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Stabilization system of the laser system of the A4 Compton backscattering polarimeter

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Abstract. The A4 Compton backscattering polarimeter is used to measure the degree of spin polarization of the 855 MeV electron beam provided by the MAMI accelerator facility. Therefore special care must be taken to optimize and stabilize the overlap of electron and laser beam in order to get the highest luminosity for shortest measurement times. For this purpose an active stabilization system for the laser beam position of our intra-cavity polarimeter's optical resonator has been developed and commissioned.

PACS. 07.50.Qx Signal processing electronics – 29.27.Hj Polarized beams – 42.60.By Design of specific laser systems – 42.60.Lh Efficiency, stability, gain, and other operational parameters

1 Introduction

The laser resonator of the A4 backscattering polarimeter has a total length of 7.8 m. Therefore the proper alignment of the laser mirrors is sensitive to any mechanical instabilities caused for example by seismic vibrations, the flow of cooling water through laser tube and dipole magnets, air turbulences etc. Furthermore there are slow drifts of the laser pointing stability due to small changes in the temperature of the laser's plasma tube, e.g. from changes in the tube current. All this affects the laser beam position and leads to variations of the overlap between electron and laser beam and of the laser power, both causing changes in the luminosity of the polarimeter.

2 Hardware

These changes in the laser beam position and intra-cavity power have been measured using quadrant photodiodes installed along the laser cavity.

To suppress the changes in the beam position, three of the four laser mirrors are mounted on piezo driven platforms. These platforms can be used to optimize the laser resonator alignment so that the position of the laser beam and consequently its power can be stabilized.

From the measured beam positions, tilt angles for the piezo mounted mirrors are calculated in the decoupling circuits. An automatic shutdown circuit protects the system from resonant oscillations that could cause damage to the piezo platforms. A passive single-pole lowpass filter at 35 Hz provides the control loops with stability. The mechanical resonance of each piezo platform depends on the geometry and the momentum of inertia of the platform and the attached laser mirror, and has been measured as a transfer function. Then an active pole-zero cancellation circuit was tuned carefully to extinct electronically the resonance structure of the piezo platform measured before. The −6 dB bandwidth of the disturbance rejection of the stabilization system in a test setup has been increased from 210 Hz to 800 Hz by this method.

The system is fully remotely programmable using MAMI standard electronics. The elements of the decoupling matrices and the control loop amplifications are respectively given by eighteen and six 12-bit multiplying DACs.

3 First results and outlook

The stabilization system has been operated so far for test purposes with four out of its six control loops running.

When reconceived in a naive picture, where all beam position noise is projected onto tilting vibrations of the (so far) two stabilizable piezo-mounted laser mirrors, one can compute the mean tilt amplitudes of the mirrors from the obtained laser beam position data and decoupling matrices. Assuming this, the effective tilt amplitude was found to be reduced from about 90 μrad without stabilization to about 10 μrad with the stabilization system running and the pointing stability on the diodes from 8 to 12 μrad without to 0.8 μrad with stabilization. Long-term drifts of the beam went down from up to 21 μm/h to 0.3 μm/h.

Furthermore it should be possible to optimize the performance of the stabilization system by retuning the pole-zero cancellation circuits and then increasing the loop amplifications. Also a DAC module will be designed to add offsets to the position signals and thereby shifting the laser beam to provide fine-tuning of the overlap of both beams.

[a] comprises part of PhD thesis