Measurement Items and Methods

TP, NO, PP

What will we learn from facilities?

- One task for the Cryogenics is to revise heat load estimations and, more importantly, to address the issue of errors and uncertainties, in order to better determine the required overall overcapacity of the plant
  - **needed for cooldown and off-nominal operation**
- Besides new estimations, what can come from the facilities?

1.4.1.	Heat loads	The heat load to the entire cryogenics system is investigated under static and dynamic conditions. Static, dynamic, and distribution system loads are considered, including tolerances and uncertainties. Overall uncertainty factors and cryoplant sizes are re-evaluated.	Peterson (FNAL), Ohuchi (KEK), Pierini (INFN), Petersen* (DESY)

ILC cryogenic system priorities for a low-level of effort

- Experimental and analytical reassessment of not only total static and dynamic heat at each temperature level but also the uncertainty factors which should be applied. These parameters have a direct impact on cryoplant sizes and cryogenic system cost estimate.
  - **Note that the relatively small input coupler adjustment described above, mostly at the 5 K level, resulted in nearly a 5% effect on cryogenic plant power.**
- Integration of the cryogenic plant cycle with cryomodule cooling should be studied. Temperature and pressure levels in cryomodules, particularly in the thermal shields, should be evaluated in the context of the full process through the cryoplants. These results may affect cryomodule design via optimized temperature and pressure levels.

from Tom, Chicago meeting

Design optimization

Plug-compatible and Cost reduction

Thermal design (based on TTF-type III)

- Thermal performance of the components
  - Thermal intercepts
  - RF cables
  - Input couplers (Tesla type, KEK type)
  - Quadrupole package and BPM
- Evaluation of heat loads at 31.5 MV/m
- Temperature profile in the module
  - Module design with or without 5K shield
  - Cooling scheme in the cryomodule

Mechanical design

- Assembly process and tooling
- Alignment method

Tests and measurements

Cold test of cryomodule with or without 5K shield at KEK-STF

CM1 at FNAL-NML
S1-Global at KEK-STF

Dynamic heat load measurements at FLASH

Design of ILC proto-type
Type IV or V at FNAL
STF2 module at KEK

from Norihito

CMTB/FLASH

- DESY has information from past experience of most module loads for the XFEL
  - **Plant is finalized…**
  - **Measured loads consistent with estimations**
- CMTB/FLASH includes measurement
  - **mass flows, temperatures and pressures in the cryogenic circuits at the feed/end boxes of the module/string**
  - **possibility of placing few temperature sensors on shields in CMTB**
- Measurement only of integral loads, including “end” effects

TTF Cryomodule Performances

							Status:15-Sep-04 R.Lange -MKS1-			
Designed, estimated and measured static Cryo-Loads TTF-Modules in TTF-Linac										
Module	40/80 K [W]			4.3K [W]			2 K [W]			Notes
Name/Type	Design	Estim.	Meas.	Design	Estim.	Meas.	Design	Estim.	Meas.	
Capture			46,8			3,9			5,5	Special
Module 1 I	115.0	76.8	90.0 *	21.0	13,9	23.0 *	4,2	2,8	6,0 *	Open holes in isolation
Modul1 rep. I	115.0	76.8	81,5	21.0	13,9	15,9	4,2	2,8	5,0	2 end-caps
Modul 2 II	115.0	76.8	77,9	21.0	13,9	13.0	4,2	2,8	4,0	2 end-caps
Module 3 II	115.0	76.8	72.0 **	21.0	13,9	48.0 **	4,2	2,8	5,0 *	Iso-vac 1E-04 mb, 2e-caps
Module 1* II	115.0	76.8	73.0	21.0	13,9	13.0	4,2	2,8	<3.5	1 end-cap
Module 4 III	115.0	76.8	74	21.0	13,9	13.5	4,2	2,8	<3.5	1 end-cap
Module 5 III	115.0	76.8	74	21.0	13,9	13.0	4,2	2,8	<3.5	1 end-cap
Module SS	115.0	~76.8	72.0	~21.0	~13.9	12.0	~4.2	>2,8	4,5	Special, 2 end-caps
Module 3* II	115.0	76.8	75	21.0	13,9	14	4,2	2,8	<3.5	1 end-cap
Module 2* II	115.0	76.8	74	21.0	13,9	14,5	4,2	2,8	<4,5	2 end-caps
Module 6 EP	Type III, EP-Cavities Goal:Solution close to XFEL Modules									(Assembly End-04??)
	Design and estimated values by Tom Petersen 1995 -Fermilab-							Modules under Test in TTF2-Linac		

~ 70 W

~ 13 W

< 3.5 W

STF

- Plans for STF are to distinguish different sources of heat load contributions, not only integral effects
  - **Thermal tests of Module-B with and without 5 K shield**
  - **Instrumentation of Module-A and C during S1-Global testing**
    - to allow static and dynamic load inventory

Test plan of 5K shield performance in STF

Target : making the effect of 5K shield on the heat load at 2K clear (heat load measurement at 2K with and without the 5K shield)

1. 4 dummy helium vessels as same size as the cavity jackets are installed in the STF-Module-B.
2. No input couplers.
3. The outer shield (80K) is cooled by LN_2, and the inner shield (5K) is cooled by LHe.
4. The average temperature of outer shield is estimated to be 86.5 K. At the temperature, the difference between the heat loads at 2K with and without 5K shield is calculated to be 1.14 W.

Test schedule of 5K shield

- 6/2009: heat load measurement of Module-B with 5K shield
- 7-8/2009: disassembling Module-B, removing 5K shield bridge and reassembling Module-B in the tunnel
- 9-10/2009: heat load measurement of Module-B without 5K shield

from Norihito

Measurements of cryomodule thermal characteristics (static and dynamic conditions)

- Heat loads of the system
  - Heat load at 2K
    - Evaporation of 2K LHe
      - Mass flow rate, Pressures and Temperatures at cavity jacket and pump discharge
  - Heat load at 5K
    - Temperature rise after stopping flow of 5K helium to the 5K shield
      - Temperatures of 5K shield
  - Heat load at 80K
    - Temperature rise after stopping flow of liquid nitrogen to the 80K shield
      - Temperatures of 80K shield
- Heat loads of the components
  - Thermal calculation of the measured temperature profile in the components
    - Temperatures of the components
      - Input couplers, Support posts, Thermal anchors, Thermal shields, RF cables
- Cool-down effect on the cavity alignment
  - Measurement of the cavity-jackets and GRPs positions during cool-down by WPMs

from Norihito, bi-weekly MTG

List of temperature sensors (Module-C)

Cernox	(calibrated from 1.4K to 100K)	PtCo	(from 4K to 300K)	CC thermocouples	(from 70K to 300K)
#1 Cavity	Helium Vessel	#1 Cavity	Helium Vessel	#1 Cavity	80K thermal anchor of input coupler
	Connection area of input coupler with beam pipe	#2 Cavity	Helium Vessel		80K thermal anchor of input coupler close to cooling pipe
	5K thermal anchor of input coupler	#3 Cavity	Helium Vessel		Warm input coupler connection flange
	HOM coupler in the input coupler side-top	#4 Cavity	Helium Vessel	#2 Cavity	80K thermal anchor of input coupler
	HOM coupler in the input coupler side-bottom	5K Shield	0 degree in the side of valve box		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the non-input coupler side-top		90 degree in the side of valve box		Warm input coupler connection flange
	HOM coupler in the non-input coupler side-bottom		180 degree in the side of valve box	#3 Cavity	80K thermal anchor of input coupler
	Piezo		270 degree in the side of valve box		80K thermal anchor of input coupler close to cooling pipe
#2 Cavity	Helium Vessel		90 degree at fixed support post		Warm input coupler connection flange
	Connection area of input coupler with beam pipe		180 degree at fixed support post	#4 Cavity	80K thermal anchor of input coupler
	5K thermal anchor of input coupler		270 degree at fixed support post		80K thermal anchor of input coupler close to cooling pipe
	HOM coupler in the input coupler side-top		0 degree at shield center		Warm input coupler connection flange
	HOM coupler in the input coupler side-bottom		90 degree at shield center	Fixed support post	80K anchor at the 0 degree
	HOM coupler in the non-input coupler side-top		180 degree at shield center		80K anchor at the 180 degree
	HOM coupler in the non-input coupler side-bottom		270 degree at shield center		Room temp. area
	Piezo		90 degree at movable support post	Movable support post	80K anchor at the 0 degree
#3 Cavity	Helium Vessel		180 degree at movable support post		80K anchor at the 180 degree
	Connection area of input coupler with beam pipe		270 degree at movable support post		Room temp. area
	5K thermal anchor of input coupler		0 degree in the side of module-C	80K Shield	0 degree in the upstream side
	HOM coupler in the input coupler side-top		90 degree in the side of module-C		90 degree in the upstream side
	HOM coupler in the input coupler side-bottom		180 degree in the side of module-C		180 degree in the upstream side
	HOM coupler in the non-input coupler side-top		270 dgree in the side of module-C		270 degree in the upstream side
	HOM coupler in the non-input coupler side-bottom	Fixed support post	5K anchor at the 0 degree		0 degree in the center
	Piezo		5K anchor at the 180 degree		90 degree in the center
#4 Cavity	Helium Vessel	Movable support post	5K anchor at the 0 degree		180 degree in the center
	Connection area of input coupler with beam pipe		5K anchor at the 180 degree		270 degree in the center
	5K thermal anchor of input coupler	GRP	Connection area to the fixed support post		0 degree in the downstream side
	HOM coupler in the input coupler side-top		Connection area to the movable support post		90 degree in the downstream side
	HOM coupler in the input coupler side-bottom				180 degree in the downstream side
	HOM coupler in the non-input coupler side-top				270 degree in the downstream side
	HOM coupler in the non-input coupler side-bottom			Beam pipe	Position inside of 80K thermal anchor
	Piezo			GRP	Upstream-top (valve box connection side)
GRP	Upstream-top (valve box connection side)				Upstream-bottom (valve box connection side)
	Upstream-bottom (valve box connection side)				Center-top
	Center-top				Center-bottom
	Center-bottom				Downstream-top (module-C connection side)
	Downstream-top (module-C connection side)				Downstream-bottom (module-C connetion side)
	Downstream-bottom (module-C connection side)				
Beam Pipe	Position inside of 5K thermal anchor				

CERNOX: Total 39
- Four cavities : 32
- GRP : 6
- Beam pipe : 1

PtCo: Total 28
- Four cavities : 4
- 5K shield : 18
- Support posts : 4
- GRP : 2

CC: Total 37
- Four cavities : 12
- Support posts : 6
- 80K shield : 12
- Beam pipe : 1
- GRP : 6

>100 T sensors/module

from Norihito, bi-weekly MTG

Pressure sensors, etc

Pressure Sensors			
GRP	CM-A	Ablsolute pressure sensor (Hitachi)	0~27kPa
	Connection pipe between CM-A and CM-C	Ablsolute pressure sensor (Hitachi)	0~27kPa
	CM-A	Ablsolute pressure sensor (Baratron)	0~13.3kPa
	CM-A	Pressure sensor	-0.1MPa~0.1MPa
2K Cold Box	4K LHe vessel	Pressure sensor (Hitachi)	-0.1MPa~0.5 MPa
	2K LHe vessel	Ablsolute pressure sensor (Baratron)	0~13.3kPa
	5K shield return gas line (cold)	Pressure sensor (Hitachi)	-0.1MPa~0.5 MPa
5K shield piping	5K shield return gas line (room temperature)	Pressure sensor	-0.1MPa~0.5 MPa
Pump system	Pump discharge pressure	Pressure sensor	-0.1MPa~0.5 MPa
Vacuum vessel	CM-A	CCG	
	CM-A	Pirani gauge	
Mass flow meter			
Pump system	Pump discharge	Volume flow meter	0~65 Nm3/h
	Pump discharge	Volume flow meter	0~10 Nm3/h
5K shield piping	5K shield return gas line (room temperature)	Volume flow meter	0~65 Nm3/h
Temperature sensor			
2K Cold Box	4K LHe vessel	Cernox, PtCo	1.5K~40K, 4K~300K
	2K LHe vessel	Cernox	1.5K~40K
Pump sytem	Pump discharge (near mass flow meter)	CC	80K~320K
5K shield piping	5K shield return gas line(near mass flow meter)	CC	80K~320K
LHe level sensor			
2K Cold Box	4K LHe vessel	Superconducting level sensor (AMI)	
	2K LHe vessel	Superconducting level sensor (AMI)	

from Norihito, bi-weekly MTG

NML: CM1 instrumentation

<table>
<tr><th>Proposal</th><th>Primary Objective</th></tr>
<tr><td>

COOLDOWN T-SENSORS

<u>Thermal Shields</u>
2 CERNOX at bottom of 5 K shield, 2 Pt at bottom of 80 K shield

<u>GHe Return Pipe</u>
Preferred: Install 14 Platinum RTDs on the outside wall of GHe Return Pipe (as specified in T. PetersonÕs note of 8/27/07)

Minimum: 2 CERNOX at lower middle GHe return pipe, 3 CERNOX at each end, inside the pipe, wires coming out of feed and return box.

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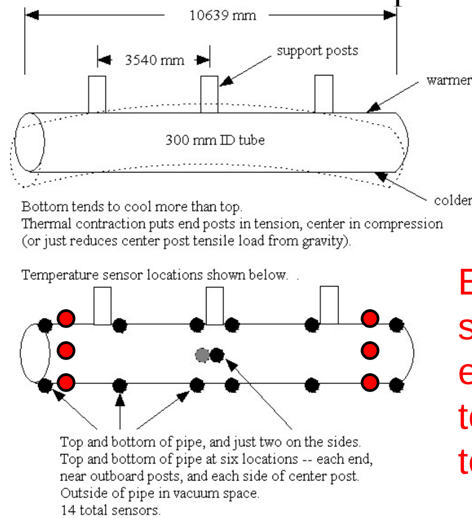
Control Top-to-Bottom thermal gradient in 300mm GHe return tube to avoid stress to post supports



Ended up with six sensors, three at each end, on inside of pipe, to detect vertical temperature gradient

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COOLDOWN STRAIN GAUGES

Install a total of 5 Strain gauges: 3 axial on column supports 1, 2, & 3; 1 transverse on the 5K shield and 80K shield at the fingers.

</td><td>

The results of this test are to validate the stress model on cool down with the goal of optimizing the cool down rate.

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HOM T-SENSORS

Install one CERNOX RTD on each HOM coupler, 16 total

</td><td>

To monitor the temperatures of the HOM cavity couplers.

26 sensors

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</table>

from Tom

Comments on CM tests

- Goal of instrumentation in single cryomodule operation is observation and control of cool-down and warm-up
- We do not expect to measure heat loads accurately with a single cryomodule
  - **End effects dominate, such as thermal radiation into the cryomodule from the ends**
  - **We will monitor total system conditions but will not be able to attribute heat specifically to the cryomodule**
- LN2 (2-phase) on the 80 K thermal shield in NML will limit the ability to measure that heat load

from Tom, bi-Weekly MTG

Comments on CM tests -- 2

- Measurement of 2 K heat via boiloff rate may miss heat entering above liquid level
  - **Such as support posts to 300 mm tube**
- With three cryomodules in NML we may have a better measurement of heat loads on the central CM
  - **But of course an even longer string (more than three) would provide a better heat load signal**
- Goal of CM1 test is quite basic -- cool down to 2 K and operate a CM with RF and a good accelerating gradient (my opinion)
  - **Commission the NML system**

from Tom, bi-Weekly MTG

Discussion

- How do we take out end effects from single module measurements?
- How precise we can estimate the module load without waiting for the test of longer cryomodule strings?
- What are the uncertainties and error bars of these measurements?

More items

- WPMs:
  - **Long experience at DESY with INFN system, which is still used in the modules being constructed for the new vendor qualification**
  - **Later talk by HH for KEK-STF WPM system**
- Instrumented transports
  - **CM1 transport in FNAL**
  - **M8 transport from HH-Paris and back**
  - **ACC39 transport FNAL-HH (soon)**
- Other?