UNIVERSITY OF AMSTERDAM

Stabilisation and precision pointing quadrupole magnets in the Compact Linear Collider

S.M.J. Janssens

Summary

This thesis describes the research done to provide stabilisation and precision positioning for the main beam quadrupole magnets of the Compact Linear Collider CLIC.
The introduction describes why new particle accelerators are needed to further the knowledge of our universe and why they are linear. A proposed future accelerator is the Compact Linear Collider (CLIC) which consists of a novel two beam accelerator concept. Due to its linearity and subsequent single pass at the interaction point, this new accelerator requires a very small beam size at the interaction point, in order to increase collision effectiveness. One of the technological challenges, to obtain these small beam sizes at the interaction point, is to keep the quadrupole magnets aligned and stable to 1.5 nm integrated r.m.s. in vertical and 5 nm integrated root mean square (r.m.s.) in lateral direction. Additionally there is a proposal to create an intentional offset (max. 50 nm every 20 ms with a precision of +/- 1 nm), for several quadrupole mangets along the beamline, to steer the beam. This reduces the required number of dipole kicker magnets. Resolving this challenge is the subject of this thesis.
Chapter 2 gives an overview of the basic principles of vibration isolation used to keep payloads stable at a defined position, and presents several stabilisation tables from literature. From these literature examples it was decided to use a stiff piezo actuator, to be robust against external forces (e.g. water cooling, ventilation, cabling,). The vibration sensor was placed on top of the quadrupole, to use the full bandwidth of the sensor. The principles of piezo actuators and vibration sensors were also described to get a better understanding of the potential problems.
Chapter 3 presents the simplified modelling done to research the basic control theory needed, and the dangers related to the type of sensor used, mounting the stabilisation and positioning system on top of an alignment stage, the effect of the flexibility of the magnet and the flexible joint connected to the actuator to protect it from non-perpendicular forces. From these simulations, it was decided to make

the modes for the alignment stage and the flexural mode of the magnet higher than 50 Hz. This was done to increase stabilisation performance. The mode related to the flexural hinge should be placed outside of the controller bandwidth due to stability issues of the controller as, in this case, the actuator and sensor are not collocated anymore.

In Chapter 4 the problem of multiple degree of freedom stabilisation was analysed. Several configurations with three and two legs were evaluated for stiffness and controllability. Finally it was decided to use two legs under an angle of 70 degrees with shear pins providing longitudinal stiffness and increased rotational stiffness.

The practical implementation of the control system is described in Chapter 5. The limitations between digital and analogue control systems are described, and the building blocks for the final control system used in Chapter 6 are presented.

Several test benches were developed to validate the control theory in a step by step manner. These different benches and the corresponding test results for positioning and stabilisation are shown in Chapter 6. These tests confirmed that the required stabilisation and positioning levels were achieved with simplified test-setups.

Chapter 7 provides a comprehensive conclusion and the future work that needs to be done to continue the project. A full system for the smallest Type 1 quadrupole magnet will be build and a new radiation hard sensor is being researched.

More stabilisation systems were investigated than presented in Chapter 2. An overview of these systems and a reverse engineering of an existing stabilisation table are shown in Appendix A.