Development of Reconfigurable Support Structures for Nano Focussing X ray Beamlines

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Abstract

Intense beams of X rays created by synchrotrons are being used for ground breaking research in the life, physical and environmental sciences. The latest generation of synchrotrons have a circumference of 500m or more with beamlines of length over 50m long. X ray optics are being developed which in the future may be able to focus the x-rays to spot sizes of less than 10nm (Ref 1). Precise ultra high stable systems are now required to take advantage of these developments. The experiment station is located at the end of the beamline and generally consists of final focussing components, sample and detectors. An important issue is the stability of the experiment station compared to the X ray source 50m or more away. Currently the approach is to mount the components and their associated motion systems onto steel or granite tables located onto the reinforced concrete floor slab via adjustable feet. This approach is not stable enough to provide for future requirements. In this paper an alternative design of end station is proposed.

1 Stability requirements

Develeopments in x-ray optics are now allowing beamlines at modern synchrotron sources to be built that could produce sub micron sized x ray beams. The stability of the support structures to support the optics and the associated sample station and detectors has therefore now become even more critical. Relative motion of the sample relative to the x ray source some 50m or more away during the exposure time will result in low resolution. The ideal end station structure needs to maintain position not only during the exposure time but also during the pre exposure alignment phase and subsequently when the sample or detector is moved for repeat exposures. Stability over some hours is required.

2 Ground transmitted vibration

Floor transmitted vibrations have been extensively measured at Diamond Light Source. Although the vibration levels are small, there are vibrations generated by pumps, cranes and even walkways that are measured on the floor of the beamlines. The main frequencies are within the 1 to 80 Hz range with dominant vibrations around 16-18Hz, 25-28Hz, 38 and 52Hz. The ideal support structure for any nano focus end station would therefore need to have modal frequencies higher than 80Hz. FEA modal analysis of typical steel frames show that modal frequencies are well below 80Hz and as the mass of components are added and the effect of adjustable feet taken into account then producing stiff frames above 80Hz is very difficult. An alternative solution is to produce a lightweight stiff structure that has a wide base to reduce amplification of horizontal vibrations. An initial design using 50mm diameter carbon fibre tube was analysed, built and tested. This demonstrated that the principle could improve stiffness but despite additional cross bracing the frequencies reduced substantially once heavy loads were applied. A second type of structure has been analysed, this uses 100mm diameter, 4mm thick carbon fibre tube. The tubes are fitted to castings to produce a 3 legged platform. Three of these platforms are then nested closely together. The analysis shows that even carrying a load of 250Kg the modal frequencies are above 87Hz.

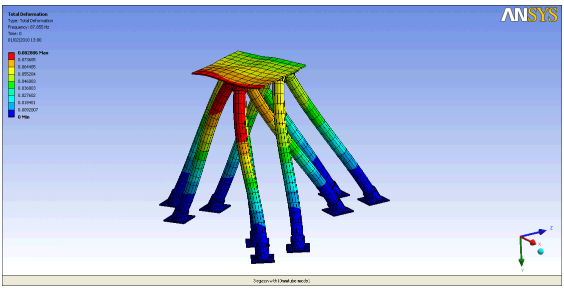

Figure 1: 100mm tube structure

3 Vibration reduction

If beam sizes of 10nm are to be produced then ideally the motion of the system should be below 10% of beam size, so 1nm. Floor vibrations are currently well above this level, so even for an ideal structure with unity transfer function this level of vibration isolation cannot be achieved. Traditional optical tables are mounted on rubber isolators, pneumatic vibration isolators or even active isolation systems. For

Synchrotron end stations it is important that the end station its alignment is maintained relative to the down stream optics and x-ray source. Free floating systems that isolate vibration are not therefore suitable. An alternative solution is to modify the legs of the 3 legged platforms such that it can move at high frequencies and compensate for floor vibrations and then be linked into a control system that maintains position.

4 Active vibration control

A modified leg has been built and is currently being tested. The leg consists of an outer 100mmØ carbon fibre tube connected by flexure couplings to an inner 50mmØ carbon fibre tube. The inner tube is then pushed and pulled axially by a high load PI-P045.80 piezo stack with a maximum displacement of 120 µm. The piezo is driven by a PI-E507 high voltage power supply. The voltage output is controlled by a signal generated by a 16 bit analogue voltage output module. A plane mirror reflecting renishaw RLE10 laser interferometer is used to measure the reference distance. The renishaw system feeds a 1mv/pp signal to a 200x interpolator which converts the signal to RS422a digital quadrature. This feeds into a differential digital input module. A labview programme is then used to read the encoder and provide a feedback signal to the piezo. The laser encoder resolution is 0.79nm.

To provide a fixed reference measurement point a set of reflective mirrors will be mounted on a small vibration isolated platform under the end station platform. A set of laser interferometers mounted onto the end station platform will then be used to measure the distance between the end station platform and the mirors. The concept is that the small vibration isolated platform only carries a set of static mirrors that do not move and are so unaffected by users changing detector postion and loading samples. To allow for longer term drifts in vertical position a second interferometer will need to be estabilished that measures directly to the floor slab.

The platform will also compensate for changes in leg length due to temperature variations within the laboratory.

Figure 2: Piezo leg shown without outer tube.

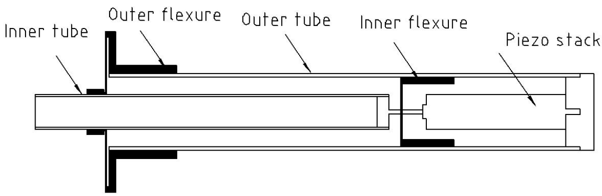

Figure 3: Schematic of Piezo driven leg

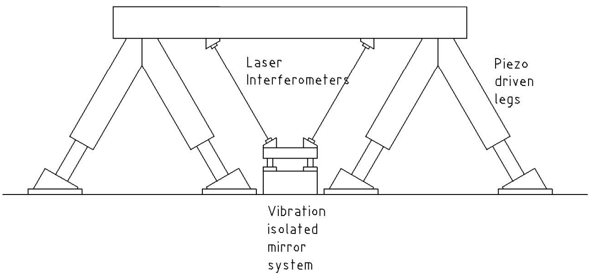

Figure 4: Platform with isolated mirror system

5 Reconfigurable structures

The concept design of a reconfigurable platform is based upon three-legged structures where the lengths of the legs can be modified to suit different applications. Using the basic building blocks a variety of heights, widths and lengths of structure can be built.

References

[1] Hard-x-ray microscopy with Fresnel zone plates reaches 40 nm Rayleigh resolution. Y.S.Chu et al. Applied physics letters 92,103119 (2008).