DORIS Current Monitor: Simulation of Temperature

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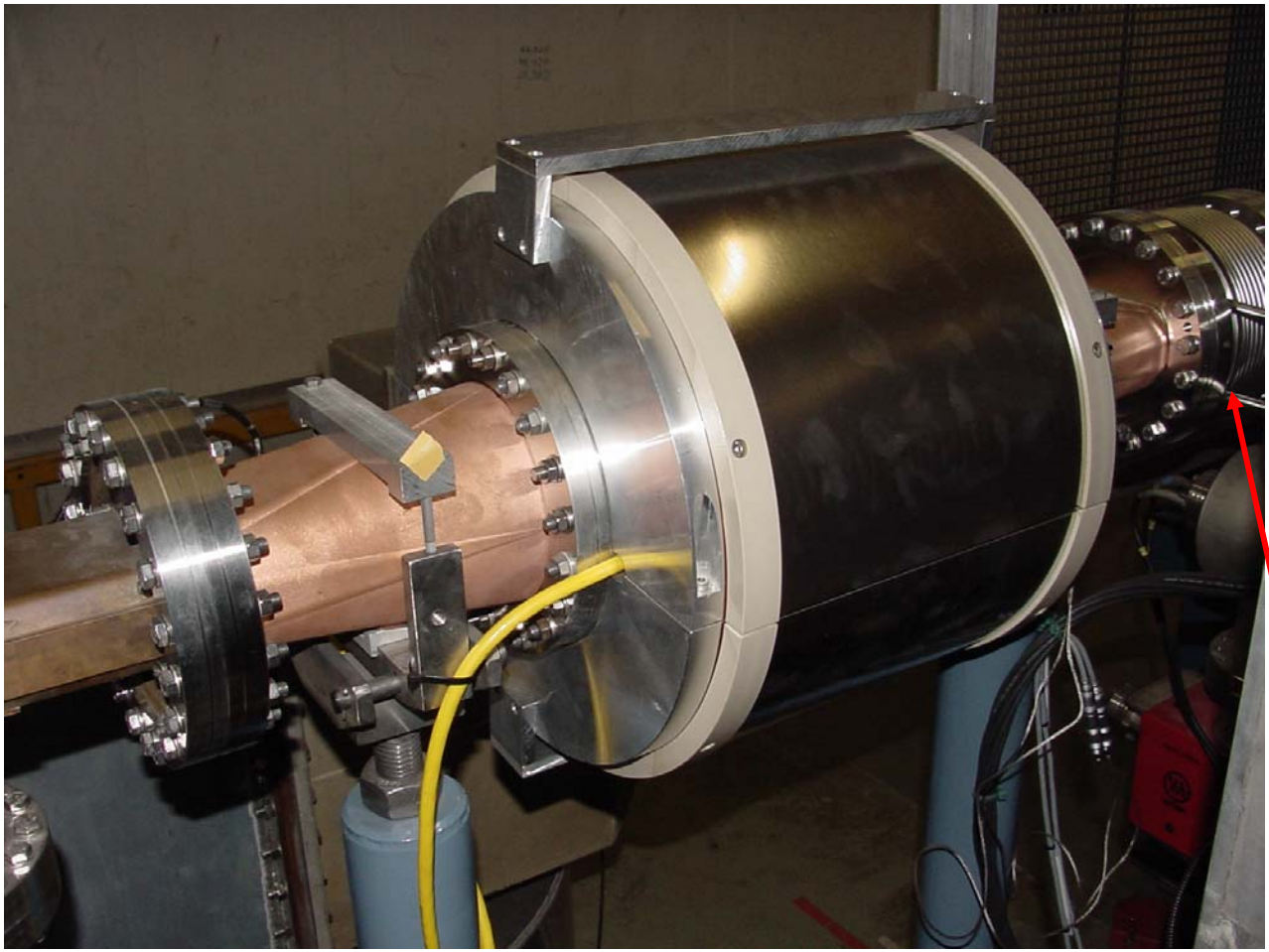
Motivation

For proper simulation of temperature distributions one has to verify that the simulation tool (here CST) gives correct results.

Here a component is chosen (current monitor at DORIS) which already is in use and temperature sensors are installed

Setup

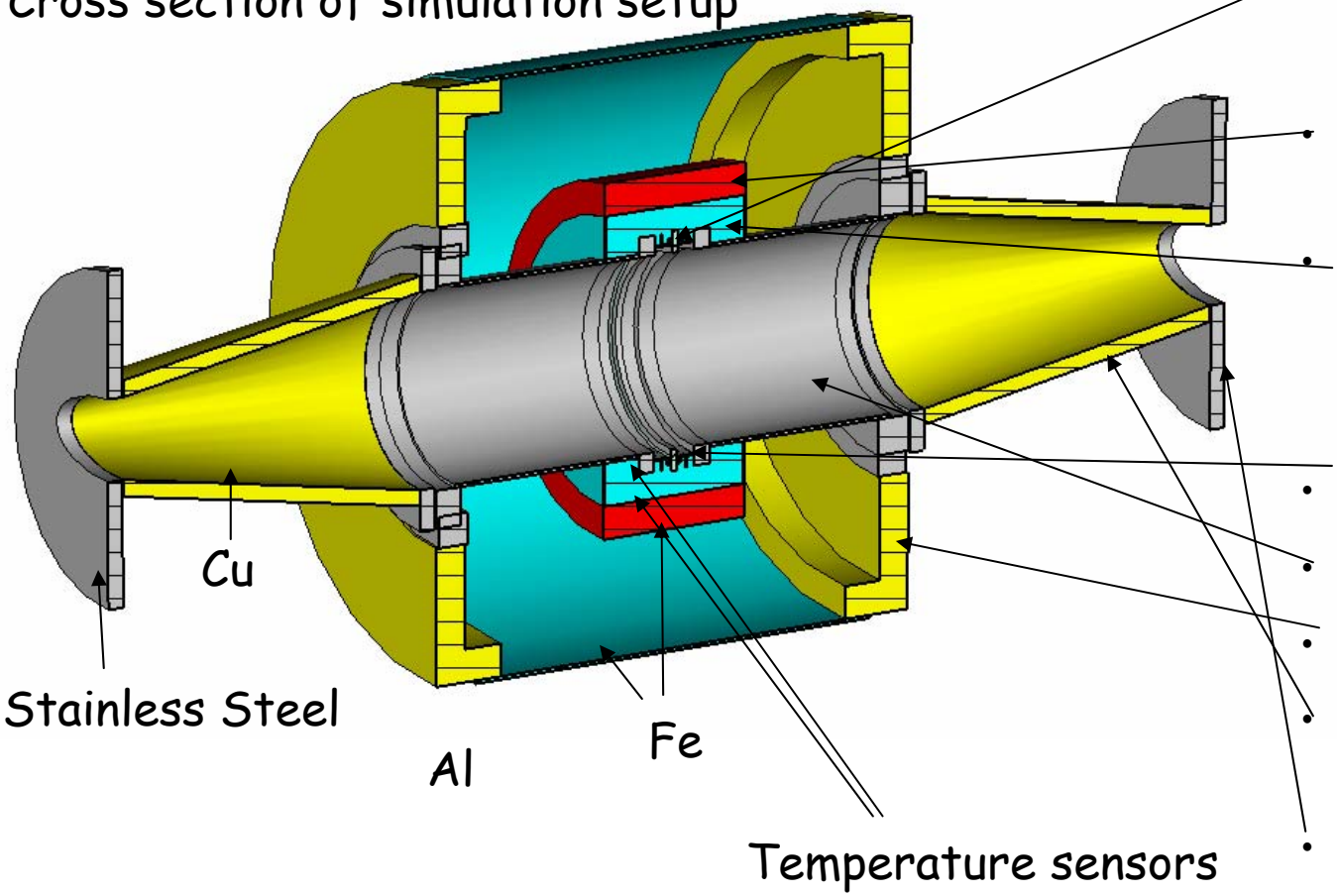


Components:

- Isolator for out-coupling the field of the bunch
- Coil for monitoring the field strength
- Heat isolator between coil and tube with two temperature sensors
- Bellow for isolator
- Tube
- Shielding of coil
- Vacuum connectors to neighbor tubes
- Cooling at one neighbor tube bellow

Setup: Simulation

Cross section of simulation setup



Components:

- Isolator (Al_2O_3) for out-coupling the field of the bunch
- Coil (Fe) for monitoring the field strength
- Heat isolator glass wool between coil and tube with two temperature sensors
- Bellow for isolator
- Tube
- Shielding of coil
- Vacuum connectors to neighbor tubes
- Cooling at one neighbor tube bellow, cooling temperature 25°C

Power Loss of Beam

$$P = I\ q\ k_{loss}$$

$$I_{DORIS,\max} = 140\ mA$$

$$q = 27\ nC$$

Determination of loss factor k_{loss}:

- simulation of eigenmodes, calculation of loss per dominant eigenmode (frequency domain)

or

- beam loss due to wakefields (time domain)

First possibility failed because eigenmodes are not visible, therefore wakefields are simulated

With bunch length of σ_z = 19.5 mm the loss due to the current monitor is 12.35 V/nC

This results in a power loss of 46.7 W

(Important for simulation: all materials involved and in touch with vacuum have to be defined correctly.)

Heat conductivity and radiation

Used heat conductivity:

Material	Heat conductivity / W/(Km)
Stainless Steel	15
Al	237
Al_2O_3	18
Cu	401
Glass wool	0.04
Fe	80
μ-metal	80

Used heat radiation emission compared to ideal black body

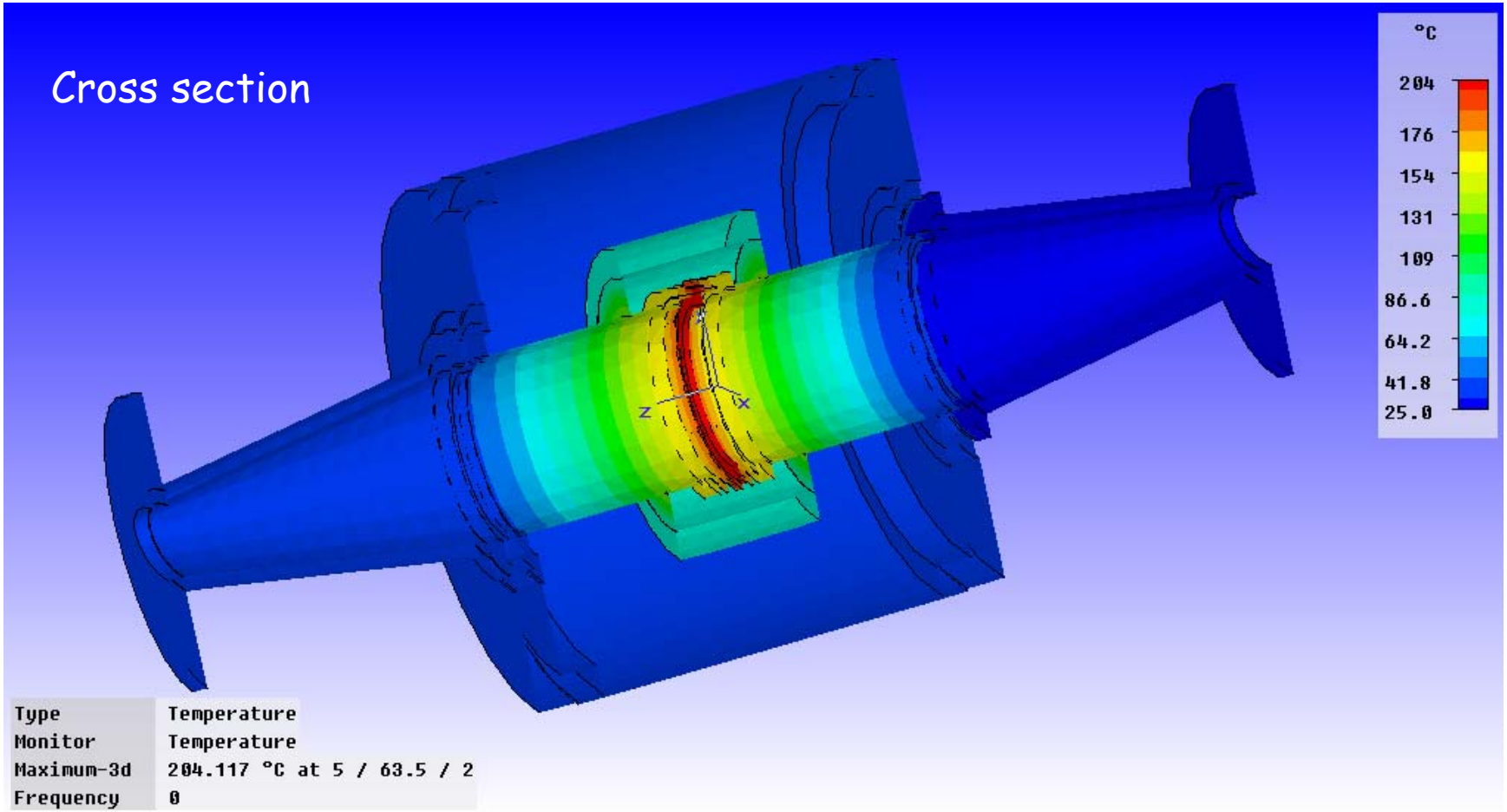
Material	Emission
Stainless Steel	0.1
Al	0.04
Cu	0.03
Fe	0.2
μ-metal	0.2

Only for materials with large surfaces

Setting the temperature simulation

1. Identify cooling position and cooling temperature, extend simulation up to this position; fix temperature only at this boundary, other boundaries without heat flow
2. Identify all components and corresponding material and set heat conductivity
3. Set heat radiation emission at surfaces; consider coatings of materials
4. Include power on the position where it is lost
5. Problem with CST simulation package: vacuum has zero heat conductivity, this results in non stable simulation without message; has to set to a small finite number

Simulation of Temperature Distribution



Temperature at sensors: T=156°C, T=84°C;

T_{max} = 204°C

Measurement of Temperature

At 140 mA the temperature sensors gives 180 and 103°C

Compared to simulation the measured temperature is higher by about 20°C

Temperature difference between both sensors are almost equally to simulation, this indicates that heat conductivity and emission are set correctly

The higher measured temperature indicates that either the calculation of the power loss gives a too low value, or more contributions of power: e.g. flange with gap of 3 mm results in 4 W, but temperature impact only 2 degrees, other contributions: synchrotron radiation …

Summary

Verification of temperature for current monitor at DORIS:

- Collected design
- Copied model in CST
- Simulation of power loss with wakefield, Eigenmode simulation failed
- Setting and performing the temperature simulation
- Compared with measurement 20 degrees lower simulation temperature: more power contributions will increase temperature; but results are comparable!