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Report on the stabilization loop for declination (pointing) of the laser beam

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R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

A. Abstract / Executive Summary

At the Max Born Institute (MBI) we are working on the development of thin-disk lasers for high pulse energy at high average power. Our CPA laser system consists of an Yb:KGW oscillator with regenerative amplifier as front-end. In the subsequent Yb:YAG thin-disk based laser amplifiers the laser pulse is further amplified to several hundred millijoule pulse energy. The repetition rate is 100 Hz. We use a regenerative amplifier to increase the pulse energy to about 180 mJ and a multi-pass amplifier as a booster. A pulse energy of more than 400 mJ was demonstrated. Due to the heat generated during operating the laser there are small thermal drifts within the different amplifier stages. The long term drift of the laser beam during the day should be eliminated or reduced as much as possible. This drift influences the beam in two ways. On the one hand the beam direction (pointing) changes slowly, on the other hand the pulse energy as well as stability changes as a result of misalignment.

Most of the drift arises from the changed thermal conditions when the thin disk laser amplifiers are switched on. For the regenerative thin disk amplifier this results in a detuning of the resonator and therefore of a reduced output pulse energy as well as worse energy stability. A small change in the beam direction is also observable. The detuning of the resonator can be compensated with the help of a motorized end-mirror that is used to realign the detuned resonator again.

The booster amplifier has a multi-pass geometry. Therefore the thermally induced drift or displacement of optical components inside the amplifier cannot be fully compensated with the help of just one mirror. In such an amplifier system a mirror has to be identified suitable to compensate the drift as good as possible.

With an active feedback loop consisting of a position sensitive detector and motorized mirror mount within the amplifier stage the daily drift should be compensated automatically.

B. Deliverable Report

1 Introduction

We describe the method (hardware and software) we developed to reduce the observed drift of the output parameters of thin disk laser amplifiers during the day. This regards in particular the pulse energy and the beam direction.

By monitoring the beam position of the amplified beam and keeping the beam at a fixed position by means of a motorized mirror, the thermal drift can be compensated to a large degree. As an example the method is demonstrated at the regenerative amplifier.

2 Objectives

We are working on the development of a high average power laser amplifier based on thin-disk technology. Within this work we pay special attention on the stabilization of pulse energy and beam pointing.

In this report we describe an active stabilization loop we have implemented to improve both the pointing stability and the energy stability at the output of the thin-disk amplifier.

3 Work performed / results / description

3.1 Regenerative Amplifier

We investigated the behaviour of the regenerative thin disk amplifier during the day. It was found that the pulse energy decreases over a time interval of about 4 to 5 hours. Additionally, the pulse energy stability became worse and the beam position moved. The pulse energy and stability can be restored by adjusting the resonator. The beam position is then mostly the exact starting position.

Figure 1 shows the layout of the regenerative amplifier. The Faraday rotator in combination with the thin-film polarizer at the entrance of the amplifier is used to separate the amplified pulse from the seed. The combination thin-film polarizer, quarter-wave plate and Pockels cell is used for in- and out-coupling of the laser pulse into and out of the regenerative amplifier. As long as the Pockels cell is under high voltage the laser pulse is caught between the two end-mirrors of the amplifier. The first end-mirror is the laser disk itself. The second end-mirror is motorized to align the resonator from outside.

By starting the amplifier the pump light heats up certain components while the water cooling of the laser head also has impact onto the breadboard where all other components are mounted on. In a first approximation we assumed that the laser disk itself does not move. The thermal movement of all other components inside the resonator can be compensated by re-aligning the end-mirror and the amplified beam will stay at the same position as long as the resonator is well aligned.

Therefore, if the position of the amplified beam is monitored and a deviation is re-adjusted to a reference position the resonator will stay stable and the beam direction is kept constant.

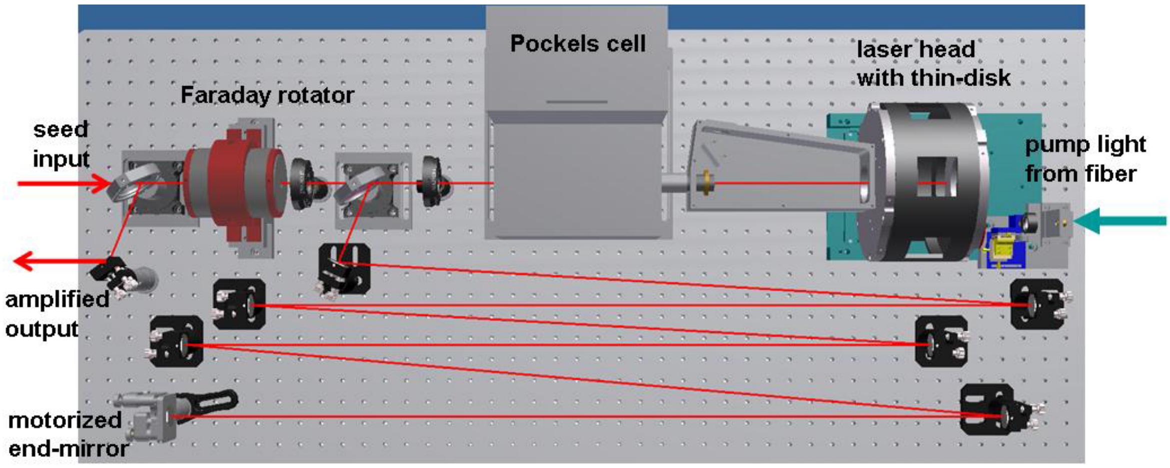

Figure 1: Layout of the regenerative amplifier.

Figure 2 shows how this idea is implemented into the regenerative amplifier. The leakage of a mirror is observed with a camera and compared by an image processing software with a reference position taken when the resonator works stable. If the actual position differs from the reference the motorized end-mirror is moved accordingly compensating a thermally induced misalignment.

As detector an IDS uEye SE camera was used. The motorized mirror mount was equipped with Picomotors from Newport/Newfocus.

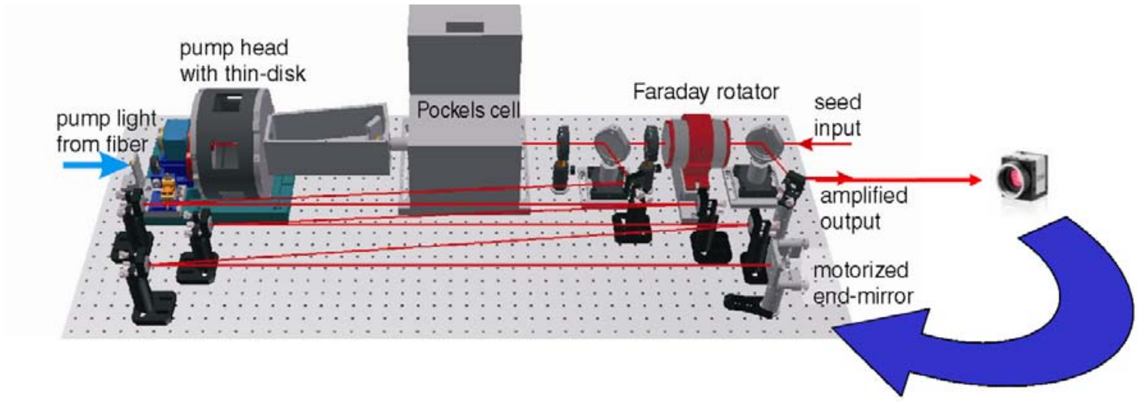

Figure 2: Implementation of the feedback loop into the regenerative amplifier.

The result of this active feedback loop stabilization is shown in Figure 3. The pulse energy without active stabilization is clearly decreasing over a period of more than 4 hours. After switching on the active stabilization the initial pulse energy is very fast reached again and then stays constant.

The active stabilization improves the stability by one order of magnitude. A fluctuation of only 0.3% (RMS) is measured for a period of more than 3.5 hours. After a day long operation the pulse energy may drop by about 1% due to a remaining drift not compensated by this method. The energy fluctuation is then increased from 0.3% to about 0.5% (RMS). The beam position does not move noticeable due to the fixation to the reference position.

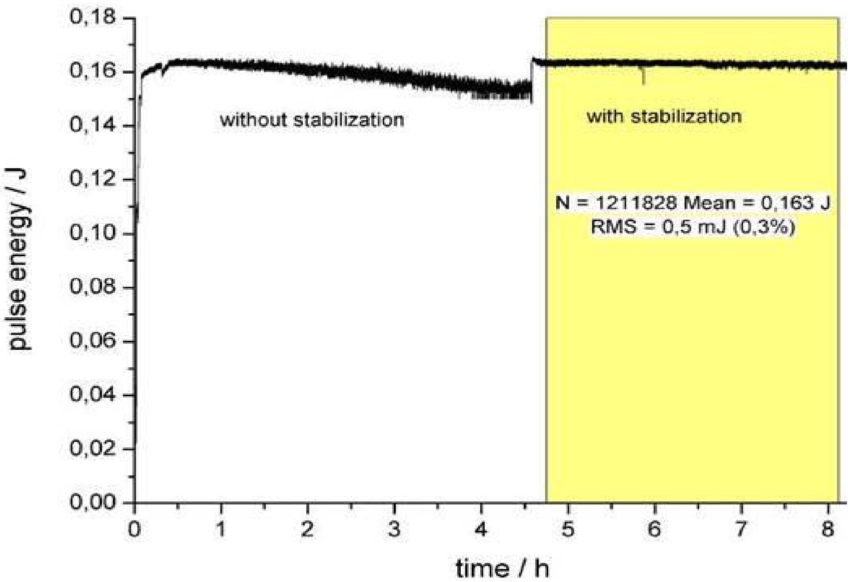

Figure 3: Pulse energy of the regenerative amplifier vs. time without and with active stabilization.

3.2 Software

The camera and the motorized mirror mount are controlled by LabView based software. The available LabView drivers for the IDS uEye camera as well as the Newfocus Picomotor were integrated into this software.

The user interface allows the configuration of several camera/mirror pairs, each assigned to one amplifier. Depending on the daily operation the stabilization for each amplifier can be activated or de-activated. For each amplifier a reference position for the output beam can be stored.

During the stabilization process the software addresses the different (activated) amplifiers. The corresponding camera takes a number of images (variable), calculates the centre of the beam, and uses the average value for comparison with the reference point. After adjusting the associated motorized mirror mount the next amplifier is addressed.

Since the thermal drift is a rather slow process there was no special emphasis on the development of a fast software solution.

The user interface (see Figure 4) shows in the main part the camera image of the beam position with horizontal and vertical cut to determine the centre of the beam. On the left the amplifier can be selected and the feedback loop can be activated or de-activated for this amplifier. Below the camera parameters, e.g. exposure time, gain, etc. can be set. On the bottom left the parameters of the motorized mirror are displayed, e.g. the ID of the Picomotor for vertical or horizontal misalignment and the number of steps that should be moved per pixel difference to the reference position. On the right side the user can choose between several actions.

- Take the current beam position as reference
- Load a stored reference position
- Change the configuration settings (camera ID, motor ID, …)
- Get a live image of the currently selected amplifier output
- Start the stabilization process for all activated amplifiers
- Stop the program

Additionally, several status lights are given, e.g. is the camera available, is the motor controller available, is the signal high enough to determine the centre of the beam, etc.

The software is especially adapted to our laser system and our needs for operating the laser system.

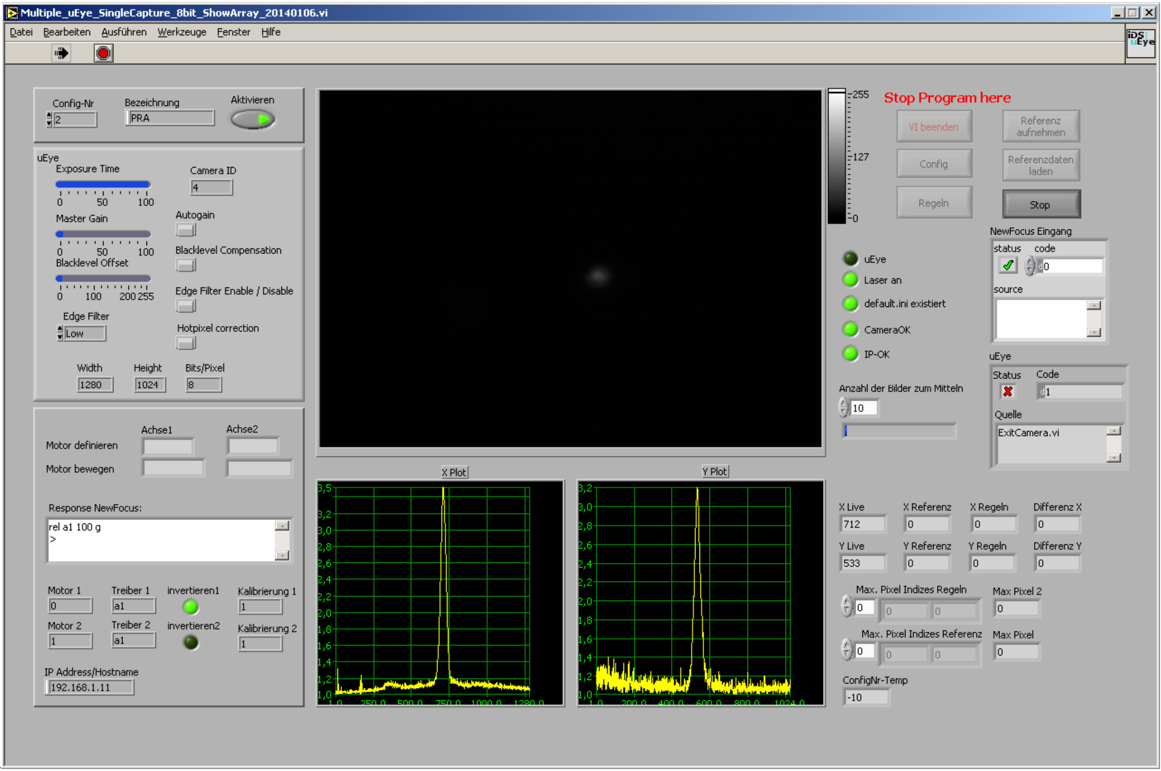

Figure 4: Screenshot of the user interface.

4 Conclusions

The active feedback loop is a tool suitable for stabilizing the output pulse energy of thin disk laser amplifiers. For the regenerative amplifier the device can nearly completely compensate the thermally induced misalignment of optical components inside the resonator. It monitors the beam position and realigns the amplifier accordingly.

The software is capable to control several camera/mirror pair assigned to different amplifier stages within the laser system. Amplifier stages that are temporarily not in use can be deactivated.

With this stabilization concept it is now possible to switch on the laser system and start working immediately. Figure 5 shows the pulse energy measured behind the booster amplifier. The measurement starts with switching on the laser system and starting the automatic stabilization with the reference points from the day before. No further manual optimization has been performed. A high stability with less than 0.6% (RMS) pulse energy fluctuation was measured during more than 8 h operation time.

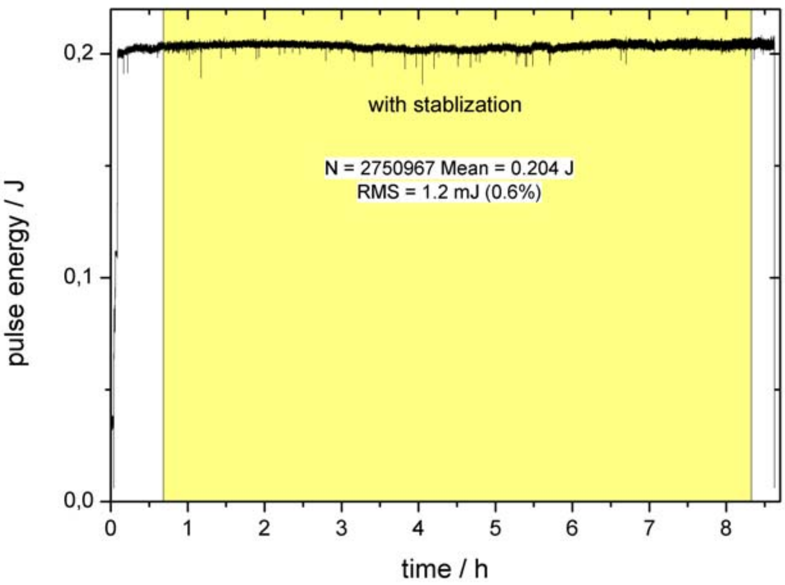

Figure 5: Pulse energy stability with active feedback loop. The measurement starts with switching on the laser system and starting the active stabilization of all amplifiers.

The described stabilization loop can most likely also be used for stabilizing other laser systems. One precondition however is that only relatively slow thermally-induced misalignment and drifts of optical components have to be compensated. Fast fluctuations due to e.g. air turbulences would require much faster actuators and improved image-processing software. Therefore, those fast fluctuations cannot be compensated by the present version of our active stabilization system.