XFEL CRYOMODULE TRANSPORT: FROM THE ASSEMBLY LABORATORY IN CEA-SACLAY (FRANCE) TO THE TEST-HALL IN DESY-HAMBURG (GERMANY)

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Abstract

The one hundred, 12 m long XFEL 1.3 GHz cryomodules are assembled at CEA Saclay (F) and have therefore to be transported, fully assembled, to the installation site in DESY Hamburg (D). Various studies and tests have been performed to assess and minimize the risk of damages during transport; a new transport frame and a specialised company are being used for the series transport. This paper resumes the studies performed, describes the final configuration adopted for the series transport and the results obtained for the first XFEL modules.

INTRODUCTION

An industrialization study performed on the XFEL cryomodule production and installation highlighted a critical point in the cryomodule transport between the assembly site in CEA Saclay and the installation site at DESY Hamburg.

The study reports a critical acceleration value of 1.5 g for the vertical and longitudinal directions (risks of coupler damages) and a limit value of 1 g in the transverse direction (45° inclination of the cold mass).

Figure 1: Cryomodule being prepared for transport.

A first transport frame (figure 1) was therefore designed, a test transport of an assembled cryomodule was done and a set of measurements was performed to verify the tooling and record the maximum accelerations. These tests have been reported in [1].

Since then, further transports of the XFEL prototype modules highlighted some criticality in the frame design and some modifications were necessary. A second transport frame was built and a new transport test was performed. The series transport was organised together with the shipping company and more than 10 modules have been transported to DESY up to now. This paper resumes the work done since the publication of the first results in 2009.

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XFEL TRANSPORT SYSTEM

The cryomodule is supported with a metallic frame consisting of two cages, one fixed to the truck and the other damped with helical coils in a compression-roll configuration connected to the cryomodule.

The supporting system includes two end-caps to lock the helium gas return pipe at the end position and to avoid transversal movement of the supporting posts.

The module is equipped with vacuum gauges to monitor the beam vacuum and 2 synchronised accelerometers to record the acceleration experienced by the module and evaluate the frame damping factor (one sensor on the fixed frame and one on the damped one).

RESULTS OF THE TRANSPORT WITH THE FIRST FRAME DESIGN

The following cryomodules were transported with the first frame: the FLASH cryomodule n. 8 (a so called TTF type 3+ module, M8) and 2 XFEL prototype cryomodules PXFEL2 and PXFEL3_1. The maximum values of the acceleration measured during the trip are summarised in table 1.

The transport of Module 8 and PXFEL3_1 present acceleration values on the inner frame below the limit of 1.5 g, while the values recorded during the transport of PXFEL3_1 triggered some further investigation (see trip summary in figure 2) [2].

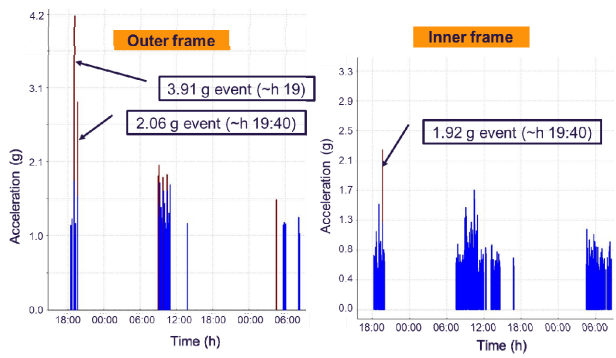

Figure 2: Event summary on PXFEL3_1.

The first event (almost 4g), although the higher-than-usual values, presents at further investigation a normal behaviour. The second event shows instead a not-so-high value on the outer frame (2.06 g), but at the same time the acceleration on the inner frame is equal to 1.92 g. The details of the vertical acceleration aZ for this event are presented in figure 3. The image shows that almost no damping happened between the inner and outer frame and

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therefore triggered a deep revision of the transport system and configuration.

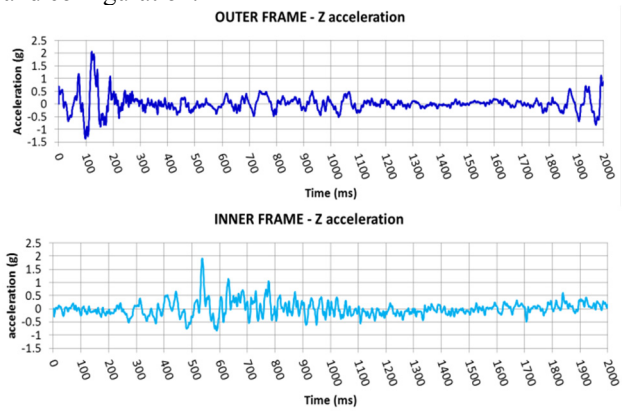

Figure 3: PXFEL3_1 Z acceleration on the outer (upper image) and inner (lower image) frame during event 2.

NEW FRAME DESIGN

In November 2012 a new transport frame with an improved damping system was delivered to DESY.

The new damping system uses the same type of helical coils, but the design and positioning of the coils are different: they are now bigger (more helixes) and concentrated around the connection between the fixed frame and the damped one, where the module is actually supported (figure 4).

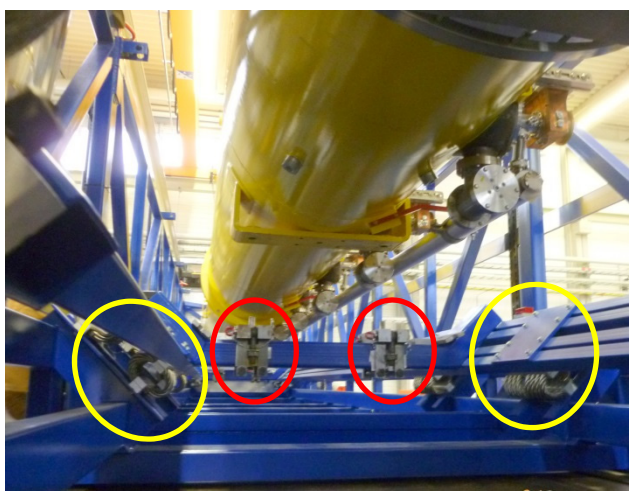

Figure 4: Position of coils in the new frame. In red: cryomodule supports, in yellow: now coil position.

Test Drive with the New Frame

A test drive with the new frame was performed in spring 2013. The test lasted about 4 hours and took place around Hamburg. Six additional accelerometers were installed on the frame for this measurement.

The maximum value measured by all the sensors during the test drive was around 1g. The different sensors showed a good agreement between each other, but the relative low maximum value measured during the test didn't allow a thorough test of the new transport frame configuration.

XM-3 and XM-2 Transport

The first cryomodule to be transported with the new frame was XM-3. Unfortunately, at the time, the special trailer, solely dedicated to the cryomodule transport (as explained in the next paragraph), was not ready and the cryomodule was transported with a standard trailed. The results of this travel are presented in table 1. The acceleration values on the inner frame are still higher than expected, but this is probably due to the non-optimal damping of the standard trailed used in the transport of XM-3 and XM-2.

The transport of XM-2 presents even worse results: values up to 5g were measure in the inner frame. After an inspection of the truck at the arrival, it was noticed that some parts of the trailer were very close to the transport frame and probably hit it during the travel, due to the shaking and vibrating of the truck.

As a side note, after the transport the two cryomodules XM-3 and XM-2 have undergone a complete set of cold tests in the AMTF hall at DESY and have shown very good results, reassuring everybody that no transport damages occurred at any level.

SERIES TRANSPORT CONFIGURATION

The transports of XM-3 and XM-2 described above were tests of the frame and monitoring system for the series transport. In the meantime, also the configuration of the transport series was fixed.

An international know shipping company is in charge of driving the 100 cryomodules between CEA and DESY, under the following conditions:

- A dedicated trailer, where the frame is permanently attached to the trailer bottom
- The same drivers, trained in advance, are employed for all the transports
- The truck position is monitored during the whole trip with a GPS system and the information is available live during the travel.

First Results and Adjustment of the Itinerary

The final configuration was applied for the first time with the transport of XM1.

With the transport of XM2, after a quick comparison of the data, it was noticed, thanks to the GPS tracking of the travel, that the highest acceleration values for both modules happened in the same region, between Metz and Luxemburg. In that area for both modules, not only the acceleration values were the highest of the whole travel, but also in average more events were recorded than in the rest of the trip.

It was therefore decided, in agreement with the transport company, to slightly modify the itinerary, to avoid that area.

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Table 1: Maximum Acceleration Measured on the Modules (aX, aY, aZ for maximum $aR = \sqrt{aX^2 + aY^2 + aZ^2}$)

	Inner frame			Outer frame		
Module	*aX [g]*	*aY [g]*	*aZ [g]*	*aX [g]*	*aY [g]*	*aZ [g]*
Module 8	0.55	0.86	1.42	0.5	1.26	1.95
PXFEL2	0.54	0.69	1.07	0.49	0.92	1.97
PXFEL3_1	-0.35	1.1	1.92	0.29	1.3	3.91
XM-3	1,26	2,61	2,86	-1.05	1.80	-1.61
XM-2	aR > 10 g outside and aR > 5 g inside -> problem with fixture of the frame to the trailer					
XM-1	-0.56	-2.00	-1.82	-1.24	-4.76	-1.96
XM1	0.32	-0.62	-0.85	0.39	0.58	1.2
XM2	-0.86	2.16	2.65	0.44	-2.34	-1.99
XM3	data corrupted			0.56	1.67	2.42
XM4	-0.94	1.57	-1.48	-0.51	1.55	1.48
XM5	-0.33	1.8	2.03	0.36	-1.64	-1.72
XM6	no data recorded					
XM7	-0.5	1.39	1.68	-0.95	2.65	2.24
XM8	-0.37	1.05	1.16	0.64	1.01	1.68
XM9	0.58	1.88	1.87	0.63	1.64	2.29

aX = longitudinal acceleration, aY = lateral acceleration, aZ = vertical acceleration

Latest Results

Since the modification of the itinerary, 7 modules (XM3 to XM9) were transported to DESY. The results are summarised in table 1.

From these results, the damping factor of the new frame looks satisfactory. Nevertheless, values higher than 1.5 g on the inner frame have to be accepted also with the new frame design.

At the time of this writing (August 2014), the transported cryomodules up to XM4 have been cold tested in the AMTF hall at DESY and presented no strange behaviour.

CONCLUSIONS

More than 10 XFEL cryomodules have been transported till now from the assembly facility in CEA Saclay to the final installation site in DESY Hamburg.

A dedicate transport concept was developed and tested over the last years. The system has now reached its final configuration which was applied for the last 7 transports, proving itself satisfactory.

Some of the transported cryomodules have already been cold tested in the AMTF hall and show no degradation or damages due to the transport.

ACKNOWLEDGMENTS

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We would also like to thank here the colleagues from the transport company for their helpfulness in finding the best transport itinerary and their availability to adapt to our variable schedule.

REFERENCES

[1] M. McGee at al., “Monitoring the FLASH Cryomodule Transport from DESY Hamburg to CEA Saclay”, PAC’09, Vancouver, Canada.

[2] S. Barbanotti, O. Sawlanski, K. Jensch, “XFEL cryomodule transport”, TTC meeting 2011, Beijing, China, http://indico.ihep.ac.cn/conferenceDisplay.py?confId=2240