Status Report on Active Stabilisation of a Linear Collider Final Focus Quadrupole Mock-up

J. Lottin[1], C. Adloff[2], Y. Bastian[2], B. Bolzon[2], L Brunetti[1], F. Cadoux[2], F. Formosa[1],
N. Geffroy[2], C. Girard[2], A. Jeremie[2], Y. Karyotakis[2], F. Peltier[2]

1) ESIA - Université de Savoie, BP 806, F-74016 Annecy Cedex, FRANCE
2) LAPP-IN2P3-CNRS, BP110, F-74941 Annecy-le-Vieux Cedex, FRANCE

Abstract

This paper summarises the work done in the LAViSta group (Laboratories in Annecy working on Vibration and Stabilisation) and presented at the CARE/ELAN meeting at CERN from November 23 to November 25 2005.

Introduction

The measurements done with the sensors available in our laboratories used for ground motion analysis are presented. In addition, the structures under study are modelled and simulations using finite element analysis are performed to validate them. These simulations are compared to the measurements. For an accurate and nanometre level stabilisation, active stabilisation is required. An appropriate feedback loop is developed and tested. For a complete validation of our study, a large size mock-up is built to install sensors, actuators and use the feedback loop. In parallel, the whole system will also be simulated. This will help refining the numerical model by comparing to measurements and will allow us to define the best parameters for the final stabilisation system.

Measurements

The LAViSta group has got two types of sensors. The first sensors studied are seismic sensors measuring ground velocity. There are also accelerometers available for measuring ground acceleration. Table 1 describes the characteristics of the sensors used for the measurements presented in this paper.

Sensors	**Calibration for 1V**	**Frequency range**	**Type**
Güralp CMG-40T	±12.5mm/s	0.033-50Hz	Pick-up coil
Endevco 86	0.1g	0.01-100Hz	Piezoelectric

Table 1: Sensor characteristics.

We have two identical sensors for each type. Figure 1 shows the results of coherence measurements.

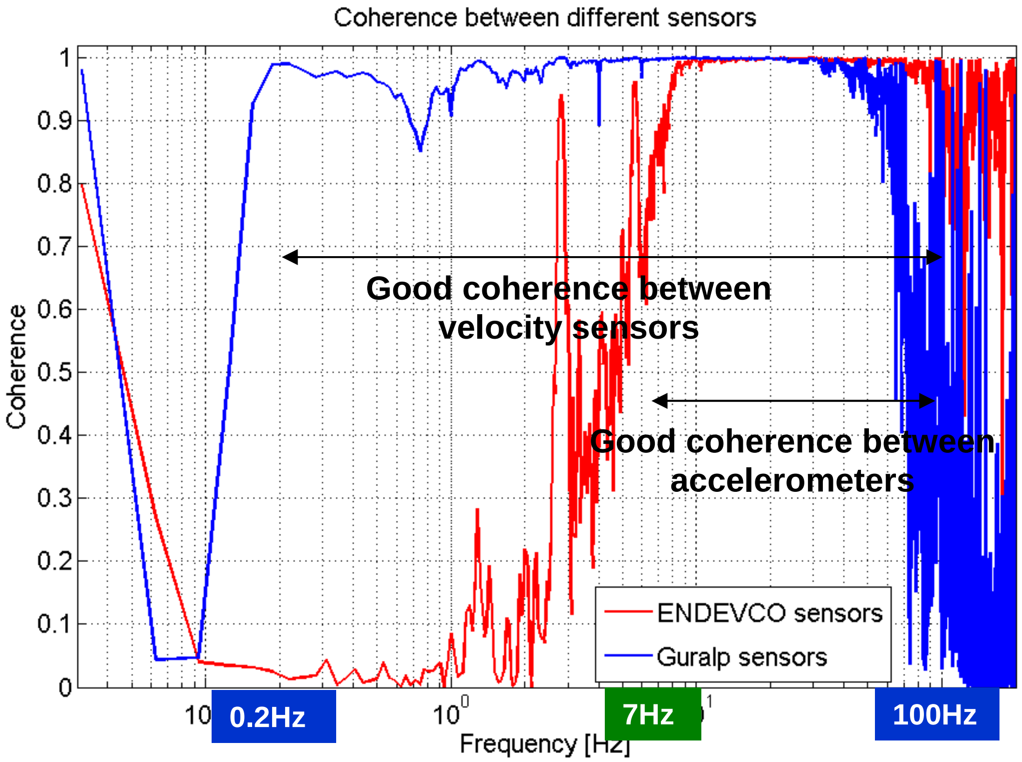

Figure 1: Coherence between two identical sensors. The red curve shows the result for two Endevco accelerometers, and the blue curve for two Güralp sensors.

The first step was to characterise the sensors. Ground motion measurements were performed, since it is an important component of the excitation of the accelerometer components. Figure 1 shows the coherence between two identical sensors, placed side by side on the ground, measuring ground motion. The ENDEVCO accelerometers show a drop in coherence below 7 Hz. At low frequencies, the ground motion has a very low acceleration amplitude, and is below the accelerometer resolution. On the other hand, the Güralp sensors measure the ground motion velocity. The amplitude of this signal is sufficiently high to be above this sensor's resolution.

Figure 2 shows the results for the determination of the sensors resolution. Notice that above 1 Hz, the Güralp sensors can measure below the nanometre. A more detailed description of the calculations can be found in reference [1].

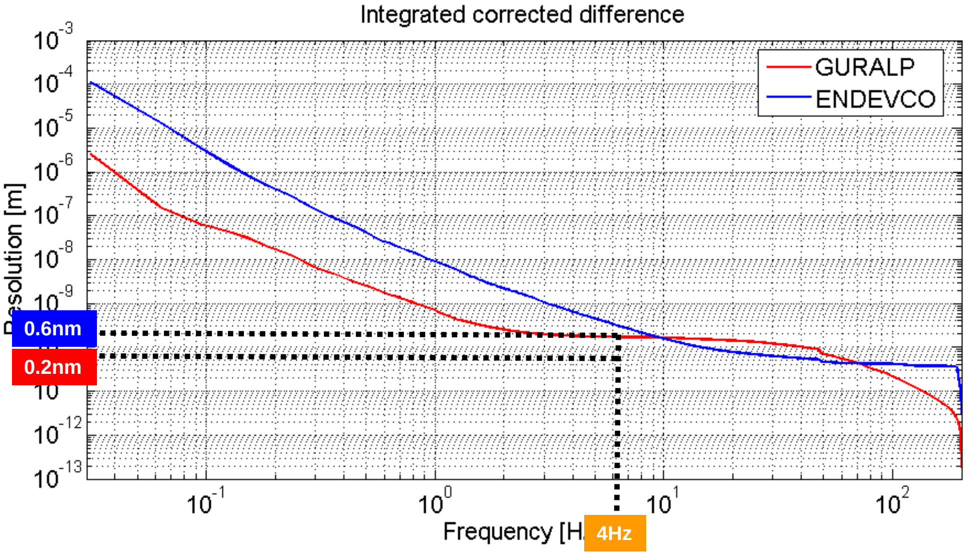

Figure 2: Sensor resolution for the Endevco accelerometers and the Güralp geophones

Modelling and simulation

The simulations have been done with the finite element analysis software from SAMCEF. It enables us to identify eigenfrequencies and display mode shapes. Another software PULSE/Me'scope makes a FFT analysis of the transfer function between an excitation and the resulting vibration modes. The set-up is shown in figure 3. The first results have been obtained on a simple case: a free-fixed aluminium beam 110cm long, 10cm wide and 2cm thick. The whole system is fixed on a stabilisation table made available by the CERN CLIC team. Endevco accelerometers have been installed on the fixed end of the beam to measure the input excitation, and another one on the free end measuring the dynamic response of the beam.

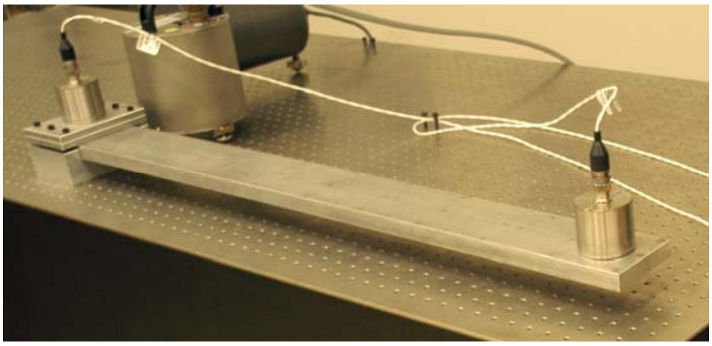

Figure 3: set-up

Figure 4 shows the result of measurements done with these sensors while the active stabilisation of the table was switched on or off.

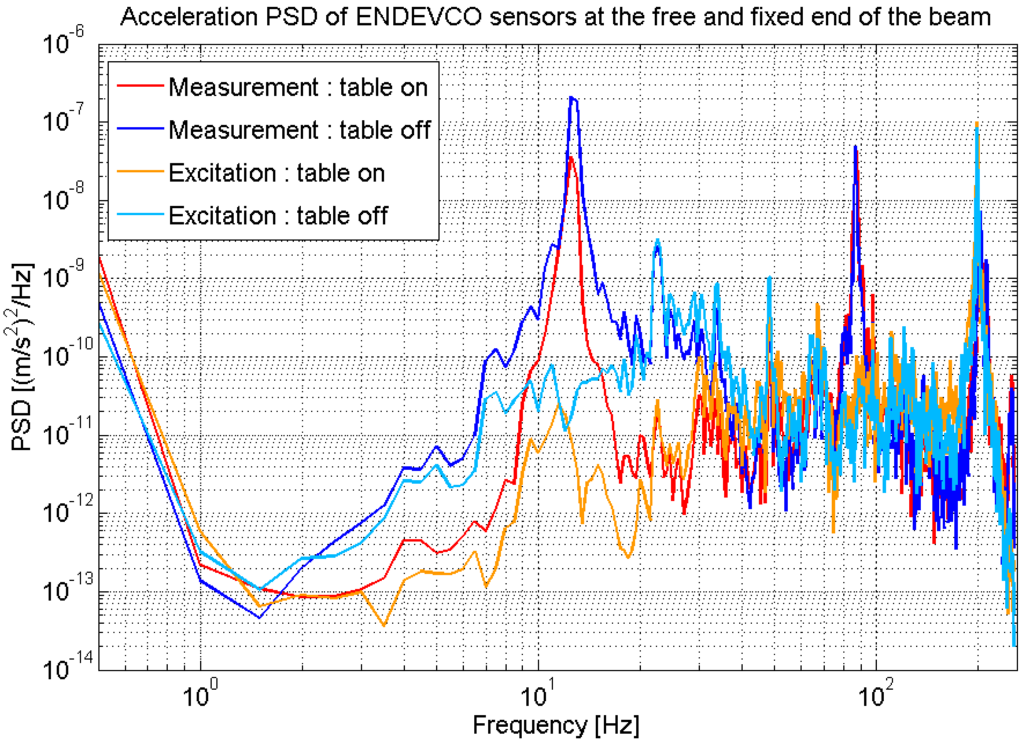

Figure 4: acceleration PSD of ENDEVCO sensors at the free and fixed end of the beam.

The results show that the active table can reduce the vibration level as a whole in the frequency range on which this study focuses. However, one sees that the active table does not damp the resonance peaks, like the one at 12 Hertz. An active feedback loop for the resonance peaks is essential to reduce the whole vibration level.

Active rejection

The aim of this study is to evaluate the performances of a new algorithm for disturbance rejection. In order to facilitate the analysis, a reduced-size mock-up is used. It should be noticed that due to limitations of PZT actuator capability and of PZT sensor sensitivity, performances are not as good as expected for the future linear collider. However it is possible to analyze the robustness of the algorithm with respect to model mismatch, to evaluate the computational burden and to get an idea of appropriate sampling rate since the frequency ranges are almost equivalent.

The innovation of the algorithm is that because of the complexity of the mechanical structure, the model is supposed unknown and only a few characteristics of the process are identified.

Instead of optimising the transfer of the system, we perform a compensation of the disturbance and as a consequence, a greater robustness is obtained. For that, we built a new algorithm, based on the estimation of the effects of disturbances and compute a sinusoid command for each frequency of disturbance. That means that there must be as many algorithms that run in the same time as frequencies to reject. The principle of the algorithm for one frequency is described in the following figure:

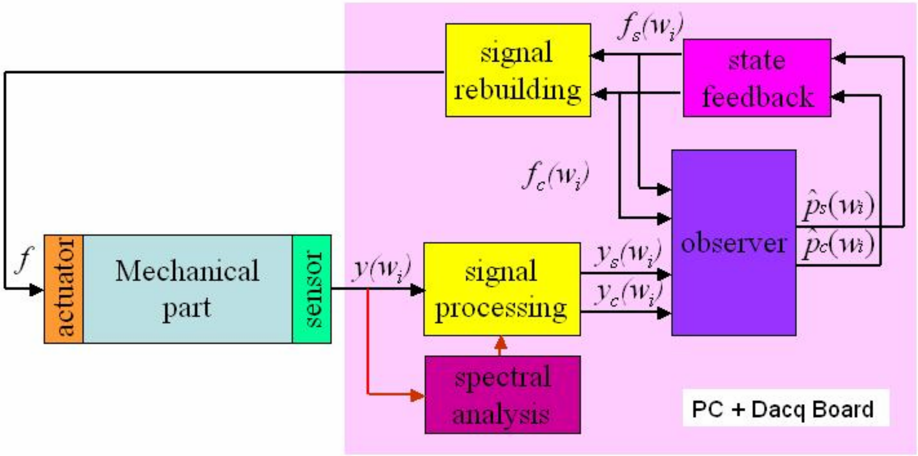

Figure 5: Principle of the algorithm

The implementation is done using the Matlab – Simulink software on a development PC. Then, the application is run in real time by the fast prototyping XPC Target with a dedicated PC. Figure 6 describes the computing architecture of the mock-up:

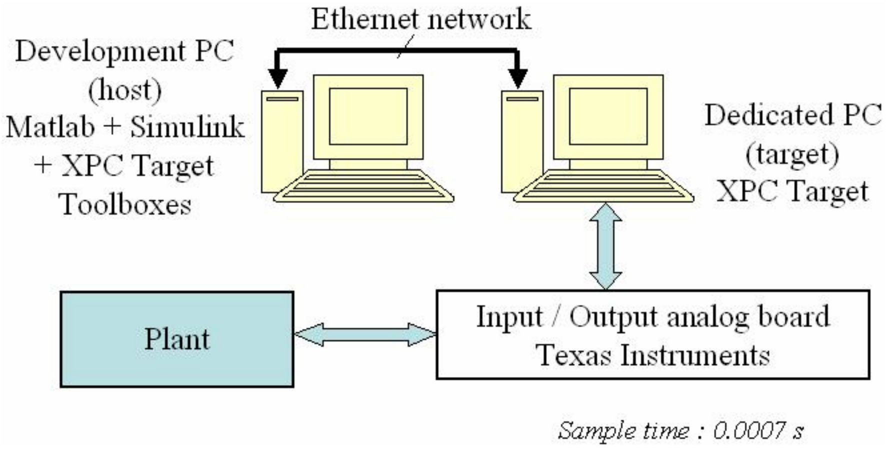

Figure 6: Computing architecture of the mock-up

The initial mock-up is composed of a steel beam in free – fixed mode and it is instrumented by two opposite piezoelectric patches (one as sensor and one as actuator). The disturbance is induced by a loudspeaker, which amplifies the environmental activity, in particular at the resonance frequencies of the steel beam.

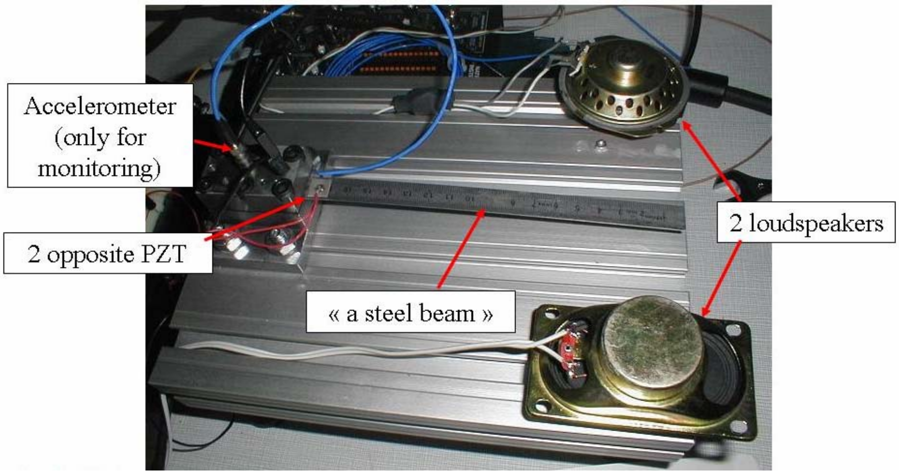

Figure 7: Photo of the mock-up

The goal is to eliminate or at least to reduce as much as possible the main frequencies of the disturbance. The following figures represent the results of the rejection of three disturbance frequencies, from which two correspond to the two first resonance modes of the steel beam and the other one comes from various sources.

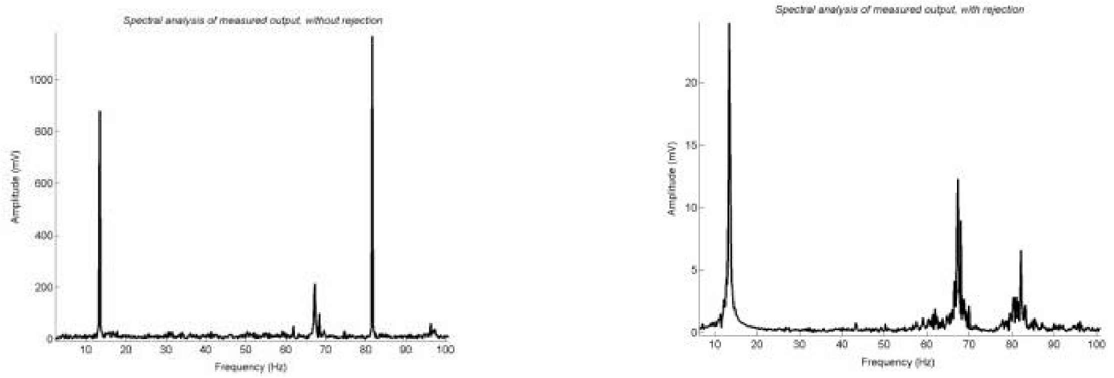

Figure 8: Results of one control experiment with three disturbance frequencies.

The current work is to evaluate the performance of a punctual control (with one sensor and one actuator) on the entire movement of the beam. Furthermore, we study the influence of the location and the technology of the instrumentation. For that, we built a new mock-up with the same steel beam in free-fixed mode but with a distributed instrumentation.

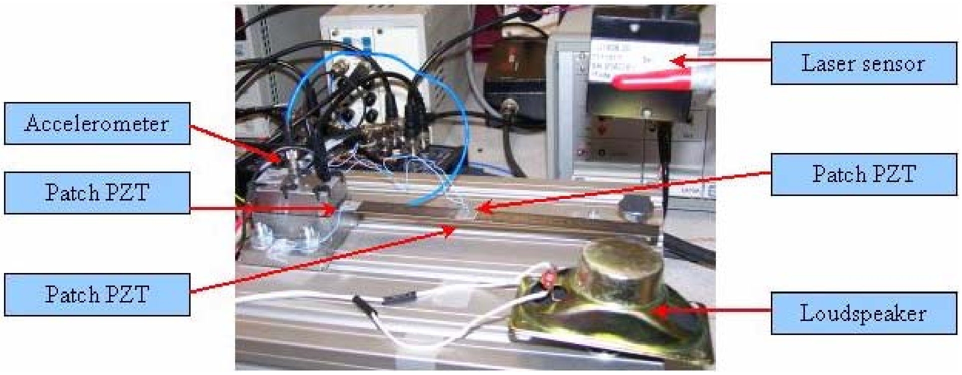

Figure 9: Photo of the mock-up with distributed instrumentation.

To improve the possible configurations of tests, to free ourselves from the possible repetition of the disturbance and even more to accurately know the displacement of the beam in all points, we have developed a simulation of the whole system.

The method consists in modelling by finite element method with the ANSYS software. The created super-element, with all the characteristics of the system, can be exploited with SDT (Structural Dynamic Toolbox), a specific toolbox of Matlab.

This modelling is linked to the control algorithm in a final application developed with the Matlab - Simulink software, and this allows the simulation of the whole system.

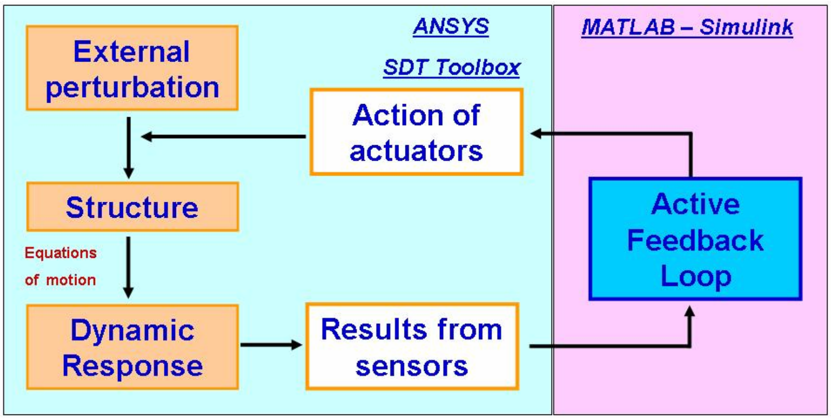

Figure 10: Simulation of the whole system.

Future prospects

A new mock-up is currently being developed that will have a geometry closer to a final focus quadrupole. Simulation will be used to simulate the whole system: the feedback loop, the sensors, the actuators and their most efficient location. Measurements will be done to validate the whole system in view of active stabilisation for a future linear collider.

Figure 11: View of the new prototype.

To define the instrumentation, we have to consider its influence on the mechanical structure. In our case, only the sensor ENDEVCO 86, because of his weight and his size, can be installed on this prototype. However, we are investigating the possibility of purchasing small, sensitive velocity sensors.

As for the actuator, we choose an assembly of piezoelectric patches in an elliptic mechanical structure, which allows to apply accurate forces in order to get very small displacement at the end of the beam. This actuator is produced by the Cedrat Company and its reference is APA 40SM.

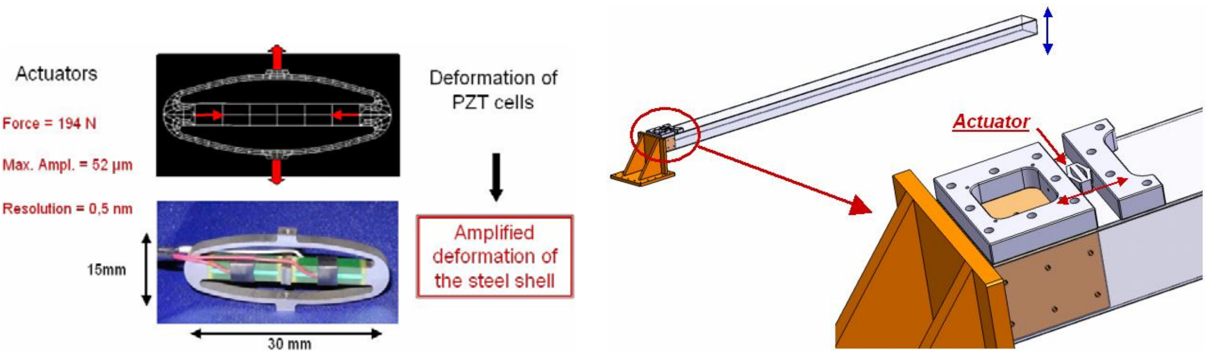

Figure 12: Actuator APA 40SM and the principle of the force application.

References

[1] B. Bolzon et al., Modelling of simple cases in view of active stabilisation for a future linear collider, Nanobeam 2005 conference, Kyoto, Japan, October 17-21, 2005.

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395)