# **Industrial Study** Of **FLASH Module Production**

Supported by EUROFEL Design Study DS6

Co-operation with BESSY

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all the work is done by: **ACCEL and BABCOCK NOELL companies** many DESY colleagues: MVP, MHF-sl, MEA..... Axel Matheisen & MKS3 crew Kay Jensch, Rolf Lange & MKS1 crew





#### The European X-Ray Laser Project X-Ray Free-Electron



- About ,FLASH' cryomodules
- ,Generic' TESLA-style cryomodule design
- Our general goal
- Cryomodule prototypes at DESY (what we have)
- Industrial cryomodule assembly studies
- Prototype ,cold masses' call for tender
- Test facilities
- Summary



## **About FLASH cryomodules**

## FLASH = Free Electron-LASer in Hamburg

History : TESLA Test Facility -> TTF1-linac -> TTF/FEL-VUV-linac -> FLASH



Installation of module 6 during 2007 shut-down

Like FLASH itself the cryomodules fulfill ,multi-purpose' functions:

- FLASH operation
- development for XFEL-linac
- development for FEL-light sources (BESSY FEL, EUROFELdesign)
- development for linear collider (ILC)

Industrialization of FLASH modules = Industrialization of XFEL modules





## Latest news from FLASH

#### **FLASH Reaches Design Beam Energy!** Electron beam accelerated to 1 GeV with 6 modules for the first time

Schreiber, Siegfried wrote: Dear colleagues,

today, 4-Oct-2007 at 19:25, FLASH was lasing the first time just below 7 nm.

http://ttfinfo.desy.de/TTFelog/show.jsp?dir=/2 007/40/04.10\_a&pos=2007-10-04T19:25:53



## On October 5, 2007 : lasing at 6.5 nm at 986 MeV





#### T4CM Design. The Master Spreadsheet (courtesy of FNAL) FLASH cryomodules represent the source for a 'generic' design also for the ILC





## **Our general Plan for the XFEL-Linac**

## **Order for XFEL-Cryomodules end of 2008**







#### What we have → XFEL Module is based on TESLA Type 3 Module

#### We have

- built three type 3 modules (M4, M5 and M6) M8 & M9 in progress
- well defined procedures for assembly, installation and operation
- averaged gradients for all these modules >25MV/m
- low static heat losses for all modules
- 11 thermal cycles with M6
- cavity/magnet axes and coupler antennas get/keep their expected positions
- long time operational experiences in TTF2/FLASH with M4 and M5 (4 years)
- vibration measurements inside/outside during assembly and operation
- introduced cavity fast tuning in M6





On the way to XFEL design: First step to XFEL design: Modules M8 and M9 of Type 3+

## Future prototypes to be built at DESY

(under participation of industry)

-Modules 8 and 9 of type 3+ → design close to XFEL design -Design very close to XFELmodule finished (for M10, M11 and M12) -Specifications/drawings available











All steps of the assembly procedures, in particular the assembly inside the clean room, can strongly affect the final performance of the cryomodule. The final accelerating gradients and the occurrence of dark currents are extremely sensitive to any contamination with particles caused during the assembly. Also the mounting of other equipment, like the tuners and main couplers, requires extreme care.

#### Cleanroom assembly



#### Assembly outside cleanroom







#### Industrial Cryomodule Assembly Studies: Motivation

#### EUROFEL Design Study DS6 contract No 011935

Preparation of the European XFEL-Project and other superconducting linac based FEL-light sources like the BESSY FEL

In particular, preparation of the serial production of about 100 XFEL-cryomodules for the European XFEL-Project

Input for the final design and assembly procedures for the XFEL-cryomodules

Each cryomodule consist of:

- 8 1.3 GHz 9-cell Nb cavities
- 1 magnet package

2 thermal shields

- 8 main RF couplers
- 8 cold tuners



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X-Ray Laser Project



## Industrial Cryomodule Assembly Studies



Experts from industry follow the whole assembly procedure of two prototype cryomodules at DESY

#### **Objectives:**

The present cryomodule assembly procedures and some aspects of the present design shall be analyzed and questioned with respect to the most cost effective serial production.

Key aspects of the study:

- Analyze the assembly procedure
- Analyze the final design of the modules
- Define cost-reduction measures
- Define performance improvement measures
- Supply a cost estimate for the module production





Industrial Cryomodule Assembly Studies: Prerequisites of the CONTRACTOR (key technologies)

#### MUST HAVE:

- 1) Experience of serial production of large Particle Accelerator Components.
- 2) Experience of design and construction of Cryogenic Components used at liquid helium temperatures.
- 3) The Know-How of industrial serial production at hand.

#### **SHOULD HAVE:**

- 4) Experience of applied Clean-Room Technology (10-100 ASTM)
- 5) Experience of applied Ultra-High-Vacuum Techniques (oiland particle free).
- General experience in the application of extensive and particular Low Tolerance Quality Assurance Procedures in the required fields



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#### Industrial Cryomodule Assembly Studies: Deliverables

Four reports on the specified issues:

- 1) Report on assembly of module 6 (Ready)
- 2) Report on assembly of module 8
- 3) Report on BESSY-FEL cryomodule special issues
- 4) Final report

The reports shall cover also special issues, as specified (some parts already delivered)

These reports <u>will be published</u> as part of the EUROFEL-Study *First report is already published* !

Cost issues shall be covered in separated attachments to the reports. These attachments are confidential and will not be published.











## Industrial Cryomodule Assembly Studies: first results (1)



First results on the cryomodule assembly study, based on module 6 assembly:

- general assembly procedures are suited for industrial serial production of 100 modules
- •no changes concerning the assembly are necessary
- transport of modules can be handled

Production of one module per week is possible if

The European

X-Ray Laser Project

- a redundant production line in the clean room is built
- qualtiy inspection is improved
- cleaning of individual parts is sourced out







### **ACCEL Cryomodule Assembly Study I**

S. Bauer, B. Griep, M. Pekeler, H. Vogel, J. Zeutschel ACCEL Instruments GmbH Friedrich-Ebert-Str. 1 51429 Bergisch Gladbach





# Industry Study on the Series Production of XFEL Cryomodules

#### C.Boffo, W. Gärtner, S. Sattler, G. Sikler, U.-M. Tai





#### possible solution for XFEL module transports

- transport frame is mounted on truck
- truck can be loaded with crane from top
- truck travels between assembly site and XFEL site
- available length: 13.6 m
- available width 2.5 m
- available height: 2.5 m
- allowable weight: 12 t





Caution: top loaded road semi trailer hard to find outside EU. In US only hard cover or flat bed trucks (weather impact) available.

## CM Transpo Cavity System

Which component is most critical? What is the maximal tolerable acceleration?



Determine for the typical modes of excitation :

- Zones of largest stress
- Pressures within the material
- Bending amplitudes (position and size)

-> Finite-element representation of the cavity system is necessary.

## Conclusions

**BABCOCK NOELL** 

- Maximum tolerable accelerations:
  - Support structure (made) uncritical
  - Cavity System (turned out to be) uncritical
  - vertical and axial: 1.5 g (limited by coupler)
  - lateral:  $1g = 45^{\circ}$  inclination
- Damping is necessary during truck transport
- Recording with Minishock-Sensors
- Active Control ?
- Crane Lifts ?

## Industrial Cryomodule Assembly Studies: first results (2)

#### Assembly of Module 8 has started at DESY

Clean-room assembly: has started in October 2007 Assembly out-side clean-room: November – December 2007

Industry has now an active part in the assembly.

Very important experience for DESY experts:

Transfer in both directions: Industry <->DESY

Control how transfer is received by active assembly by industry

-> feed back to specifications



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## **Pressure Vessel Code Qualification**

For the approval to operate the XFEL-linac

- a ,Certificate of Conformity' (to the european pressure vessel guidlines) is required for the XFEL-modules
- -> the european harmonized rules have to be applied
- -> the cold linac is treated as a single pressure vessel
- -> TUEV-Nord (german third party authority) has been put into charge to prepare a general procedure for the design and construction of the modules (,Baumusterzulassung')
- -> results are expected 12/2007













## **CMTB** for test of prototypes







## Summary

- Our general goal: order XFEL-modules end of 2008
- Cryomodule prototypes at DESY: participation of industry
- Industrial cryomodule assembly studies: first results
- Prototype ,cold masses' call for tender: in progress
- Test facilities: prototype test facility in operation

# THANK YOU !

