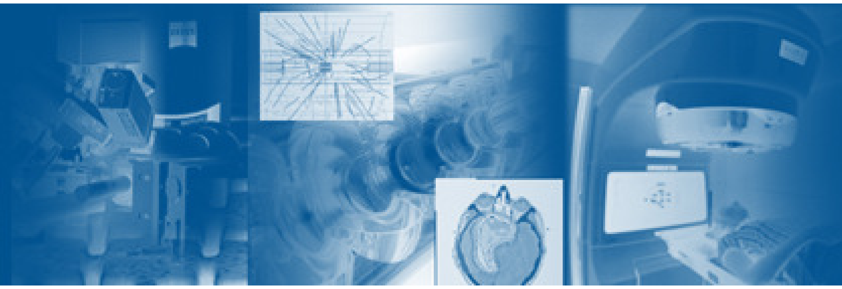
Accelerator Research and Development (ARD)



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PT1: SC RF Technologies

Generic R&D related to superconducting RF technologies for electron and hadron accelerators

Hans Weise / DESY , ***for the PT1 Team***

Pushing SRF limits

continuous wave, low losses, high current

PT1 Activities
continuous wave, low losses, high current

Continuous wave (cw) operation – cavities and components

- Development of components needed for cw operation of superconducting accelerator modules using state-of-the-art cavities
- Develop key aspects/components for high-current CW SRF
- 100-mA class accelerators L-Band structures / HOM waveguide dampers

Single-crystal multi-cell cavities and samples:

- R&D towards realization of single-crystal multi-cell cavities
- Production of single-crystal samples to be made available for coating experiments.

Understanding Niobium and new superconductors:

- Trapped flux studies / Properties of thin films on single crystal samples.
- Development of surface coating techniques to be used for cavities.

Introduction…
CW operation of XFEL modules

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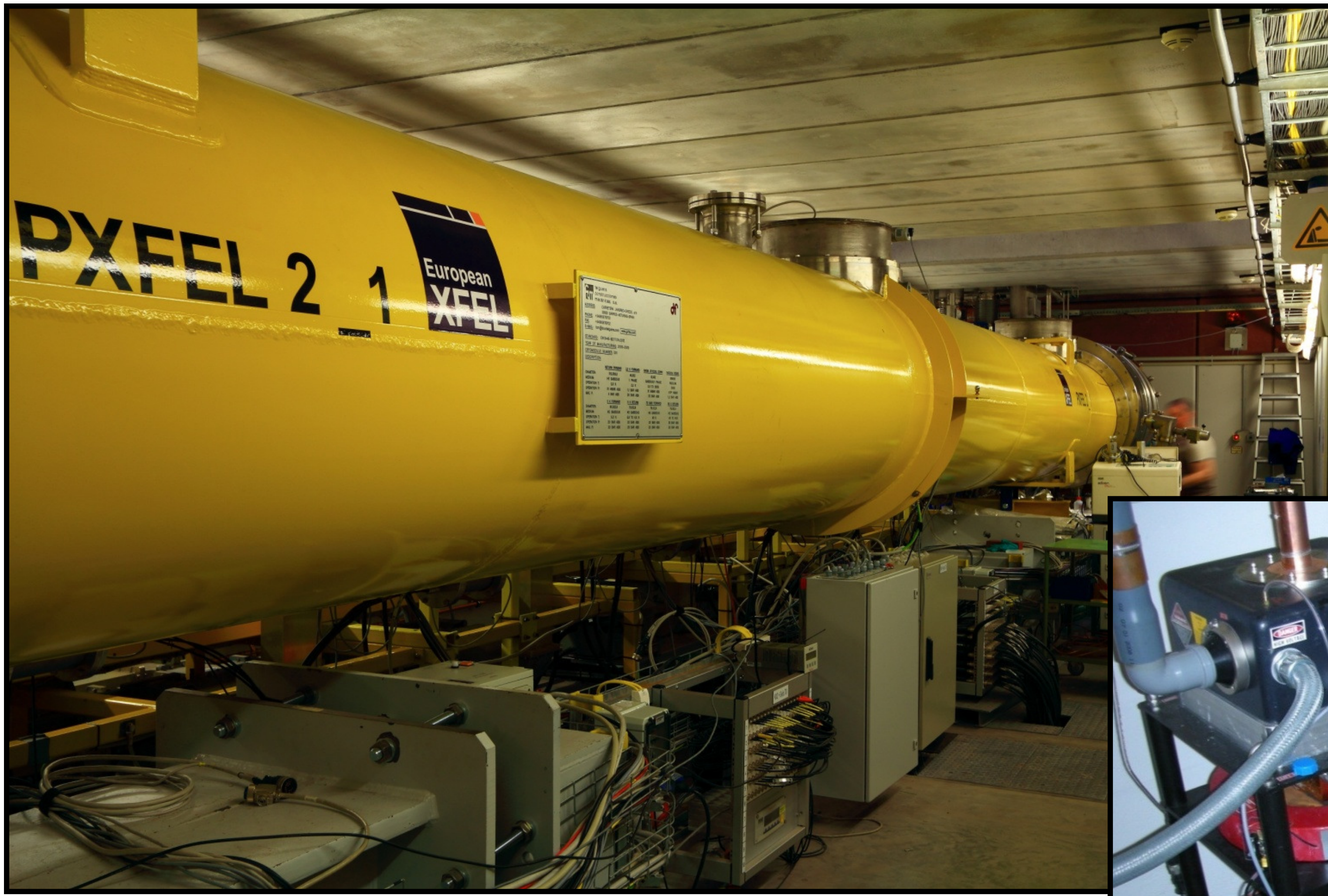
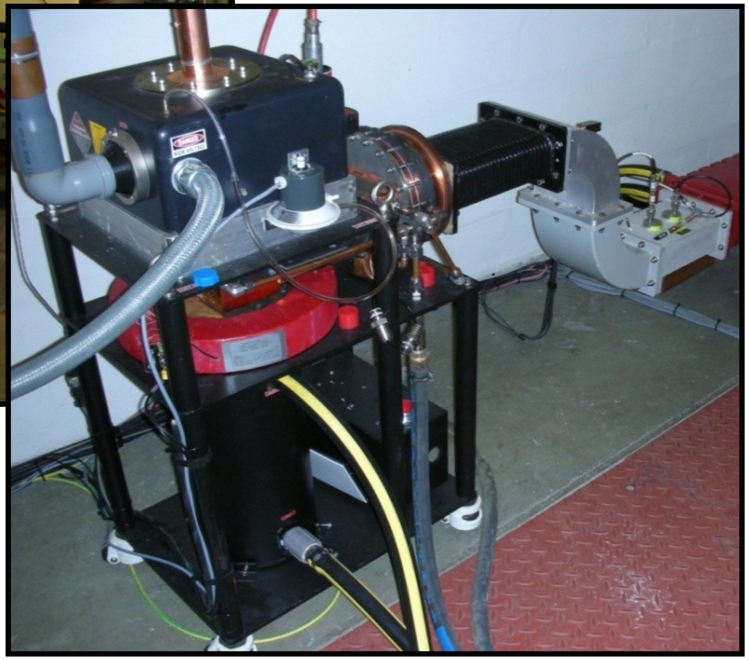


First successful test in June 2011.



- Overall performance of PXFEL 2_1
- Heat load at 2 K / 1.8 K

Cryomodule PXFEL2_1 Performance
A first long run at moderate gradient…

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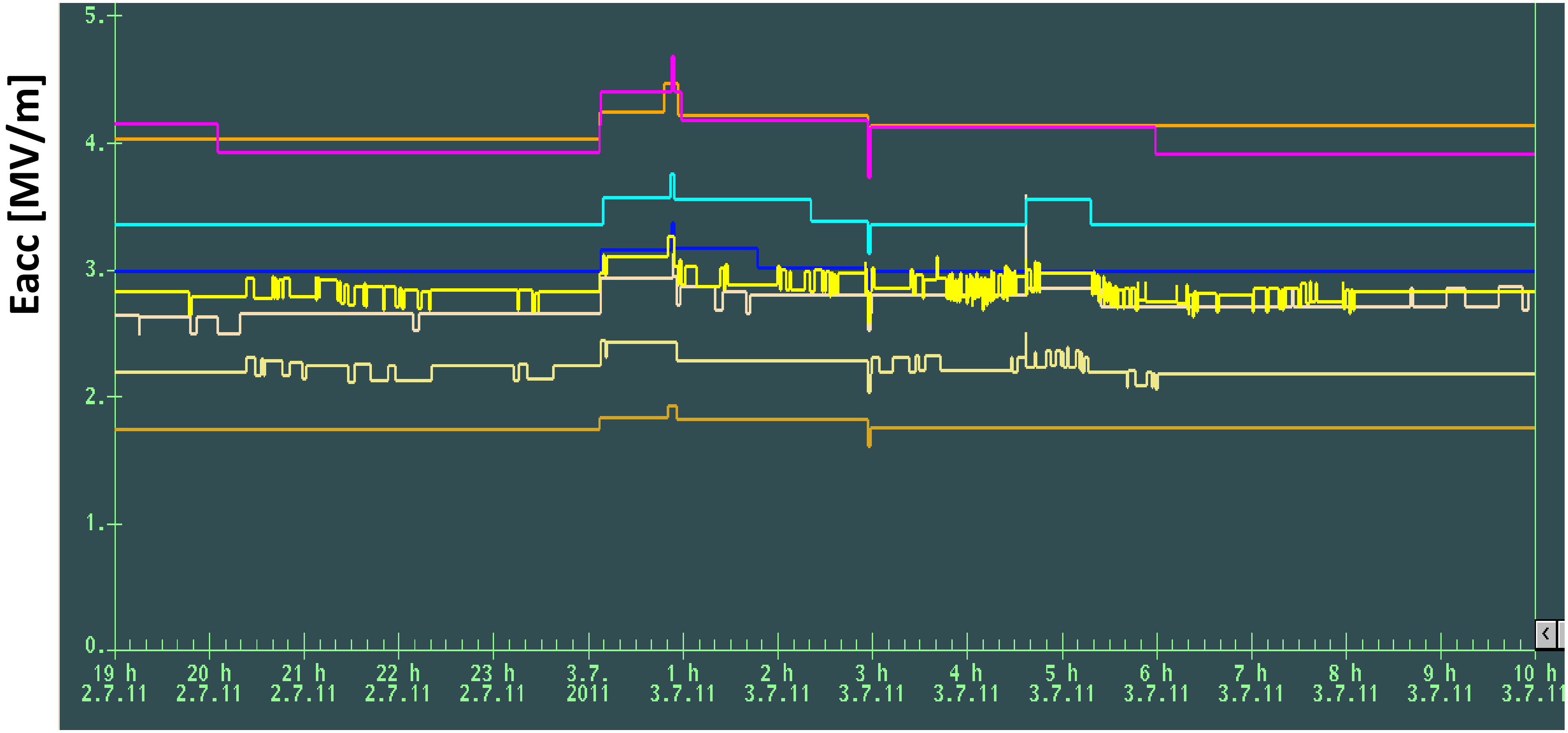
The longest run (**15 h**) with stable conditions:

- no LLRF (6 cavities with 81Hz resonance width)
- no frequency control
- no special measures for the cryo-stabilization (36 Hz/mb)



Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011

"CW and LP Operation of the XFEL-type Cryomodule; second test" J. Sekutowicz, W.-D. Möller

Cryomodule PXFEL2_1 Performance

Heat load measurements

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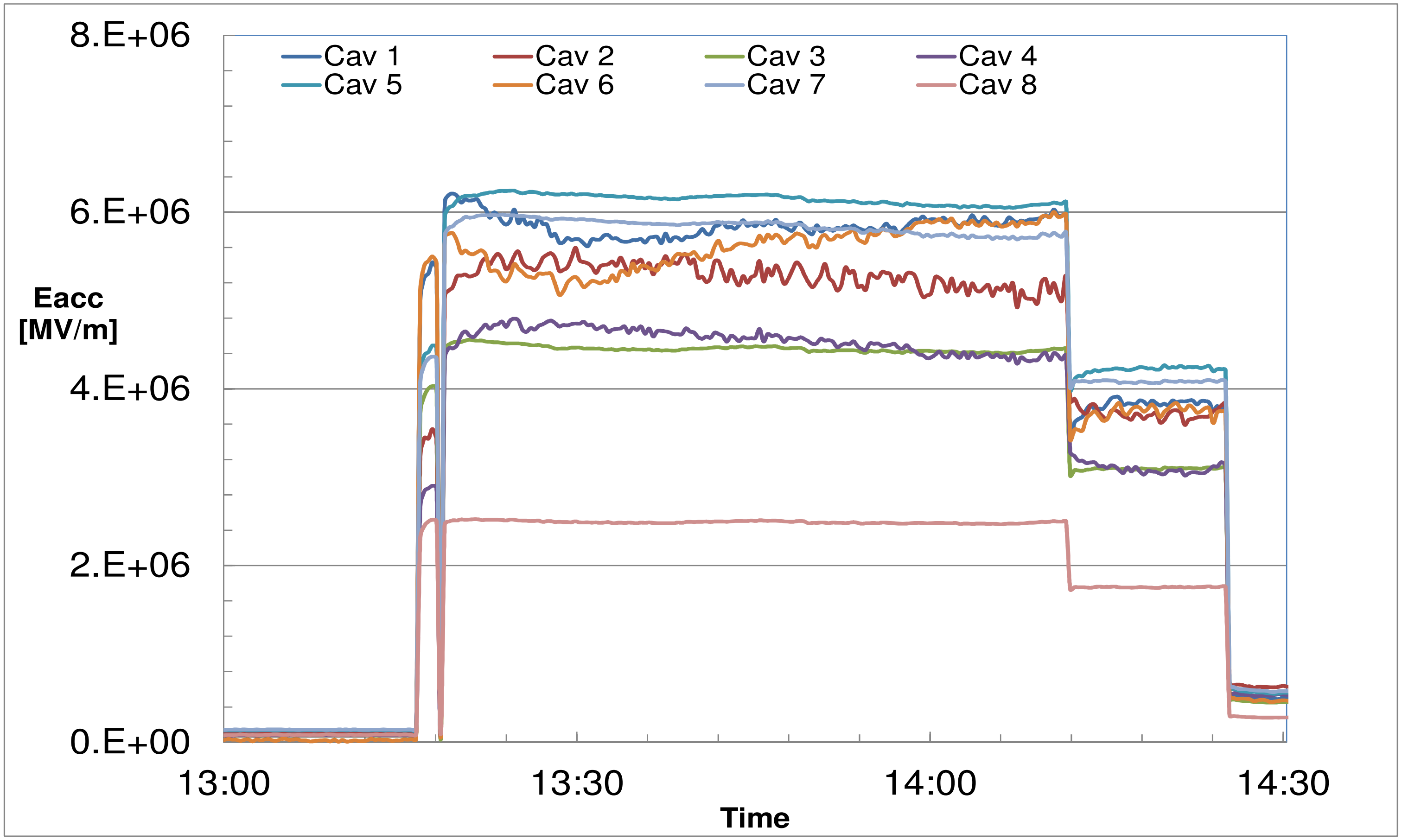
Heat load measurements at 2K for cw (~1h, June 30th, 2011):

- no LLRF
- no special measures for the cryo-stabilization



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Cryomodule PXFEL2_1 Performance
Heat load measurements

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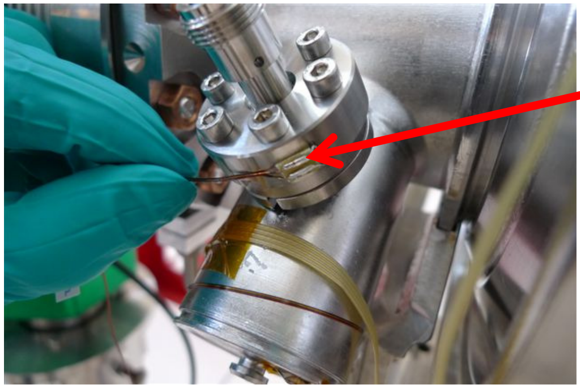
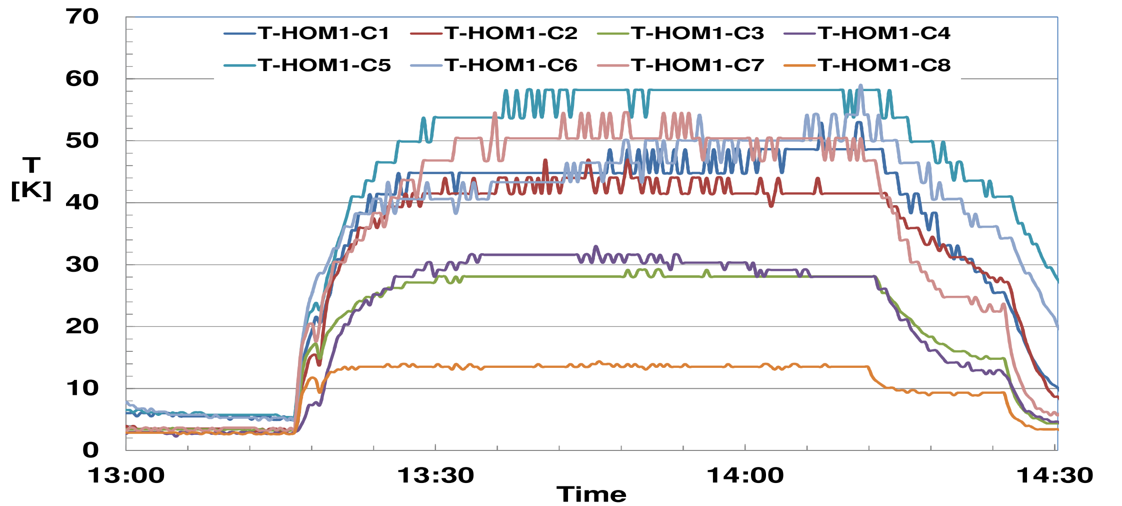
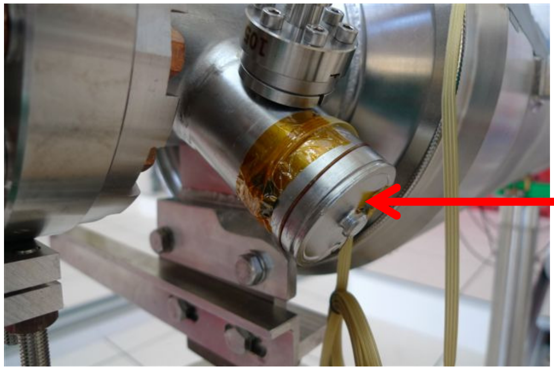
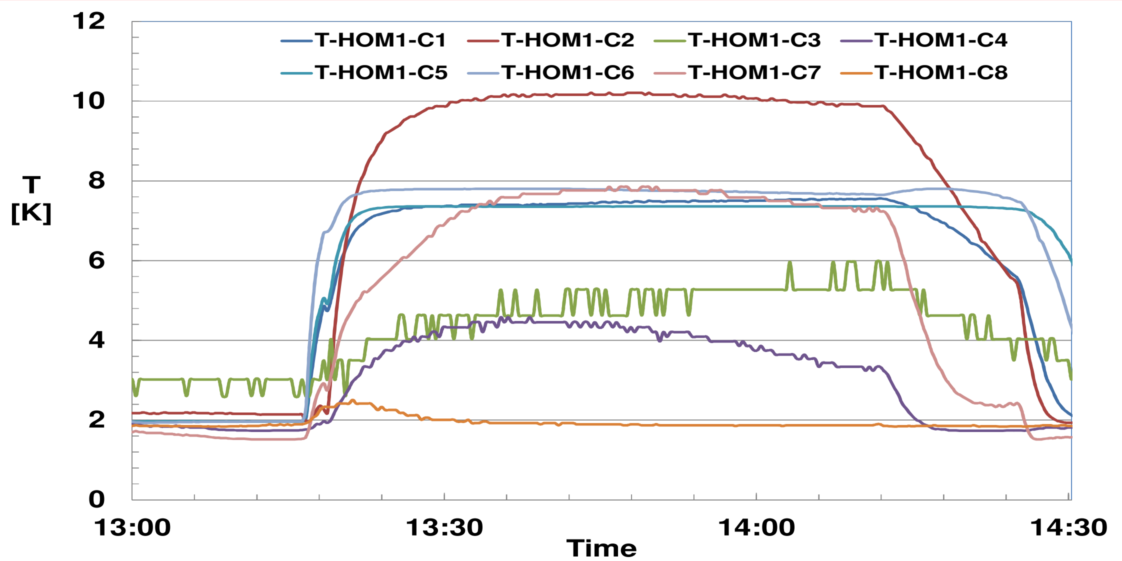
cw heat load measurements at 2K (~1h, June 30th, 2011):









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Heat load measurements

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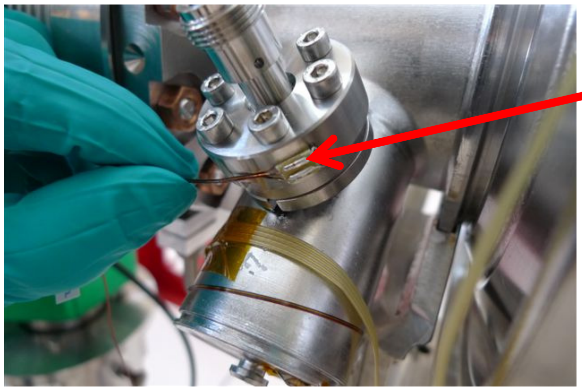

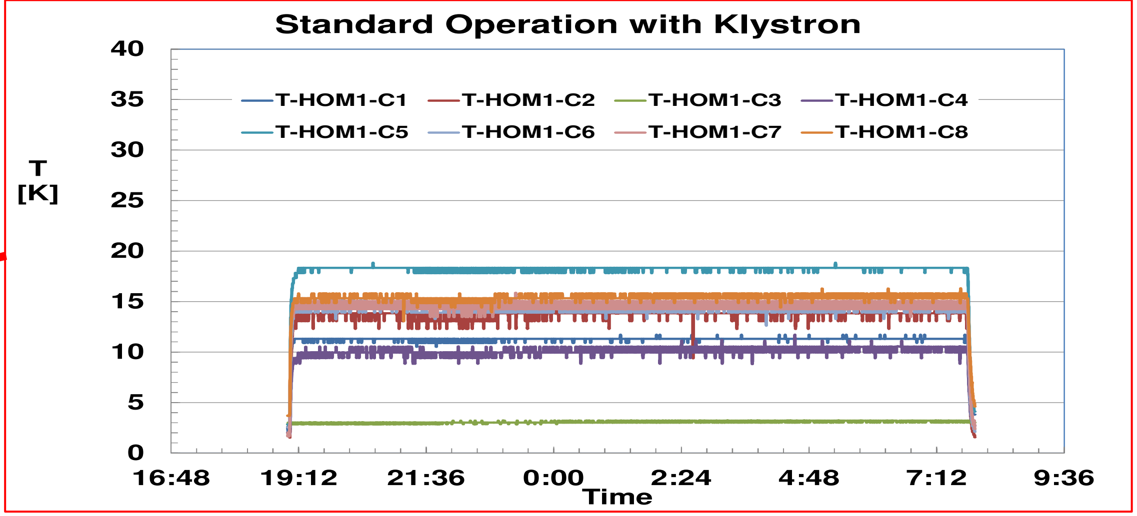

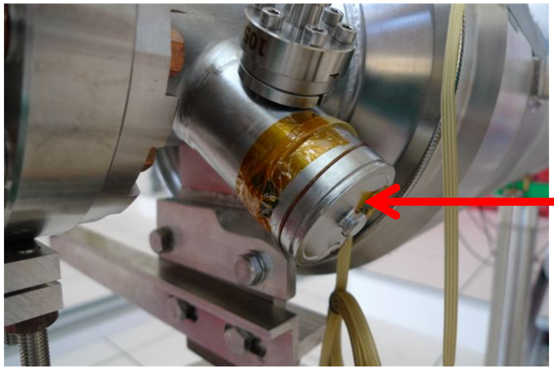

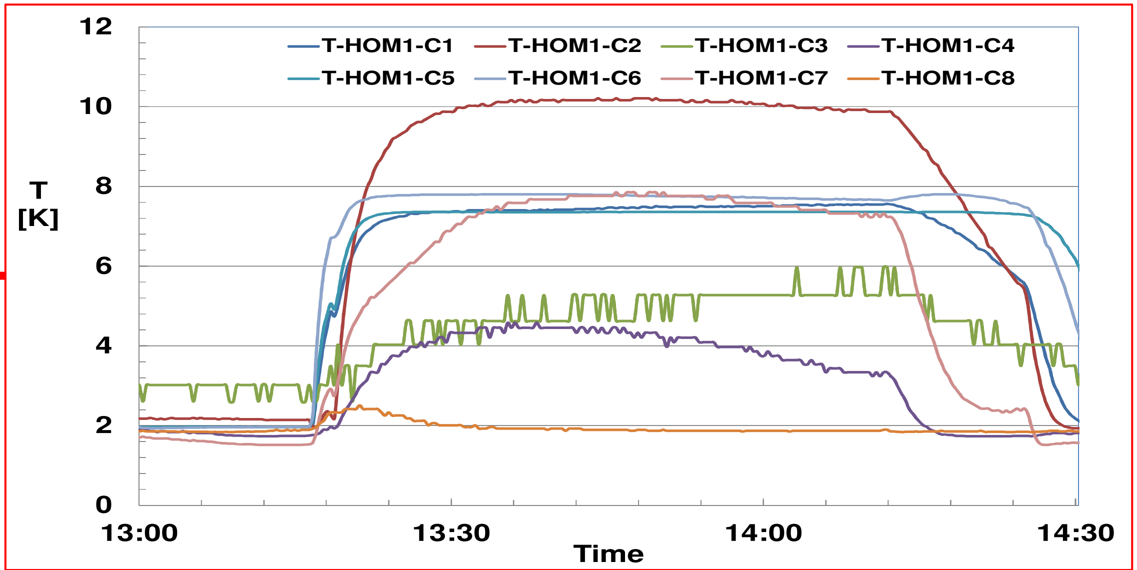

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"CW and LP Operation of the XFEL-type Cryomodule; second test" J. Sekutowicz, W.-D. Möller

Cryomodule PXFEL2_1 Performance
Heating of HOM antenna

Heat load measurements at 2K for cw (~1h, June 30th, 2011):

Summary:

1. No observable T change of LHe bath (vessels) for all 8 cavities, no quench..
2. At 2 K 18% (5/27) of the total heat was very probably due to the heating of the HOM antennae (~0.3W/antenna)
3. At 1.8 K almost no additional heat.

<Gradient >	Total Heat at 2K	Dynamic Heat at 2K	Estimated (Qo=1.5E10) Dynamic Heat at 2K	ΔDH
[MV/m]	[W]	[W]	[W]	[W]
5.3	27	20.8	16.0	~5

<Gradient>	Total Heat at 1.8 K	Dynamic Heat at 1.8 K	Estimated (Qo=3.5E10) Dynamic Heat 1.8 K	Comment
[MV/m]	[W]	[W]	[W]	
3.3	9.3	2.6	3.1	**No additional heat**

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"CW and LP Operation of the XFEL-type Cryomodule; second test" J. Sekutowicz, W.-D. Möller

Second Test with PXFEL3_1
Improved HOM feedthrough cooling

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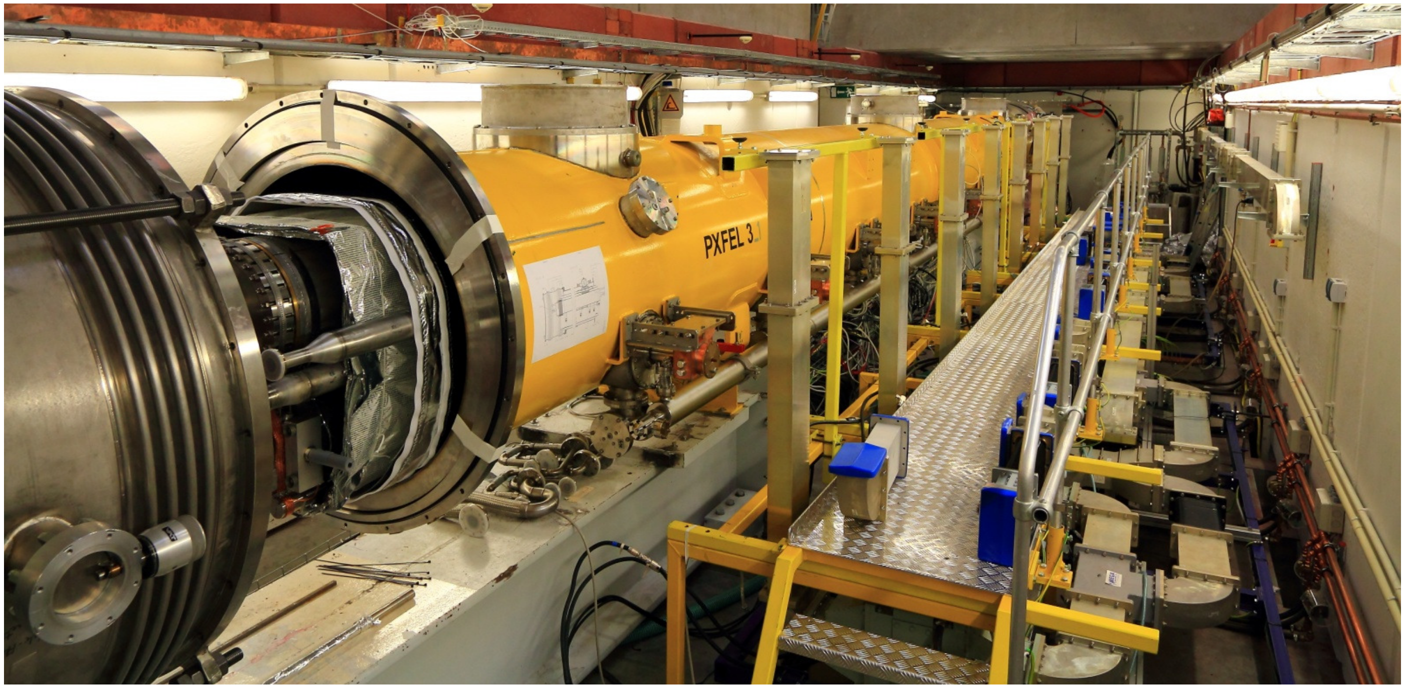
- further investigation towards cw and long pulse operation with the next cryomodule, PXFEL3_1, under better thermal conditions:
  - 5 out of 8 cavities have <u>high thermal conductivity HOM feedthroughs</u>
- test of new generation <u>LLRF (µTCA)</u> and new electronics driving the piezos



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"CW and LP Operation of the XFEL-type Cryomodule; second test" J. Sekutowicz, W.-D. Möller

Second Test with PXFEL3_1
Objectives for the 12/2011 test

Objectives:

Having more experimental time, we want to:

1. learn more about the HV power supply and the IOT
2. measure stability, amplitude and phase, of the vector sum
3. map the function max(Eacc) vs. DF at 1.8 K and 2 K
4. measure precisely the heat load at 1.8 K and 2 K
5. verify the functionality of µTCA and new piezo electronics in cw and long pulse operation modes for cavities with Qext in the range of 1.5E7 to 2.5E7

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"CW and LP Operation of the XFEL-type Cryomodule; second test" J. Sekutowicz, W.-D. Möller

Pushing SRF Limits - cw

Improved 1.3 GHz HOM F-part

Motivation

•The TESLA HOM couplers were originally designed in 1992 for pulse-operations with very low duty factors <1%.

•They have been placed outside LHe vessel to reduce the cost of cavities for the TESLA collider.

• Avoiding the warming up of TESLA-like HOM couplers in cw and long pulse operations is of great interest for future applications of the TESLA cavities.

•In collaboration with JLab we have developed a version of the HOM coupler, which antenna is marginally exposed to the magnetic flux and thus the heating of antenna is significantly reduced.

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"HOM coupler with hidden antenna" J. Sekutowicz, W.-D. Möller

Pushing SRF Limits

Improved 1.3 GHz HOM F-part

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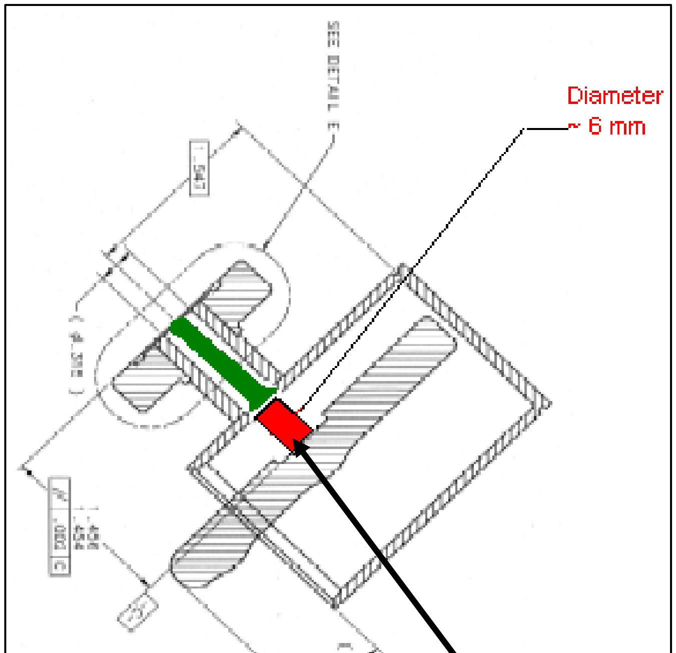
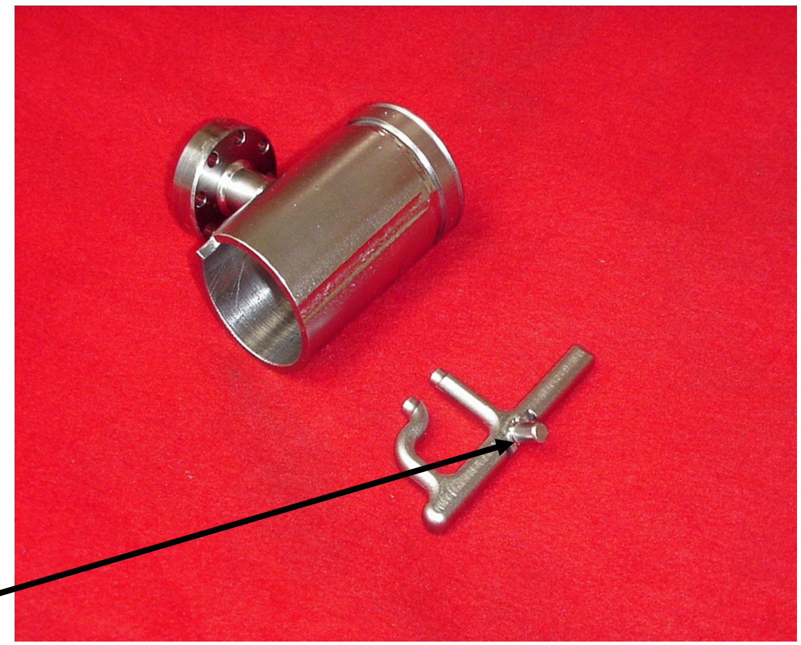
Modification of the DESY HOM coupler to allow for dedicated XFEL like cw modules.





Third inductance post allowing for antenna to be retracted

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
“HOM coupler with hidden antenna” J. Sekutowicz, W.-D. Möller

Pushing SRF Limits

Improved 1.3 GHz HOM F-part

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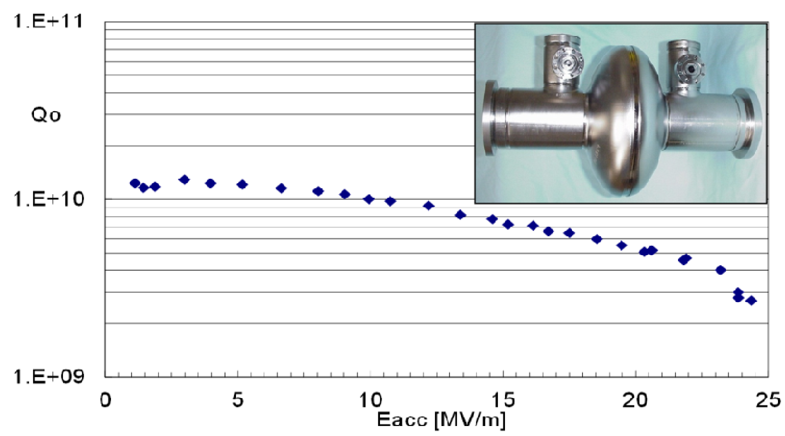
The prototype coupler has been tested on 1.5 GHz one-cell cavity and it performed well up to 25 MV/m.

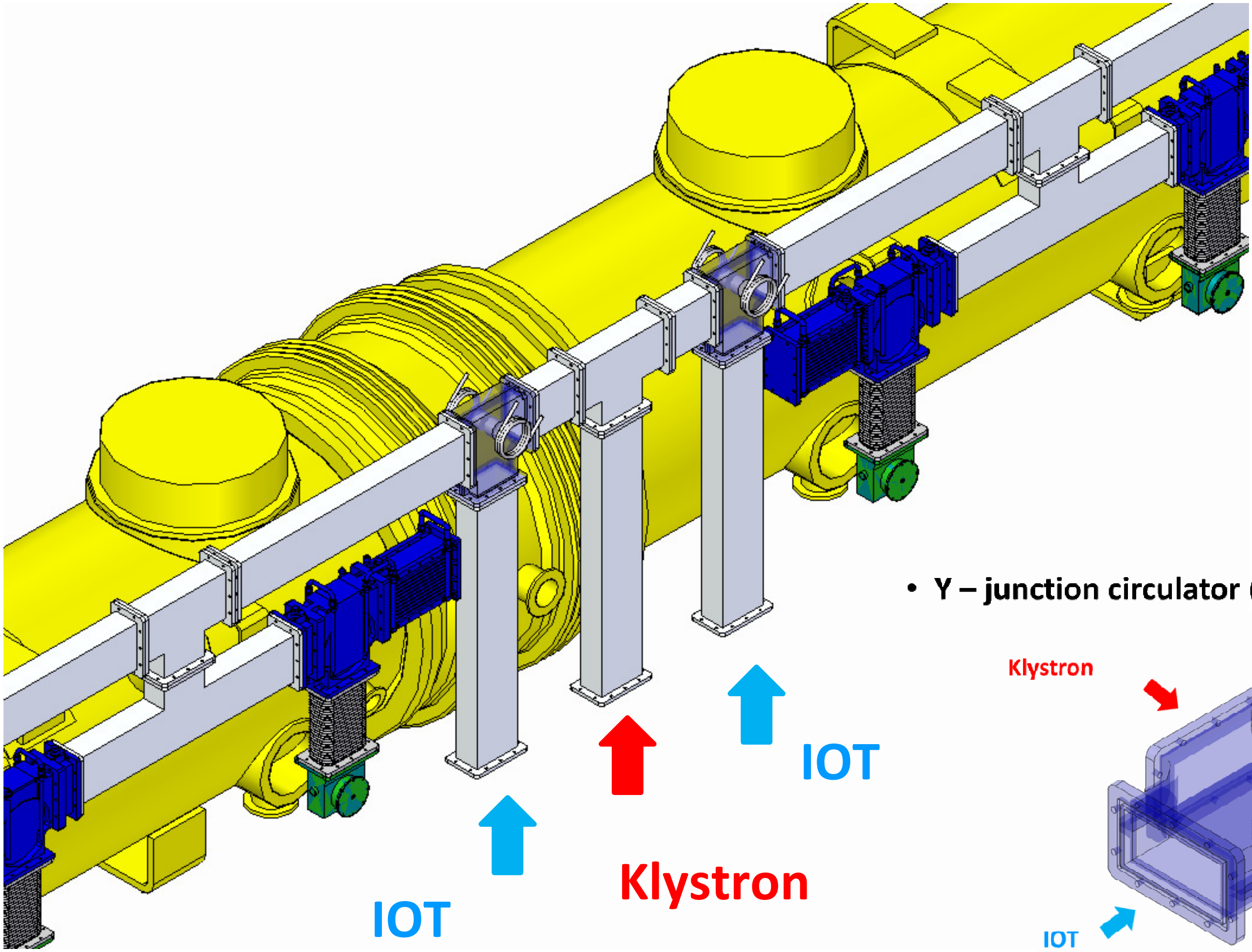


We propose a cryogenic test of the new HOM couplers on a 9-cell cavity to investigate

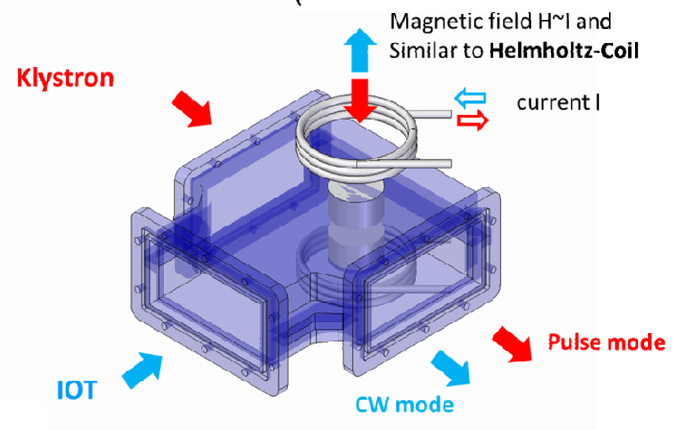
1. their performance for the fundamental mode
2. Multi-pacting phenomenon
3. damping of HOMs of the standard 9-cell cavity
4. cleaning procedures

Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"HOM coupler with hidden antenna" J. Sekutowicz, W.-D. Möller

Pushing SRF Limits
Power Ferrite Waveguide Switch



- **Y – junction circulator** (similar FLASH circulators)



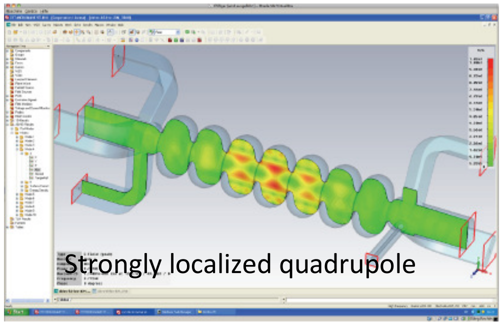
Slide taken from Beschleuniger Ideenmarkt III, DESY, 13/14 -09- 2011
"Power Ferrite Waveguide Switch" R.Brinkmann, S.Choroba, J.Kahl, V.Katalev

For 100-mA class accelerators L-Band structures are attractive

- 1.3 GHz for many ERLs
- 1.3 GHz for compact sources (e.g., TBONE)
- 1.25 or 1.75 & 1.5 GHz for BESSY VSR short pulse options (storage ring)
- Both types of systems operate with little beam loading but at high current

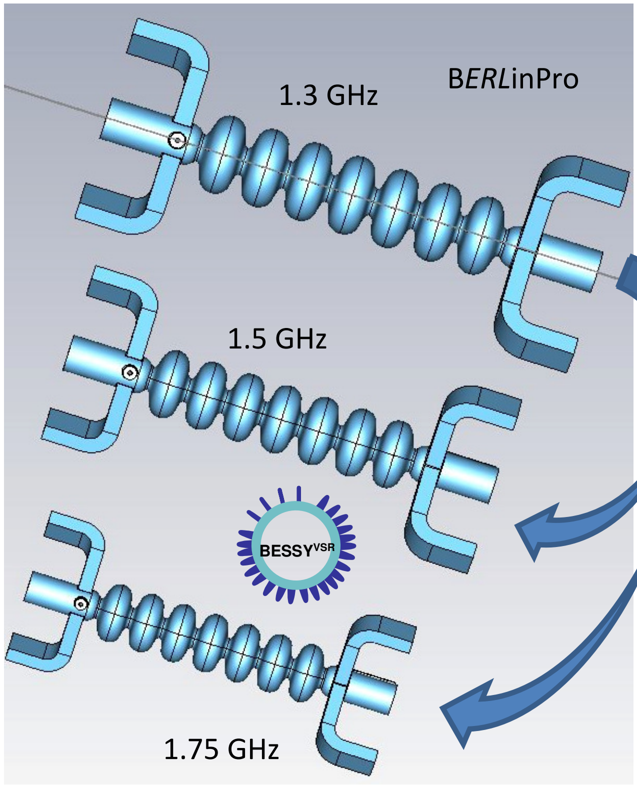
Design cavity for low HOM generation

- Trapped modes critical



Design HOM waveguide dampers

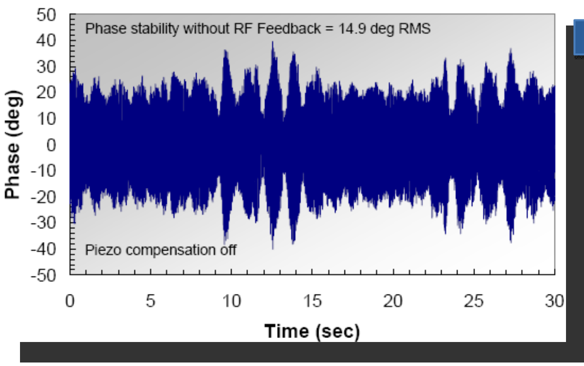
- Rejection of fundamental, broad band
- Operate in cold
- Filling factor maximized
- Robust …



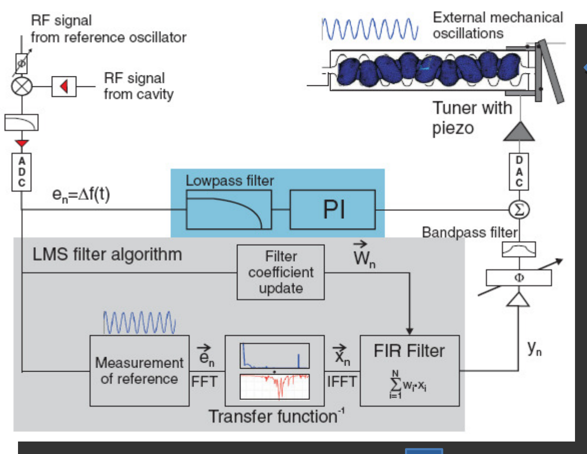
Use design for other frequencies

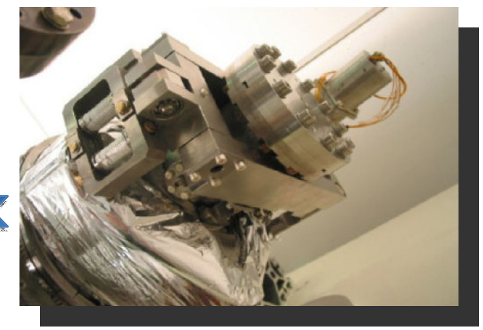
Study various aspects RF system for robust/efficient CW operation

- Long-term operation of 10-20 kW CW transmitters (solid state), noise studies
- LLRF systems for cavity control, feedback/feedforward
- Reduction of microphonics to minimize required RF power & improve stability

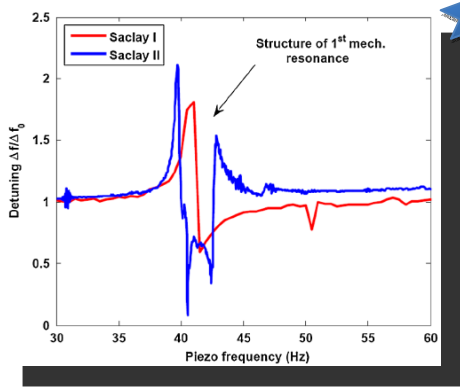


Original noise

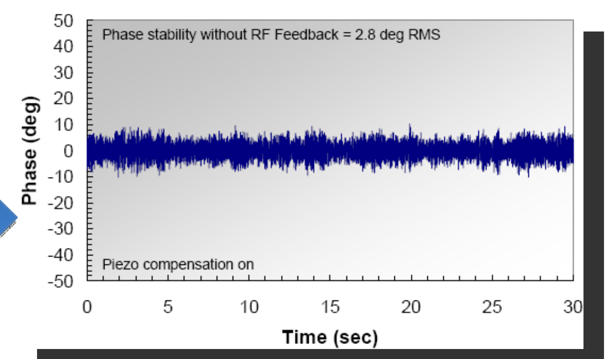




Tuner equipped with fast piezo elements



Measured transfer function
Resonances play a critical role



Reduced noise due to compensation

Pushing SRF Limits – DESY Schedule
CW operation of an XFEL Accelerator Module

Planning for cw operation ACC, single crystal and thin SISI layer coating activities at DESY

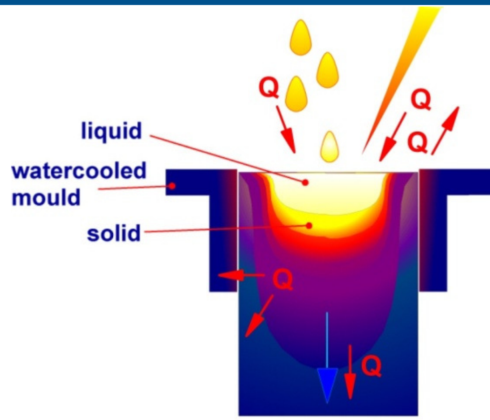
Programme: 'pushing SRF limits'		program period I					program period II				
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	**cw operation ACC**										
1.1	**R&D for RF used for XFEL module CW operation**										
1.1.1	R&D and purchase (at industry) of improved IOT usable for XFEL CW operation										
1.1.2	R&D and purchase of improved IOT power supply										
1.1.3	Purchase of IOT pre-amp										
1.1.4	RF-control hardware										
1.1.5	R&D for CW RF-control firmware										
1.1.6	Demonstration of full availability of RF used for XFEL module CW operation										
1.2	**Test of improved 1.3 GHz HOM f-part at 9-cell cavity**										
1.2.1	manufacturing of 9-Zell single crystal or large grain cavity with new HOM f-parts										
1.2.2	vertical test										
1.2.3	dressing the cavity										
1.2.4	horizontal test										
1.3	**Prototype module, single crystall 9-zell with new HOM f-parts for cw operation**										

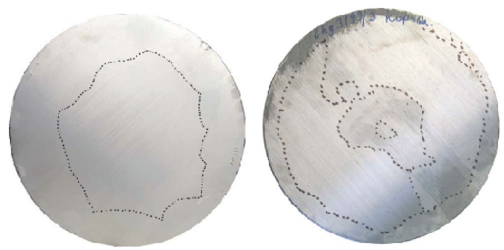
1.1 XFEL module cw operation

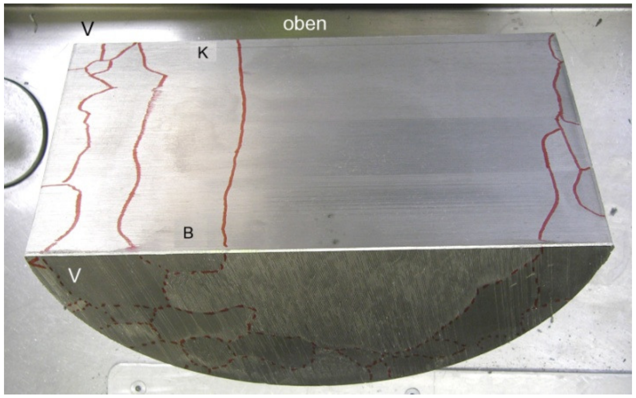
1.2 Improved 1.3 GHz HOM F-part at 9-cell cavity

1.3 Prototype cw module, single crystall 9-cell with new HOM F-parts (PoF III)

Pushing SRF Limits
Single crystal multi-cell cavities







DESY / W.C. Heraeus collaboration on large grain material

Grain boundaries (GBs) in niobium cavities may be one of the important causes of extra power dissipation by reducing the field of first vortex penetration because the superconducting gap and the local depinning current density Jb on the GB are reduced.

Positive experience

- several large grain ingots were produced
- large grain crystals are growing in axial direction

Still disappointing

- transition phase from start crystal to continuously growing crystal is critical
- quite a few of the well prepared start crystals were destroyed
- not a really stable process
- no reproducible growth of the required 150 mm diameter central grain

Pushing SRF Limits - Schedule

Single crystal multi-cell cavities and substrate samples

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Planning for cw operation ACC, single crystal and thin SISI layer coating activities at DESY

Programme: 'pushing SRF limits'		program period I					program period II				
		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	cw operation ACC										
...											
2	Single crystal multi-cell cavities and substrate samples										
2.1	R&D for single crystal Nb ingot manufacturing with defined crystal orientation										
2.2	R&D for manufacturing multi-cell single crystal cavities with defined crystal orientation										
2.3	Provision and characterization of single crystal sample material with defined crystal orientation										
2.4	Provision of single crystal cavities										
...											
3	Thin SISI layer coating										
...											

2. Single Crystal multi-cell cavities and substrate samples

2.1 Ingot with defined crystal orientation

2.2 multi-cell cavity

2.4 Provision of single crystal cavities during PoF III period

Pushing SRF Limits
Lowest dynamic losses

Goals

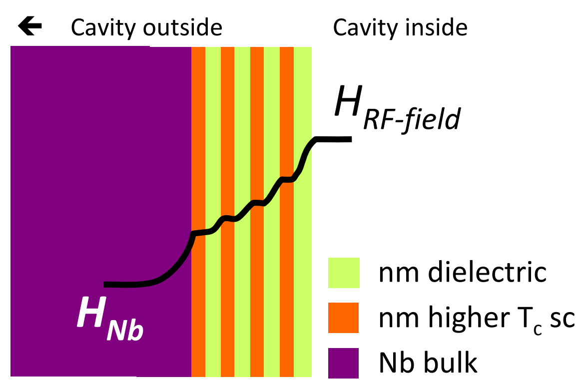
- Understand residual losses in niobium operating around 20 MV/m
- Find alternative sc material for use in SRF cavities

Roadmap: Start with samples

- Develop high-surface-resistance-resolution sample test stands
- Study losses in niobium following various treatments
- Find partners for sample production of new SC (e.g., Saclay, CERN, IPJ Swierk)
- Investigate possible candidates: e.g., Nb_3Sn, NbTi, MgB_2
- Investigate multilayer coatings on Nb (Gurevich 2006) that screen the external magnetic field and prevent vortex dissipation
- Investigate flux trapping

Apply lessons learned to cavities

- Optimize treatment, material, operating conditions for niobium
- Collaborate on coating techniques for cavities



Thin layer coating – DESY Schedule
A proposal to be aligned with HZB plans

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Planning for cw operation ACC, single crystal and thin SISI layer coating activities at DESY

Programme: 'pushing SRF limits'		program period I					program period II				
		2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
3	**Thin SISI layer coating**										
3.1	**Catching up to the actual worldwide comprehension of the subject**										
3.2	**SISI layer deposition**										
3.2.1	Inquiry of suitable layer deposition methods										
3.2.2	Forming suitable collaborations for layer depositions										
3.2.3	Setup of apparatuses at DESY										
3.2.3.1	Evaluation centrifugal barrel polishing apparatuses										
3.2.3.2	Purchase of centrifugal barrel polishing apparatus										
3.2.3.3	R&D of apparatus for cavity coating										
3.2.3.4	setup or purchase of apparatus for cavity coating										
3.2.4	Application of the layer deposition methods at samples										
3.2.5	Coating single cell cavities										
3.3	**Surface and layer examination**										
3.3.1	Inquiry of suitable surface and layer examination methods										
3.3.2	Forming suitable collaborations										
3.3.2	Setup of apparatuses at DESY										
3.7	Application of the surface and layer examination methods										
3.4	**Examination of the SRF properties of layer coated samples**										
3.4.1	Using single crystal samples with different crystal orientations as substrates										
3.4.2	Using polycrystalline samples as substrates										
3.4.3	Varying the SISI layer composition and thickness										
3.5	**Coated single cell cavities**										
3.5.1	Surface treatment of coated cavities										
3.5.1.1	R&D on surface treatment methods for coated cavities										
3.5.1.2	Setup of surface treatment methods										
3.5.1.3	Surface treatment of coated cavities										
3.5.3	Surface examination of coated cavities										
3.6	**Examining the SRF properties of SISI coated single cell cavities**										
...											

Clearly a view into the future

Timeline for planned HZB activities

Program period 1

Sample & cavity testing

- Installation of necessary infrastructure for cavity/sample preparation: 2011 – 2012
- Test facilities for cavities and samples: 2012 – 2013

CW losses

- Study dynamic losses in Nb cavities: 2012 – 2013, 2015 (after sample results)
- Study of losses in niobium and thin film sample: 2013 – 2017

CW RF

- CW optimized LLRF system with microphonics compensation: 2013 – 2015
- 10 kW+ class CW SS amplifiers optimization for low noise: 2013 – 2015

High current structures/cryomodule

- Prototype L-Band high current design with WG HOM absorber: 2011 – 2013
- Integration of final design in cryomodule: 2014

Program period II

- Beam tests of module with SRF photoinjector (see talk P. Michel for injector): 2015
- Contingent upon additional funding: Design/production/commissioning of modified module for BESSY VSR system for short pulses in BESSY II (see talk A.-S. Müller): 2015 – 2019

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