
- demanding relative stability requirements
  - humidity influence on fiber 2.5 $\frac{\text{fs}/\text{m}}{\%\ \text{RH}}$
  - temperature influence on fibers 55 $\frac{\text{fs}/\text{m}}{\text{K}}$
  - temperature influence on aluminum baseplate 77 $\frac{\text{fs}/\text{m}}{\text{K}}$
- absolute requirements on the setpoint
  - MZI has zero temperature coefficient at around 27 deg C
- rack climatization for LLRF will be $\pm$ 1 deg C
- conclusion: careful stabilization of temperature and humidity needed

Engineering for Humidity Stabilization

- low air exchange rate

Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued

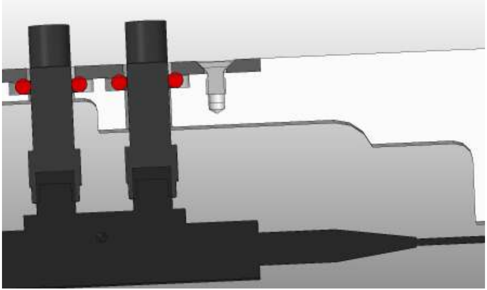


Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued
  - RF feed-through sealing ring (rubber)

Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued
  - RF feed-through sealing ring (rubber)



Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued
  - RF feed-through sealing ring (rubber)
- silica gel (ProSorb) acts as humidity buffer (storing and releasing humidity)

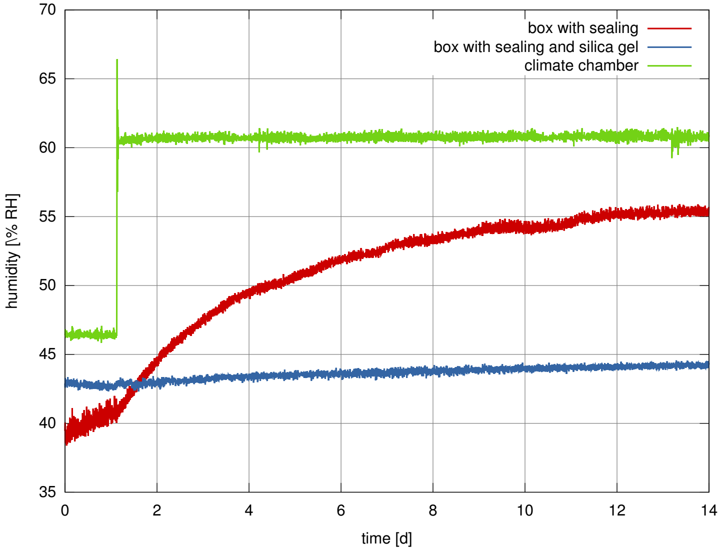
Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued
  - RF feed-through sealing ring (rubber)
- silica gel (ProSorb) acts as humidity buffer (storing and releasing humidity)
  - usually used in museum display cases
  - 250 g per box
  - 30 % (weight) water adsorption at 50 % RH
  - custom made dust-proof sachet

Engineering for Humidity Stabilization

- low air exchange rate
  - housing made from low water absorption plastic (HD-PE, 0.01 % adsorption) and aluminum
  - box joints with sealing (Tesa) or glued
  - RF feed-through sealing ring (rubber)
- silica gel (ProSorb) acts as humidity buffer (storing and releasing humidity)
  - usually used in museum display cases
  - 250 g per box
  - 30 % (weight) water adsorption at 50 % RH
  - custom made dust-proof sachet
- overall costs are very cheap (the silica gel sachet for example is 50 EUR)

Humidity Measurement Results

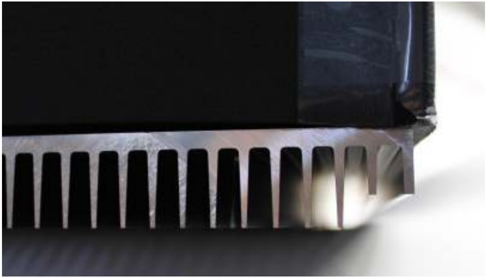


Engineering for Temperature Stabilization

- two peltier elements (35 W each) for active stabilization
- analog temperature controller for tests (teamwavelength PTC10k-CH)
  - later use of TMCB is planned

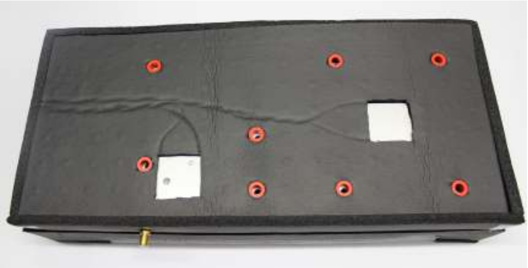
Engineering for Temperature Stabilization

- two peltier elements (35 W each) for active stabilization
- analog temperature controller for tests (teamwavelength PTC10k-CH)
  - later use of TMCB is planned
- full length, but low heatsink



Engineering for Temperature Stabilization

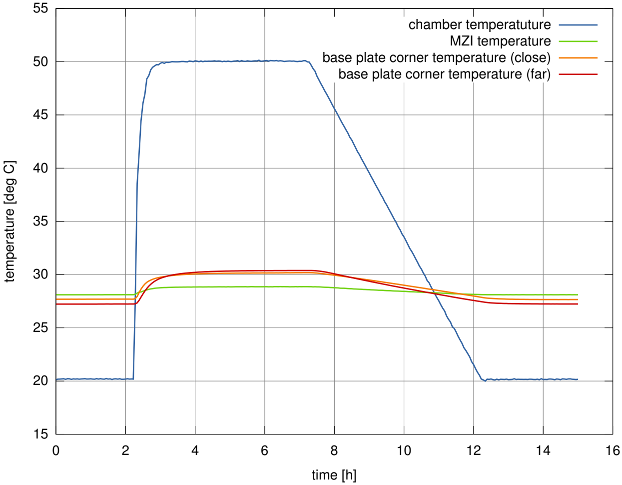
- two peltier elements (35 W each) for active stabilization
- analog temperature controller for tests (teamwavelength PTC10k-CH)
  - later use of TMCB is planned
- full length, but low heatsink
- closed isolation by 9 mm Armaflex (nitrile rubber) foam, 35 $^{mW}/_{K\,m}$
- plastic screws for fixing, in order to reduce heat losses



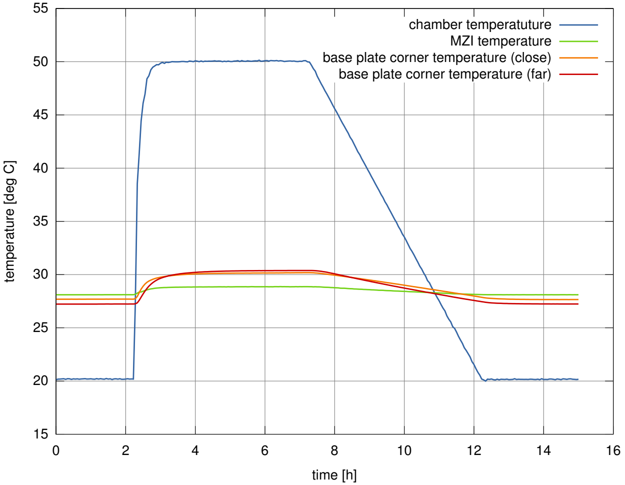
Engineering for Temperature Stabilization

- two peltier elements (35 W each) for active stabilization
- analog temperature controller for tests (teamwavelength PTC10k-CH)
  - later use of TMCB is planned
- full length, but low heatsink
- closed isolation by 9 mm Armaflex (nitrile rubber) foam, 35 mW/K m
- plastic screws for fixing, in order to reduce heat losses
- tests with passive heatpipes to reduce temperature gradient over the plate ongoing
  - first results (from Monday) were pointing into the wrong direction, reason unclear

Temperature Measurement Results



Temperature Measurement Results



- huge temperature step from 20 deg C to 50 deg C
- suppression of factor 50 at the MZI, factor 10 in the corner of the plate

Temperature Measurement Results Discussion

- the setpoint around 27 deg C is fixed because MZI has a zero temperature coefficient there
- temperature stability in the LLRF racks is supposed to be $\pm$ 1 deg C (Frank), setpoint unknown

Temperature Measurement Results Discussion

- the setpoint around 27 deg C is fixed because MZI has a zero temperature coefficient there
- temperature stability in the LLRF racks is supposed to be $\pm$ 1 deg C (Frank), setpoint unknown
- 250 mm of unstabilized fiber at the corner of the plate will drift then around 2.75 fs
- thermal expansion of aluminum will lead to free-space length changes of roughly 2 fs (estimated due to temperature gradient)

Temperature Measurement Results Discussion

- the setpoint around 27 deg C is fixed because MZI has a zero temperature coefficient there
- temperature stability in the LLRF racks is supposed to be ± 1 deg C (Frank), setpoint unknown
- 250 mm of unstabilized fiber at the corner of the plate will drift then around 2.75 fs
- thermal expansion of aluminum will lead to free-space length changes of roughly 2 fs (estimated due to temperature gradient)
- thermal losses for a 30 deg C step change by about 38 W (already omitting screws, RF cables etc)
- temperature gradient can be almost explained by this heat flow through the plate and thermal conductivity of aluminum

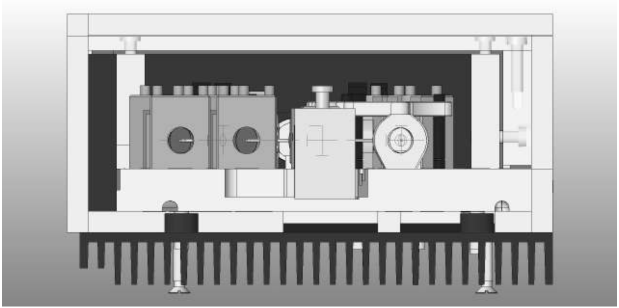
Temperature Measurement Results Discussion

- the setpoint around 27 deg C is fixed because MZI has a zero temperature coefficient there
- temperature stability in the LLRF racks is supposed to be $\pm$ 1 deg C (Frank), setpoint unknown
- 250 mm of unstabilized fiber at the corner of the plate will drift then around 2.75 fs
- thermal expansion of aluminum will lead to free-space length changes of roughly 2 fs (estimated due to temperature gradient)
- thermal losses for a 30 deg C step change by about 38 W (already omitting screws, RF cables etc)
- temperature gradient can be almost explained by this heat flow through the plate and thermal conductivity of aluminum
- isolation has to become better

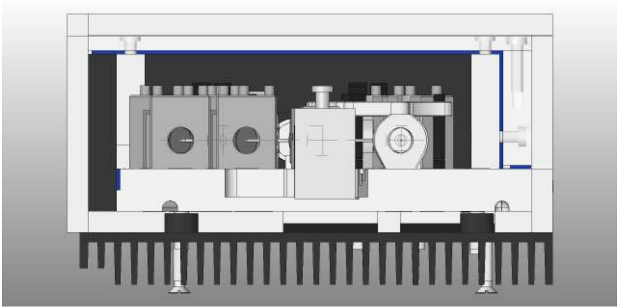
Temperature Measurement Results Discussion

- the setpoint around 27 deg C is fixed because MZI has a zero temperature coefficient there
- temperature stability in the LLRF racks is supposed to be $\pm$ 1 deg C (Frank), setpoint unknown
- 250 mm of unstabilized fiber at the corner of the plate will drift then around 2.75 fs
- thermal expansion of aluminum will lead to free-space length changes of roughly 2 fs (estimated due to temperature gradient)
- thermal losses for a 30 deg C step change by about 38 W (already omitting screws, RF cables etc)
- temperature gradient can be almost explained by this heat flow through the plate and thermal conductivity of aluminum
- isolation has to become better
  - more efficient materials are difficult to handle or expensiv
  - vacuum panels are expensive (500 EUR per piece) and can't be cut
  - Aerogel based products go down to 13 $^{\mathrm{mW}}/_{\mathrm{K\,m}}$ but are difficult to handle (very fine dust ...)
- isolation could also just become thicker ... but it seems like there is no space available for that

Space Constraints

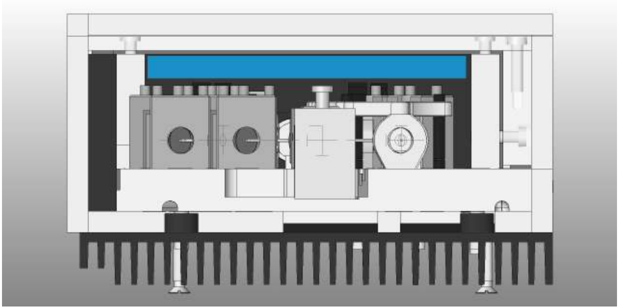


Space Constraints



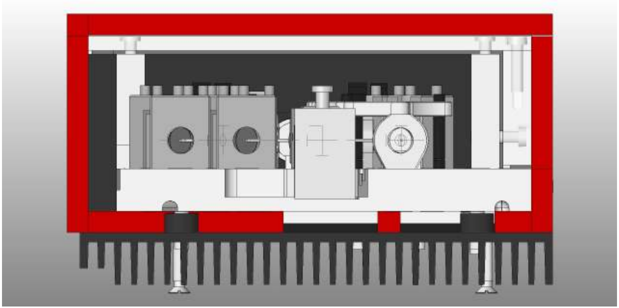
- sealings

Space Constraints



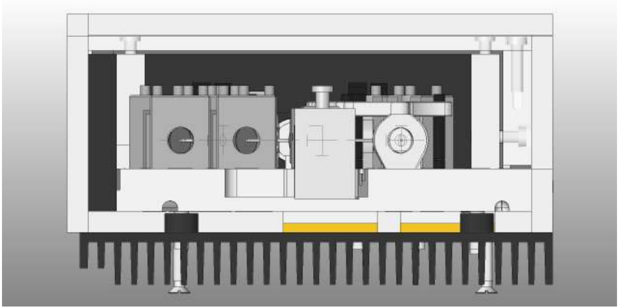
> silica gel

Space Constraints



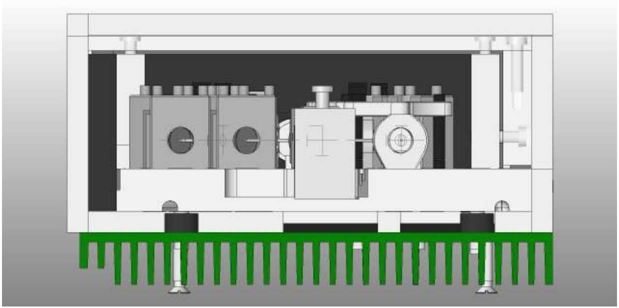
- isolation

Space Constraints



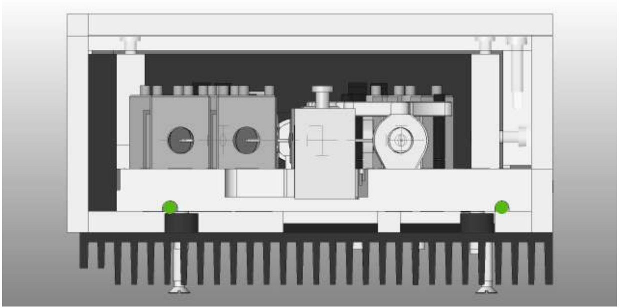
- peltiers

Space Constraints



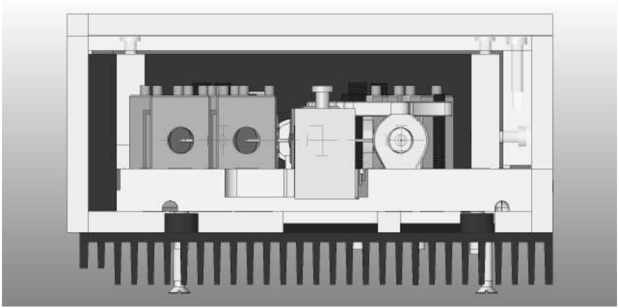
- heatsink

Space Constraints



- heatpipes

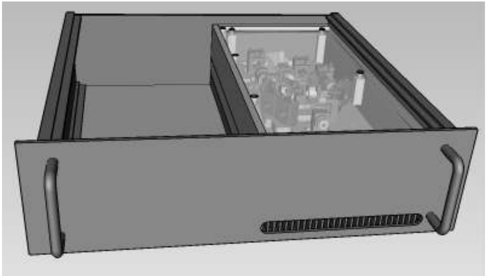
Space Constraints



- fits exactly into 3 U
- going to 2 U is hardly posible
- remember also that better isolation is needed ...

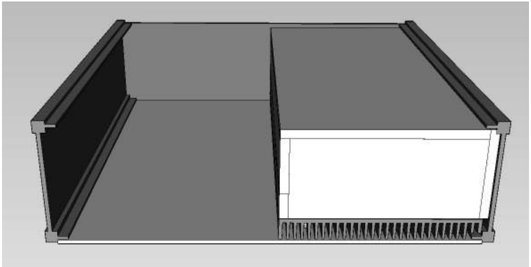
L2RF Components in the 19 Inch Package

- L2RF optical compartment



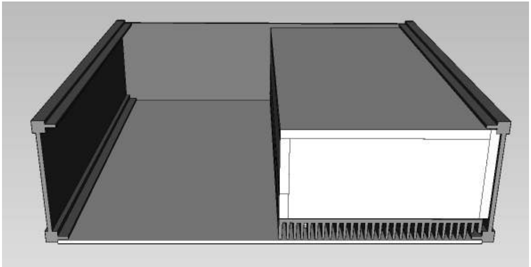
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)



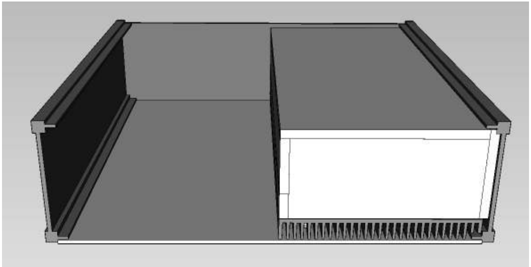
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator



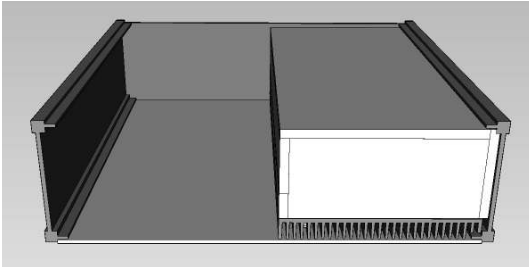
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier



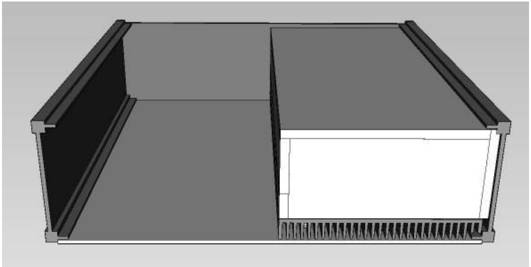
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring



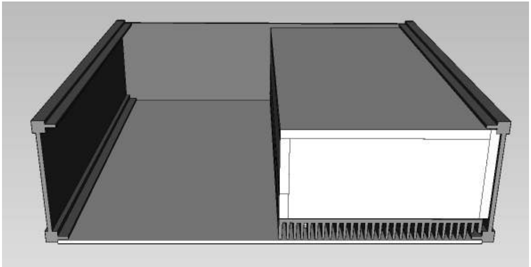
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring
- splitter for output multiplication



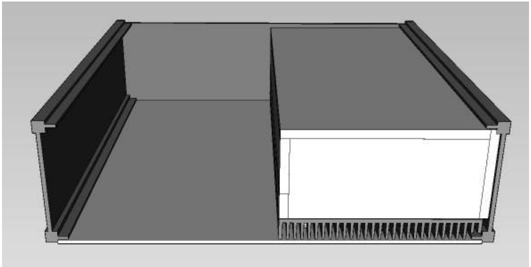
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring
- splitter for output multiplication
- TMCB (PLL, temperature and RF monitoring, temperature control?)



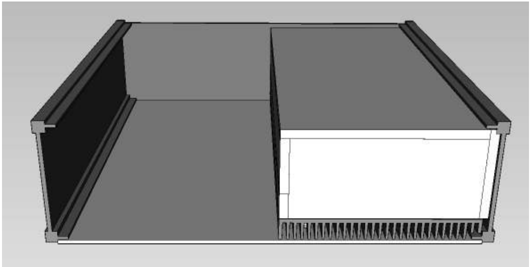
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring
- splitter for output multiplication
- TMCB (PLL, temperature and RF monitoring, temperature control?)
- stand-alone temperature controller (prototype only)



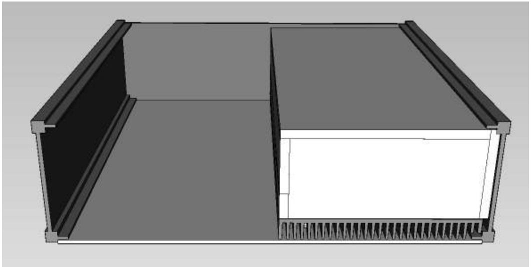
L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring
- splitter for output multiplication
- TMCB (PLL, temperature and RF monitoring, temperature control?)
- stand-alone temperature controller (prototype only)
- heat sink for RF amplifier and temperature controller



L2RF Components in the 19 Inch Package

- L2RF optical compartment
- L2RF detector electronics (Ewa)
- vectormodulator
- high power amplifier
- RF couplers and power detectors for monitoring
- splitter for output multiplication
- TMCB (PLL, temperature and RF monitoring, temperature control?)
- stand-alone temperature controller (prototype only)
- heat sink for RF amplifier and temperature controller
- plus components for reflectometer or 3.9 GHz system



Summary

- integration of L2RF almost finished
- small final redesign might be needed after final tests at FLASH

Summary

- integration of L2RF almost finished
- small final redesign might be needed after final tests at FLASH
- finish measurements on integrated setup (optics and electronics)
- investigate RF components (vector modulator, amplifier)

Summary

- integration of L2RF almost finished
- small final redesign might be needed after final tests at FLASH
- finish measurements on integrated setup (optics and electronics)
- investigate RF components (vector modulator, amplifier)
- finish 19 inch integration of RF components

Summary

- integration of L2RF almost finished
- small final redesign might be needed after final tests at FLASH
- finish measurements on integrated setup (optics and electronics)
- investigate RF components (vector modulator, amplifier)
- finish 19 inch integration of RF components
- test prototypes at FLASH
- finish integration with RF interferometer for XFEL

Outlook

Thank you for your attention.

Dziękuję za uwagę.