Automated Alignment of Laser Resonators

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Abstract

Within a collaborative research project, a new, miniaturized diode pumped solid state laser (MicroSlab) has been developed for a fully automated assembly. The rectangular shaped slab laser components of the new design simplify the assembly on a common base plate and thus enable an automated assembly of the device. In this paper concepts and results from the automated resonator alignment of the laser resonator are presented.

1 Introduction

In a previous paper [1] we introduced our basic approach towards a flexible automation of precision assembly processes and first results from the development of a novel 6DOF micromanipulator. These developments have been motivated by a growing demand for more efficient production processes for laser systems due to increasing market demands and production volumes.

For solid state lasers or similar laser configurations the alignment of the resonator is the key step in the fabrication process. It classically is a very time-consuming and complicated procedure because of the high accuracy needed to bring the resonator mirrors into tolerance.

Alignment processes can in general be categorized in two approaches, passive and active [2]. The first one is based only in the geometry of the system, it is commonly used to achieve a prepositioning of the components. The more accurate the method, the smaller the effort needed for the active alignment.

The active alignment consists of monitoring the key performance parameters of the laser, such as output power or beam profile. Basically, one of the resonator mirrors is manipulated until one or more of the parameters are optimized.

2 Self-optimizing alignment process

The MicroSlab resonator consists of two mirrors – the incoupling (curvature radius of 500mm) and the outcoupling mirror (plane) – forming a hemispherical resonator. The reflecting surfaces of both mirrors have to be aligned to each other and to the pre-assembled laser crystal with angular tolerances of a few millidegrees. As the effort to characterize and measure these features for all components is unacceptably high, self-optimization of the alignment is a promising approach to reduce planning efforts and increase the efficiency of an automated assembly.

The self-optimizing alignment process has been designed as a two-stage process, where the fine alignment movements were performed with the automation approaches presented in [1].

- A passive alignment of both mirrors by means of a reference laser beam;
- An active alignment, where the laser is being switched on and the functional output of the systems is being measured, evaluated and optimized.

3 Passive alignment

Passive methods are performed when the system is not running and are based on measurements of the geometry of the system. Methods based on reference lasers are the most common, as they provide an easy way to magnify (for easier visualization) small misalignments. Nevertheless, they are limited to angular adjustments in two axes only.

The applied passive alignment method is based on a low power reference laser pointed to the mirror being aligned, whose reflections are guided in such a way that they are projected on a screen (Figure 1,a). This setup has been analyzed geometrically and a model describing the relation between the distance of two reflections on the screen and the differences in angular orientation has been found. These relations have been embedded in an alignment algorithm to enable an automated alignment of both mirrors to the reference beam.

Image processing can be implemented based on projecting the reflections on a screen with a camera in front of it or by projecting them directly on a CCD camera. For space limited systems projecting the light directly on a CCD is preferred (1,b).

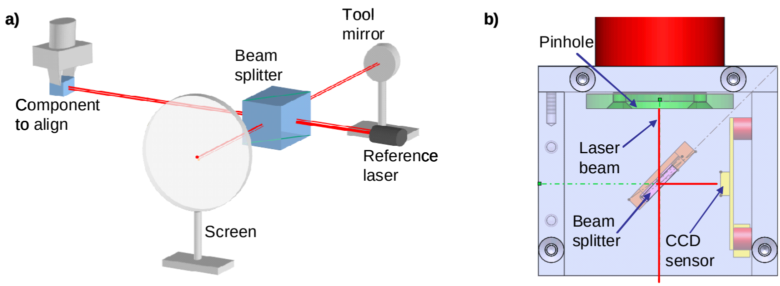

Figure 1: a) Reference laser with screen, b) Reference laser direct on a CCD

3 Active alignment methods

Active methods are based on monitoring the behavior of the laser during resonator alignment. While modifying the position or orientation of a mirror, it is determined if the modification produced an improvement or a negative effect. Different algorithms can be designed in order to reduce the alignment time and increase the precision of the alignment.

As output power is the most representative parameter of the alignment quality, it has been monitored during resonator alignment of the MicroSlab.

An adequate algorithm to find the maximum output power is crucial for reducing the alignment time. The important factors to consider when designing an alignment algorithm are:

1. The maximum misalignment of the resonator at the start of the active alignment
2. The specific sensitivity of the laser to resonator misalignments

For the MicroSlab resonator a 3D graphic of the sensitivity of the resonator to angular misalignments was experimentally obtained (Figure 2,a), and an active alignment strategy to reduce the alignment time was designed and programmed.

The strategy consists on sample the output power in a few locations following an “X” pattern. Starting from the maximum found, the resonator is finally aligned by optimizing each axle iteratively. The resulting plots of this strategy (Figure 2,b) show the reduced number of samples necessary to align the resonator.

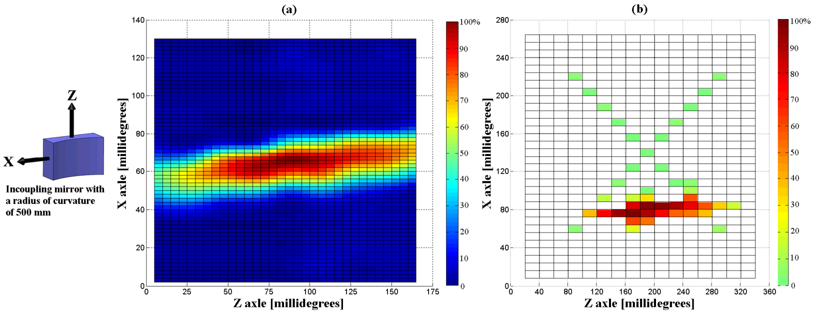

Figure 2: a) Relative power at several resonator misalignments, b) Example of an “X” scanning algorithm

4 Conclusion and Outlook

For the assembly of the newly developed MicroSlab laser the core process of resonator alignment has successfully been automated. The process concepts is based on a self-optimizing two-stage procedure involving a passive and an active alignment step.

Based on this self-optimizing approach a significant time reduction for the active alignment could already be achieved compared to the manual procedure, and further improvements promise a total alignment duration for the resonator of less than five minutes.

5 Acknowledgments

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