Piezo-based, automated active alignment of laser resonators

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This paper focuses on the precision assembly of laser resonators, which is one of the last and at the same time the most crucial assembly steps in terms of beam quality and laser power. The paper presents an alternative approach for laser resonator alignment consisting of a piezo-based active alignment tool developed for miniaturized laser systems for marking and engraving applications.

1 Introduction

Laser technology is a key technology with a continuously rising application range in many domains. The large number of laser systems in combination with a strong trend towards miniaturization and diversification leads to complex requirements for the production technology. Particularly the manually dominated assembly of micro optical systems, providing an added value of up to 80 % [1], indicates one of the most important potentials for optimization and cost savings in high-wage countries [2]. An automation of complex alignment processes to support expensive personnel costs at repetitive tasks can be achieved in two ways. Either precision tools can be used for positioning and alignment or precision actuators can be integrated into the system itself. Due to manufacturing tolerances, every single laser resonator requires an individual active alignment process [3]. The integration of active components into the system can simplify the final and most time-consuming step of many laser systems: the laser resonator alignment. Moreover, an integrated solution offers possibilities to compensate misalignments after the joining process or after long-term instabilities and therefore leads to more stable systems, because even small misalignments of 0.01° can lead to a loss of power of about 20 %. This paper discusses possibilities of actuator integration into laser systems for alignment and long-term stability purposes.

2 Concept

For the alignment of the output coupler two degrees of freedom are needed (pitch and yaw axis). Previous experiments show that an alignment of both axes, pitch and yaw, needs to be realized in a field of at least +/- 0.1° [4]. A larger angular field will result in a less precise prepositioning of the components which have to be aligned. Further on, the precision of alignment should be at least two milli-degrees to reach the optimum set-point as close as possible.

3 Solution

For this purpose a solid state hinge is to be used, which is deflected by means of two piezo elements (one a time for pitch and yaw) as the active part, see Fig. 1. The benefit of a solid state hinge in combination with piezo stack actuation is the absence of the slip-stick phenomenon. This benefit makes it possible to reach the required positioning resolutions of at least two milli-degrees. Furthermore, the resolution is only limited by the signal-to-noise ratio of the power-amplifier for the piezo elements.

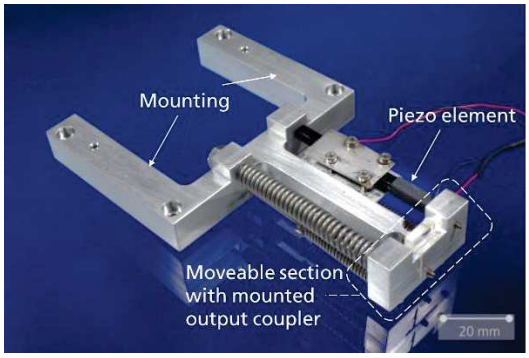

Fig. 1 *The assembled alignment tool*

FEM calculations have been performed to determine a suitable combination between solid state hinge and piezo actuation. Thus a combination of aluminum (AlZnMgCu1.5) for the material of the solid state hinge and the PSt150/3.5x3.5/60 (manufactured by Piezomechanik) for the piezo actuation are chosen. By using this configuration we calculate a rotary movement of ± 0.22° on the pitch-axis, depicted in Fig. 2 and ± 0.3° on the yaw-axis taking into account a safety factor of 1.12 before plastic deformation of the solid state hinge starts at the maximum deflection angle.

The control-algorithm is realized in LabVIEW and uses a DA converter to control the movement of the piezo actuators and an external laser power sensor to capture the actual laser output power. The measured laser power is utilized as the input for the control loop to find the maximum output power P_{max} as

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this is defined to be the optimum set point. To find this operating point, three different methods are implemented, an x-scan, a meander-scan and a manual selection of coordinates.

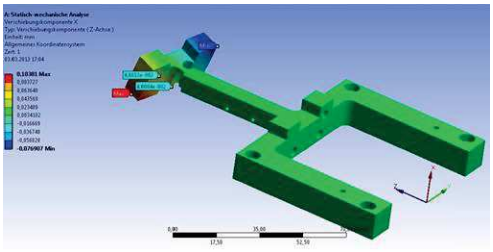

Fig. 2 Maximum deflection on the pitch axis

4 Results

To validate the results of the FEM simulation a mirror is placed at the front of the fixed solid state hinge. Under a defined angle a HeNe-laser radiates on the mirror and is reflected on a wall. At the maximum deflection angle of the solid state hinge the movement of the reflected laser beam is measured and converted to the according angle of the solid state hinge. The achievable maximum angles are ± 0.2170° on the x-axis and ± 0.2952° on the y-axis, see Tab. 1. Thus, the experiment confirms the FEM calculations relating to the deflection angle. The difference between the simulation and the actually measured rotation angle are differing about 1 %.

	FEM-simulations	Experimentally measured
x-axis	0.21676°	0.2170°
relative error	-	1.27 %
y-axis	0.29856°	0.2952°
relative error	-	0.12 %

Tab. 1 Comparison between simulated and measured deflection angles

Experiments have also been performed by aligning a pre-aligned output coupler of a microslab laser with an average output power of approx. 3 W (λ = 1064 nm). In order to find the optimal position of the output coupler the procedure works iteratively, depicted in Fig. 3. The first step is a low-resolution x-scan (x-axis: 37 milli-degrees/step; y-axis: 27 milli-degrees/step) carried out a large-area. The determined maximum output power in this first iteration step is 1.24 W. In two further scans the scanning area is reduced in each step (zoom in), also the step size to a minimum of 0.54 milli-degrees/step on the x-axis and 0.74 milli-degrees/step on the y-axis. Furthermore, the scanning method changed from an x-scan in the first step to a meander scan to cover the whole field of interest. After three iterations, an output power of P_{max} = 3.24 W is measured. An increase of approximately 260 % compared to the beginning of the adjustment process.

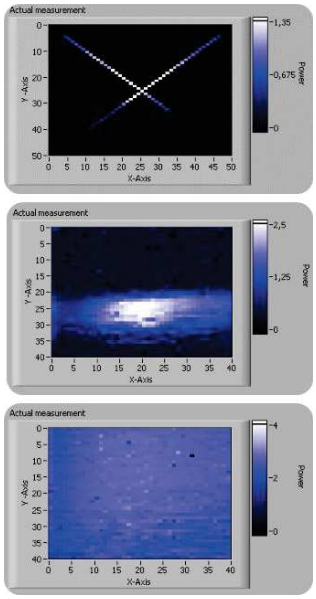

Fig. 3 Steps to find the optimum set-point; magnification of the relevant section in every step

5 Conclusion

The developed tool for the alignment of the output-coupler is able to align and realign the output coupler to reach the maximum laser output power. An angular resolution of less than two milli-degree has been achieved due to the use of piezo actuation in combination with a solid-state hinge. The tilting section on both axes of the solid state hinge (pitch/yaw) is larger than ± 0.1° which is sufficient for a fine positioning of the output coupler. The verification of the developed alignment tool has been performed by the alignment of an output coupler of a microslab laser.

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References

[1] T. Bauer, Aufbau und Verbindungstechnik für Mikrooptische Systeme und Module, Jenoptik Polymer Systems GmbH (2008).

[2] S. Haag, T. Müller, C. Brecher, Toolchain concept for the automated assembly of micro-optical systems, in: SPIE Photonics Europe, Brussels, Belgium, 2014, 91300S.

[3] P. Loosen, R. Schmitt, C. Brecher, R. Müller, M. Funck, A. Gatej et al., Self-optimizing assembly of laser systems, Prod. Eng. Res. Devel. 5 (2011) 443–451.

[4] C. Brecher, R. Schmitt, P. Loosen, V. Guerrero, N. Pyschny, A. Pavim et al., Self-optimizing approach for automated laser resonator alignment, Optics and Lasers in Engineering 50 (2012) 287–292.