Report/ Bericht

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1 General

In this report we analyse the transportation of XFEL modules from the manufacturer premises to the XFEL site.

To avoid damage from transportation and guarantee only small forces to the modules during transport it is important to secure the modules against impact and vibration. For previous projects we solved these requirements using a specially designed suspension frame for module transport. The frame consists out of an inner frame, where the module is mounted to and an outer frame. The connection between the two frames are wounded steel cables. They act as springs and take the function of resilient elements. Therefore the movement of the inner frame is damped with respect to the outer frame.

In Figure 1 the suspension frame used for transportation of superconducting 500 MHz Cornell type modules is shown. It has been used meanwhile in ten worldwide (Canada, Taiwan, USA, England) transportations using truck and airplane.

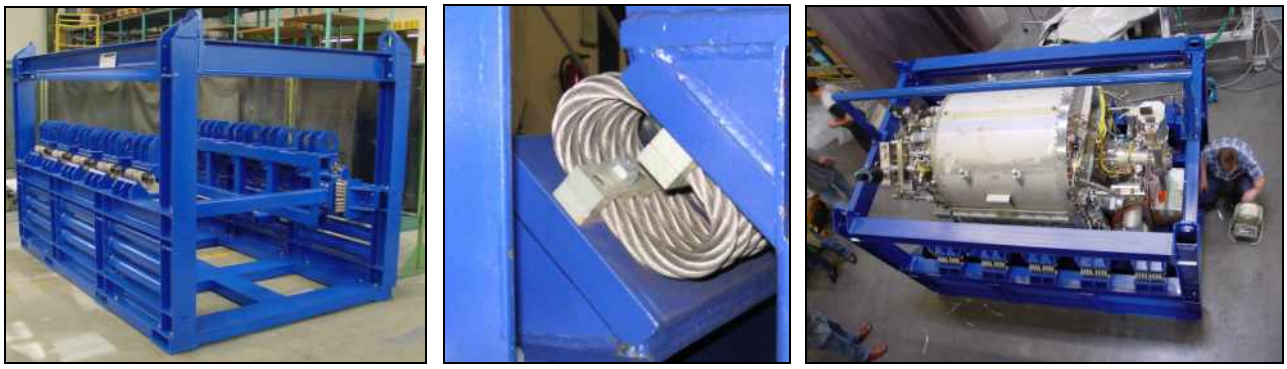

Figure 1: Suspension frame (left), steel cable spring between inner and outer frame (middle) and superconducting 500 MHz module mounted into suspension frame (right)

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2 Transport security

As the transport frame is only attached to the vacuum vessel of the module, it is important, that the interior of the vacuum vessel is secured relative to the vacuum vessel. For the 500 MHz modules, the helium vessel is hanging on four G10 threads and during the transport the helium vessel is in addition locked down to the vacuum vessel by a threaded rod, diameter 12 mm attached between the bottom of the helium vessel and the vacuum vessel.

To avoid a movement of the XFEL cold mass inside the vacuum tank, special end caps should be designed and fabricated. They should allow a form-fit of the 300 mm He-pipe as well as the vacuum tank. Those cups can also be designed to close the insulation vacuum and be used for leak checking purposes.

The couplers should be fixed via the instrumentation ports. This fixation will avoid swinging of the big flange assembly between cold and warm part during transportation.

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3 Transport frame for XFEL modules

Transferring this kind of support frame design to the XFEL modules we have worked out two acceptable solutions. For both solutions a truck is needed where the trailer can be loaded by crane and where afterwards the module is protected and covered from rain and wind. Best solutions are given by the standard curtain trailers.

Version 1: The suspension frame is fixed on the road semi-trailer:

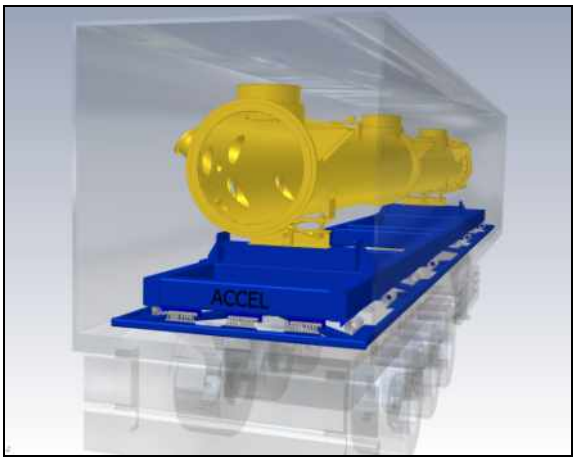

Figure 2: Suspension frame version 1 on truck

After completion of the assembly the module can be first stored separately on simple girders. For the transportation the module is lifted on a special trailer where the transport frame is already integrated to. The transport to the XFEL site follows and at the XFEL site the module is again stored on simple girders.

Advantages:

+ Low crane load
+ Simple design
+ Simple crane crossbar
+ Only one transportation device required, which can constantly drive between the assembly location and the XFEL site.

Disadvantages:

- During craning the module it is not spring mounted
- Craning and transportation takes time and requires very careful operation
- Additional (simple) girders required

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Version 2: The suspension frame including the module will be moved on the road

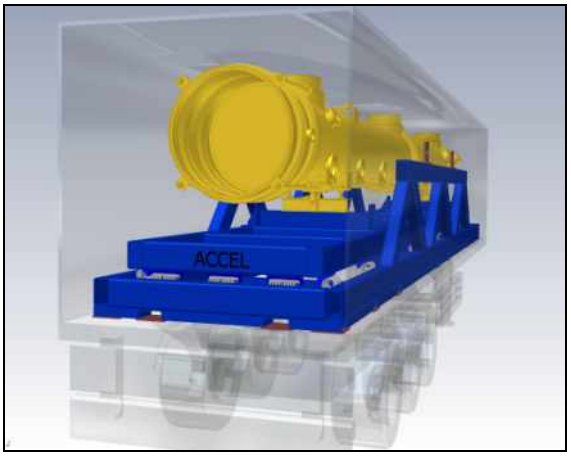

Figure 3: Suspension frame version 2 on Truck

After assembly the module is already stored in a transport frame at the assembly location. The module with the frame is loaded to a normal air suspended truck. The module is offloaded with the frame at the XFEL site. Further usage of the module at the XFEL site in a timely manner is desired in order to free the frame and ship it back to the assembly site thus to minimize the number of frames to be produced

Advantages:

+ The module in the suspension frame is independent of the trailer
+ During craning of the module, it is spring mounted
+ Easy storage and transportation
+ No further storage devices required

Disadvantage:

- Higher crane loads (the total weight might exceed the standard 10t limit)
- Expensive design as more than one suspension frame are required

We prefer version 1. During transportation at the XFEL site for final installation the module has to be craned without the spring frame anyhow and it looks like it will be the most cost effective solution. In case the transport takes longer than 3 days, the second solution might become more attractive.

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4 Transportation of the module

4.1 Transport at the module assembly location

To move the module during or after assembly in the assembly hall, normal industrial trucks might be used. It might be advisable to use a suspension frame here too. A remote controlled truck is shown as an example in figure 4.

Figure 4: remote controlled truck

4.2 Transport on roads of the EU

During the transport within Europe an air suspended road semi trailer, shown in figure 5 might be used. When moving back the top curtains it is possible to crane the module to the trailer. Afterwards the curtains are being closed and the module can be moved to the destination protected from climatic influences.

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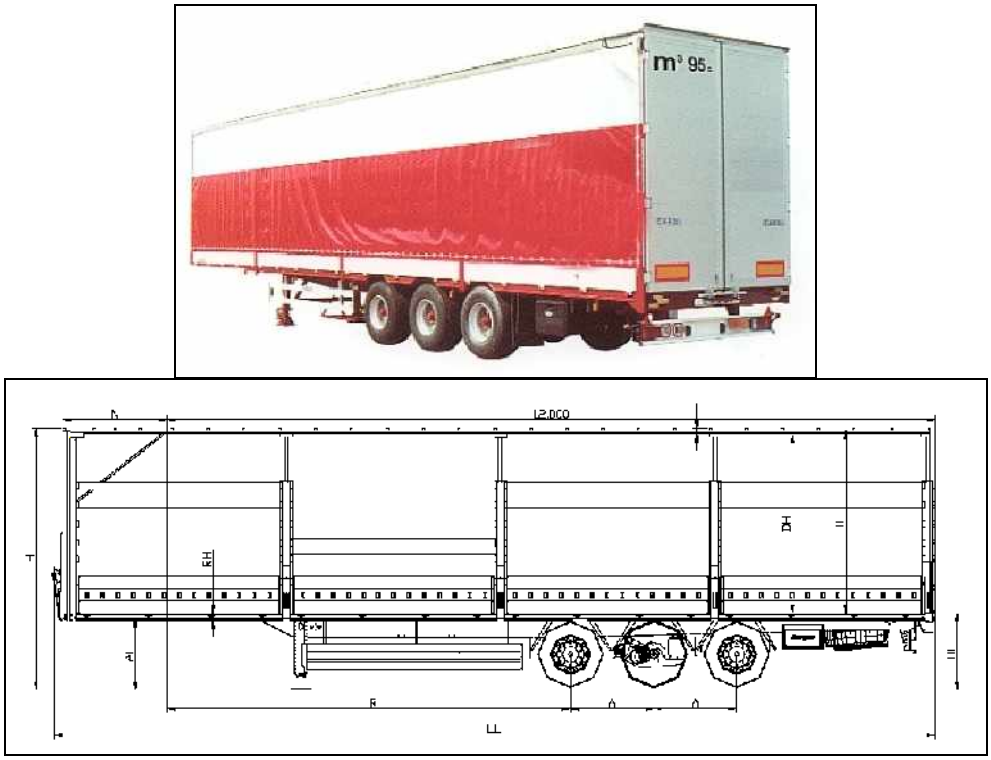

Figure 5: Air suspended road semi trailer (sketch)

Characteristic of possible road semi load trailer:

Sizes:

- Sattellast / vertical load : 11.000/12.000 kg
- Fahrzeugbreite / width of trailer: 2.550 mm
- Länge Ladefläche / length of bed: 13.620 mm
- Breite Ladefläche / clear width: 2.490 mm

Achsen und Federung / axis and suspension:

- Wartungsfreies 3-Achs-Luftfeder-Achsaggregat .Tragkraft der Achsen je 9t / maintenance-free 3-axis-air suspension-axis aggregate. Load capacity of one axis: 9t.
- Luftfederung mit Hebe- und Senkeinrichtung, Federung senken: 80mm, heben: 110 mm (von Fahrtstellung aus gemessen), automatische Rückstellung der Luftfederung auf Fahrniveau / air suspension with lifting (110mm) and lowering device (80mm) from driving niveau, automaticly reset of the air suspension to driving niveau.

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4.3 Transport on none EU roads

From previous transports we recognized, that it is almost impossible to find road semi trailers with curtains outside of Europe. There only hard cover trucks which can not be loaded by crane or flat bed trucks covered only with a tarp (not ideal for climatic influences) are common. Using a flat bed truck requires waterproof packing of the module.

Figure 6: hard cover truck (left) and flat bed truck (right)

4.4 Transport by air plane

When transport by plane is necessary, it is important that during the whole chain of transportation, the module is moved on roller beds. In this case, only the version 2 of the transport frame (see above) is possible.

The transport should be done as following:

- Crane the module to the suspension frame Type 2
- Crane the frame to a 12,12m long air fright pallet
- The loadmaster of the air cargo company fixes the frame to the pallet
- Crane the pallet with frame to a truck with roller beds (see Figure 7)

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Figure 7: Roller bed on truck

- Transport to the airport
- Transfer to a trolley (see Figure 8) using roller beds

Figure 8: Transfer station at airport with roller bed (left), trolley on roller beds (right)

- Transport to the airplane
- Transfer to the lifting platform using roller beds (see figure 9)

Figure 9: Lifting platform at aircraft

- Transfer into the airplane using roller beds
- Secure the pallet with the air plane fixing system (see figure 10)

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Figure 10: Roller bed in aircraft (left), air plane fixing system (right)

The unloading and the transport to the final destination is done vice versa.

Figure 11: CARGOLUX Boing 747 cargo, with open nose

4.5 Supervision of the transport

To guarantee a secure and “smooth” transport it is necessary to be at the tranship stations with special trained (preferably own) personnel.

This is especially important with regard to the loading and unloading of the aircraft. It is essential to advise the air cargo company personal to treat the fright carefully. It is almost in all cases possible to be personally present during all the loading / unloading operation when a prior consultation of the air cargo company took place.

To proof the safe and smooth transportation the complete transportation is recorded by means of monitoring by tri-axial accelerometers, capable to record acceleration, impact and temperature with a timestamp. As a second benefit the persons involved in the transport will be especially careful when they know that the transport is recorded. One accelerometer can be fixed on the frame, another one on the module. Then it is traceable which forces and impacts were present at which time on the frame and on the module itself.

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From our experience the impact value which is the integrated acceleration over impact time is of most importance, as a medium acceleration with a long impact time is much more critical as a very short impact with a high acceleration.

The critical value of 0,1 m/s impact should not be exceed.

An example of the record of the accelerator used during transport of a 500 MHz module is shown in figure 12. The good protection of the module by the transport frame is visible from the records, as the event time and the impact on the frame is much bigger than on the module itself.

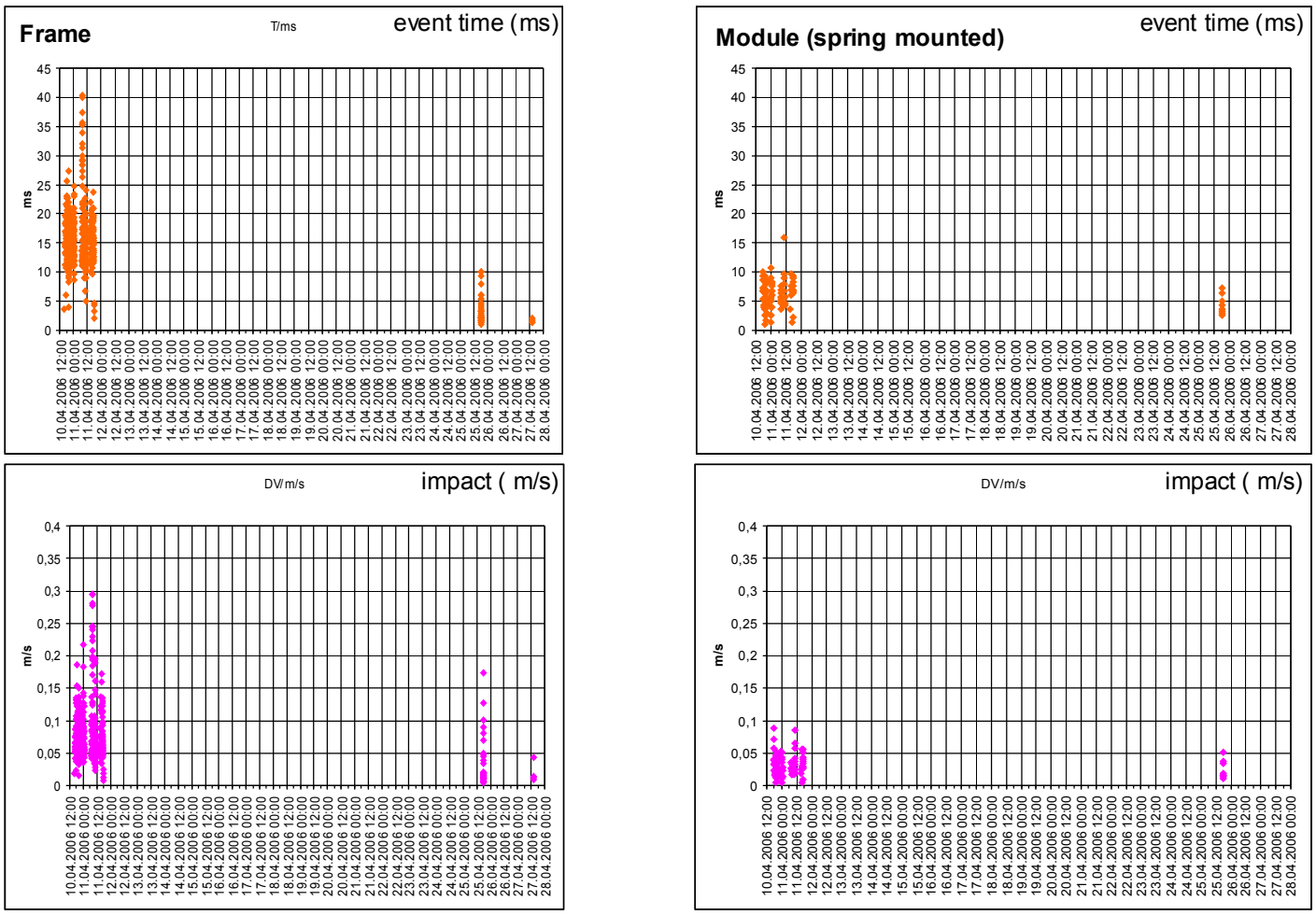

Figure 12: Detected event time and impact measured on the transport frame and the module itself

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