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# ACTIVE ALIGNMENT SYSTEM OF THE ATF DAMPING RING

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## Abstract

*The ATF (Accelerator Test Facility) at KEK has been built for studying the techniques related to building a linear collider. One of the primary goals of the accelerator is producing ultra-low emittance beams in the Damping Ring (DR). An active alignment system is employed to keep the components of the DR constantly aligned by compensating for the floor motion. The accuracy of the alignment has to be in level of tens of microns [1]. Light beams and position sensitive detectors are used to monitor the relative position of mover tables, on which the accelerator components are mounted.*

## Introduction

The ATF is a test accelerator for studying techniques needed to build a linear collider. It consists of a 1.54 GeV injector linac, beam transport line, damping ring (DR), beam extraction line plus a number of other components. One of the primary goals is to achieve very low beam emittance and small beam size in the damping ring.

To achieve a low emittance, the alignment of the accelerator components has to be very accurate, with a RMS deviation from the ideal positions below 60 microns [1,2]. The movements of the floor due to for example temperature changes and human activities like construction work will affect the accelerator operation.

The accelerator components have been installed on active mover tables that can be controlled by stepping motors with a positioning accuracy of about 2.5 microns [3]. There are a total of 36 mover tables, 18 in each of the two circular arcs. With the position measurement system the floor movement can be monitored. When the dislocations get too large, they can be corrected using the mover system without need for a shutdown and a global alignment survey.

Techniques that have been used before like wire alignment cannot be applied to the circular sections and we developed a position monitoring system based on laser diodes and light detectors. With the system we can monitor the relative positions of the mover tables and to minimize the relative displacements, apply algorithms like smoothing [4]. This method involves fitting a smooth curve to the observed beam path. We also need to establish the positions of the individual magnets on the mover table; these can be measured applying techniques of beam-based alignment.

## System Setup

The active alignment system consists of the active mover tables, the position measurement system and a control system to collect the position data and to command the mover tables. The mover tables can be controlled by sending commands to the mover control unit through the alignment control system. The control system also collects the measurement data into a database.

The position measurement system consists of a laser unit and a detector arm. The laser is attached to the end of one mover table and the detector arm to the end of a neighbour mover (see figure 1.)

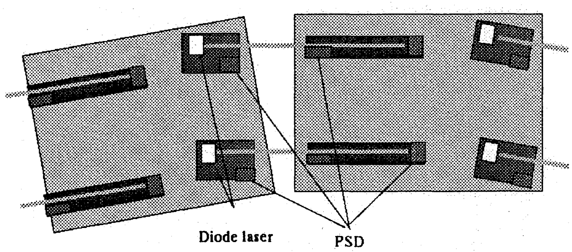


Figure 1. Setup of the position sensors.

The detector arm has two 2-dimensional position sensitive detectors (PSD) and a beam splitter arranged so that the incoming laser beam is divided into two and hits the two PSDs.

The laser is placed on top of a movable mount plate with a PSD to monitor changes in the laser beam so that the effects of the laser instability can be cancelled from the final measurement result.

## Measurement Hardware

As a light source we use a diode laser unit with a 670 nm diode laser, power control circuit and a focusing lens placed in a metal housing.

As sensors we use S-2044 PSDs by Hamamatsu Photonics. These sensors operate with charge division and give four output signals. These signals are amplified, converted to coordinate information and digitized to give values of X, Y and total light intensity (sum). The X and Y values are normalized with the sum to get the real displacement. The amplifiers for two PSDs and a 12-bit, 8-channel A/D converter are assembled into one unit. Six ADC channels are used for PSD readout, leaving two free channels for other use like adding temperature sensors. The readout accuracy of the PSDs is about one micron (see figure 2.)

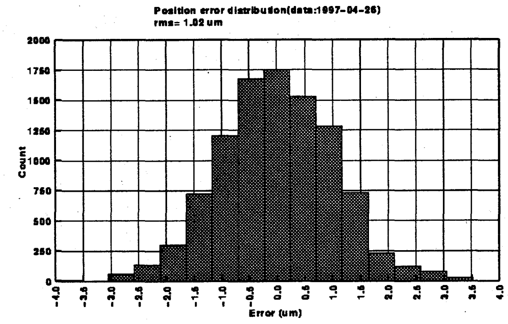


Figure 2. Readout accuracy of the PSDs.

With the setup, movements in five degrees of freedom can be monitored. In pure X- or Y-axis displacement, both PSDs in the detector arm indicate movement of equal magnitude. The rotations around X-axis (pitch) and Y-axis (yaw), can be calculated by subtracting from the position data the common movement in the respective directions. The angles can then be calculated using the difference and the length of the sensor arm. The rotation around Z-axis (roll) can be calculated from the difference in Y-axis movement of two sensor heads and the displacement between them.

## Performance tests

We made a series of tests to determine the accuracy and stability of the system. The tests indicate that it is possible to achieve better than one micron resolutions with a sufficient optical power. The detectors are also very linear over the whole active area.

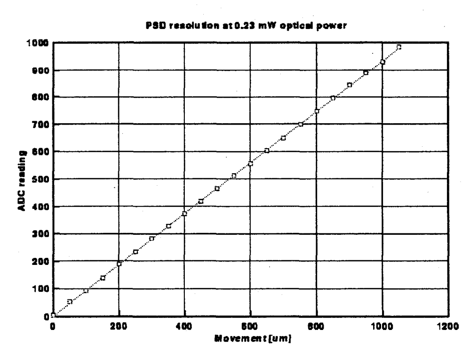


Figure 3. The resolution of the PSD.

The accuracy that can be achieved in the long term is affected by several factors like the instability of the laser. In short term these can be neglected but in a time span more than hours they dominate the accuracy. With a PSD placed about 25 cm from the laser, the spot was found to drift over an area of about 30 times 30 microns in about 100 hours. With a full detector setup, the monitor PSD was used to cancel the laser beam movements. After the cancellation, the achieved resolution was 2.6 micron (figure 5.).

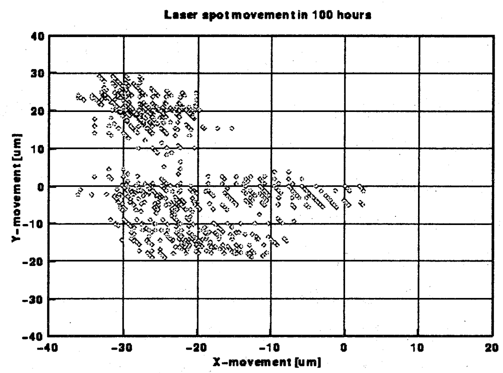


Figure 4. Laser spot movement in 100 hours.

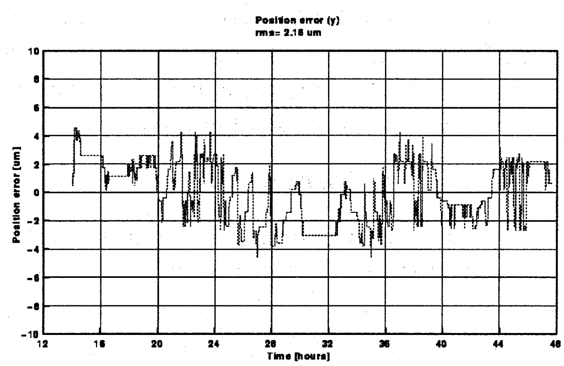


Figure 5. Residual position error after cancellation.

## Control System

The control system collects the measurement data and can be used to send commands to the mover tables. It is implemented as an subsystem of the main control and utilizes reconfigurable processors for autonomous handling of the detectors. By using a reconfigurable processor the hardware interface can be dynamically changed so the system is extremely flexible. Also, the processing can be tailored to the task at hand, enabling very fast algorithms if necessary.

A simple reconfigurable processor board is applied for reading the position sensors, communicating with the mover controller through a serial (RS-232c) line and the upper level control through a serial data link. A processor at the upper level collects the data from the sub-controllers and acts as an interface to the CAMAC-based control system. The ATF control system can then read the data from the CAMAC interface and send the mover commands through this interface.

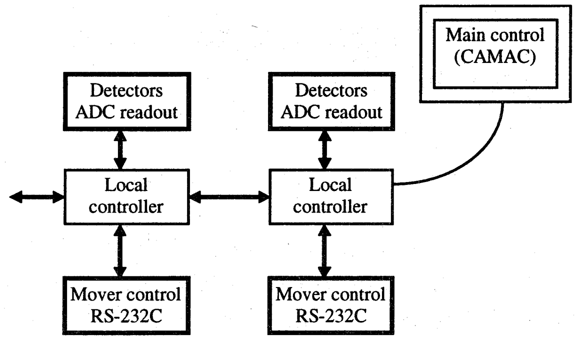


Figure 6. Diagram of the control system

## Summary

A position measurement and control system was developed for the ATF active alignment. With this system we can measure the floor movements and compensate for them to keep the ATF DR constantly aligned. We are now doing the final tests to integrate the system into ATF and are waiting to do the final installation.

## References


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