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Handling and mounting of microoptical components

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ABSTRACT

The manufacturing of beam shaping optics consisting of two or more microoptical components in a hybrid microsystem places high demands on the assembling process for positioning accuracy making a manual alignment process inadequate. The basis for the micro-assembly forms a robotic system. This robot makes it possible to handle, to grip and to join the components with very small position deviations and to apply very small drops of adhesives. The dispensing of adhesive drops of approximately 1 nl volume is an essential part of the task.

Subject terms: micro-optics, micro-handling, micro-mounting, micro-robots, bonding of micro-optics

1. THE AIM

Microoptical components are to be produced with different technologies and in some parts with a very good quality /1/. Currently the developing institutes and the producer factories are restricted to making single components.

Recently better solutions to the problems inherent to hybrid microoptics make possible increasingly lucrative applications in this area, for instance:

- beam-forming of light sources for laser-diodes, especially for high-power laser-diodes, possesses a great application potential. Due to high variety of emitter configurations, there are no standard lens-configurations.
- high-precision measuring techniques, for example Shack-Hartmann-Sensor, which need special lens-arrays
- coupling between lightsource, modulator and optical fibre and coupling between fibre and detector. This question is increasingly important especially for optical communication engineering.
- an increasing spectrum of beam deflection elements, switches and modulators, necessary for a set up of movable microoptic arrays.

The named applications need not only single microoptic components, also more or less complicated microoptic systems, in some cases built in a micromechanical system. The installing of several microoptical components into proper relationship such as in micromechanical system is an unsolved problem and interferes with the accelerated introduction of microoptical systems. Manual activities involve using the microscope and a pair of tweezers. The aim is to build a basis for a flexible and automatic installation in the field of microoptics, so that the small and medium-sized companies can produce the optical/opto-elektronical microsystems economically and with high quality.

For the installation of hybrid microsystems the compliance of positioning tolerances should be between 10 µm and 0,1 µm The angular tolerances are between one arcsec and several arcsec. This accuracy can only be realized in the future in an automatic process, where the potential for human error is minimized. In order to achieve this aim, we have to develop several processing steps:

- the preparation of the single components (optical elements, mounts etc...)
- the transport and adjustment movements including transfer of the microcomponents with spe?ial grippers
- position-identification, measurement of positioning and creation of software for the functioning of microoptical components and for the precision-adjustment of the components
- the final mounting and fixation of the components.

2. THE ASSEMBLY JOB

Micro-optics are used frequently to collimate the light of laser-diodes and afterwards to focus a circular light bundle in a plane beam (for example on a fibre end or a laser crystal). The light-bundle is emitted from an edge-laser diode and it is known that the divergence of the bundle is in to two vertical directions. The astigmatism is strong and depends on the manufacturing process. The acceptance of the bundle lies at $25E < \theta\zeta < 40E$ and $4E < \theta** < 12E$, the astigmatic distance is between 10 µm and 50 µm. To create an elliptical bundle which has a circular cross section or which has a circular beam-waist it is necessary to realize an anamorphotic projection by combining several optic components. Fig 1. shows for example a combination consisting of a GRIN-cylinder-lens and a SELFOC-lens for the focussing of the laser light.

The assembly of optical microsystems is made by alternative methods:

- the joining of optical functional surfaces by adhesives and afterwards the installallation into a protective mount
- the joining of the rim-surface by installation of a precision mount and afterwards final fixing by adhesive or solder.

By the first procedure it is possible to make a necessary distance between the refraction elements by plane-parallel spacer made of glass. However with laser diodes having greater laser-power there is an unfortunate possibility that through light-absorption the adhesive will be destroyed.

The joining of microoptical components with other optical elements causes the danger of position disturbance. Temperature-variation can cause the functioning of the whole system to fail. To compensate variation of temperature, the method of joining should offer suitable alternative constructions using different mount-materials.

When producing semiconductor lasers with beam forming-optics for low output applications it is practical to produce optical components with the first method. The combination of laser diodes with mounts is still to be realized. For both methods it is a problem to fix the elements together during the process of duration of the adhesive /2/.

3. THE MOUNTING ASSEMBLE

3.1. Transport system

For transport reproducability accuracy in the area of sub - µm with microoptical elements, it is necessary to design the precision parts of the adjustment set up very solidly. The introduction from external powers (for example by a manual activity) has to be minimized. Using control drivers at exposed positions guarantees that the auxillary-materials are in proximity to the joining place, inside the free operation space. The necessary assembly-movements and the changing of the tools can be controlled by a precision robotic. For micro-assemblying a robotic system, so called µKroS, is suitable. The µKRoS 316 is a robotic system based on six-axis kinematics with a reproducability accurate to several µm. The characteristics are a high versatility due to large work space, an easy installation including overhead mounting, six degrees of freedom, a tool-changing capability and a close order construction /tab.1/.

Parameters	
working load	< 1 kg
nominal radius	57,7 mm
operating space, spherical	max. 927 mm
operating speed	max. 5 m/s
pose	< 10 mm repeatability
orientation	< 50 µrad repeatability
pose accuracy	< 50 µm
path repeatability	< 30 µm
path accuracy	< 50 µm
pose stabilization time	< 1 s
transient overshoot	< 50 µm
pose resolution	< 1 µm

Tab. 1 Specification of the handling system µkros 316 robotic system /3/

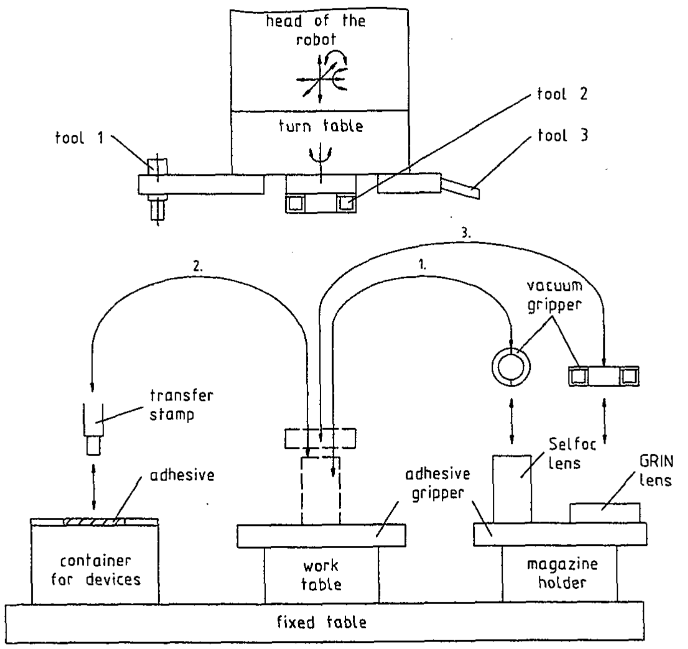

Fig. 1. Control circuit of the robot

Under the assumption that the optical components are joined by adhesive bonding the following assembly steps have to be developed in an automatic manner:

- the first lens has to be picked up from a magazine (for instance a gel pack) and is fixed on a working station
- a small volume of adhesive has to be deposited on the optical surface of the first lens
- the second lens has to be fixed with UV-curing adhesive in an accurate position to the first lens after picking up from another magazine.

The steps two and three have to be repeated, if more than two optical components should be assembled.

3.2. Handling - adjustment

For the handling of microoptical parts a modular conception of grippers has been developed. The following requirements are necessary:

- enough high claw power (hold power > assembly power)
- no damage from the claws
- a small adhesion coefficient between grippers and the object
- a small number of required handling points
- a small freespace for the claw function
- to grip both small parts and larger flat parts
- readjustment during the joining operation
- prevention from pollution of optical funktional surface from claw sediments.

Handling demands will be best fulfilled using the vacuum claw and a pair of micro tweezers with highly adjustable claw power. The tension which arises through the joining operation is a potential problem, if there is to make a readjustment in the adhesive bed. This tension effects the normal power P_N caused by the vacuum and the adhesion-friction R_H . The adhesion from the tension of the claw can be interfered by the weight and inertia power of the acceleration movement and also by the adhesion- and cohesion-power within the system object 1 - adhesive - object 2.

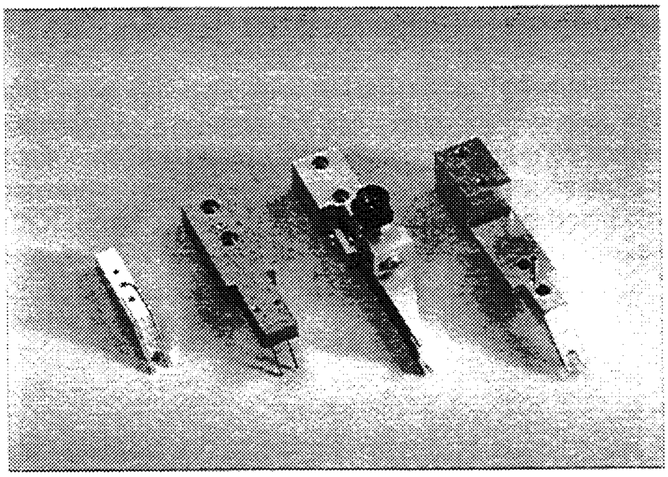

Fig. 2. Variation of sucking grippers

3.3 Joining technique

A successful joining technique uses adhesive to fix components. For optimum optical functioning with positioning tolerance in the order of 0,5 µm - 5 µm it follows that the adhesive needs these properties:

- a short curing time for the primary fixing after the endadjustment
- possibility of curing at room temperature
- minimal shrinkage of adhesives
- low viscosity
- flow and crawl must be within position-tolerance
- adjusted refractive index and transmission.

Favorable application properties for microoptics have adhesives which are harden through UV-irradiation. UV-curable adhesives can easily bond optical components together within a few minutes at room temperature. Among the conventional UV-curable adhesives, epoxy shrinks the least because the reaction involves ring-opening cationic polymerisation. Other UV-cured adhesives such as acrylates and polyesters shrink by more than 6% during curing because the bonding reactions involve additional polymerisation. The fabrication of microoptic modules requires an adhesive that shrinks by less than 2% and has a low coefficient of thermal expansion as shown in Fig. 3.

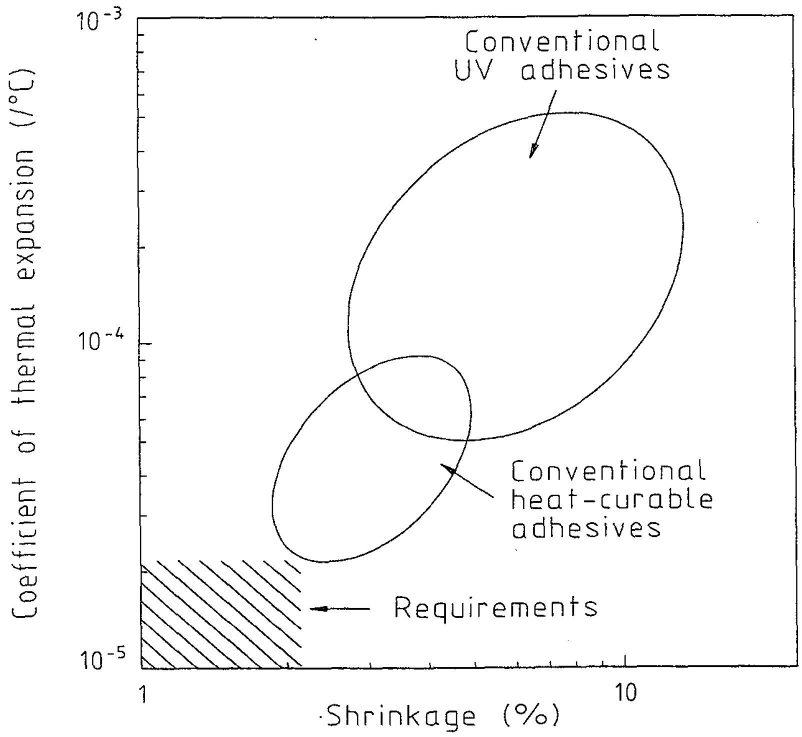

Fig. 3. Coefficient of thermal expansion and shrinkage during adhesive curing /4/

Small joint-diameters require a good adhesion, an accurate position of the drops on the object and a little shrinkage.

For example the volume of adhesive for a 10 - 20 µm thick joint of a fibre-end face requires only 0,5 - 1nl while the joining of a planar with a cylinder-GRIN-lens requires 5 - 30nl. It is impossible to get such small volumina with the conventional measure out principle of piston pumps. An alternative to this is the stamp-transfer-method either a thread inker or a modified ink-jet-technique, the DOD-microdrop procedure. The adhesive drops will be propelled in a high frequence. This method is known as DOD-procedure = „drop on demand". A piezo electric impuls generates the drops out of a fine nozzle (fig. 4).

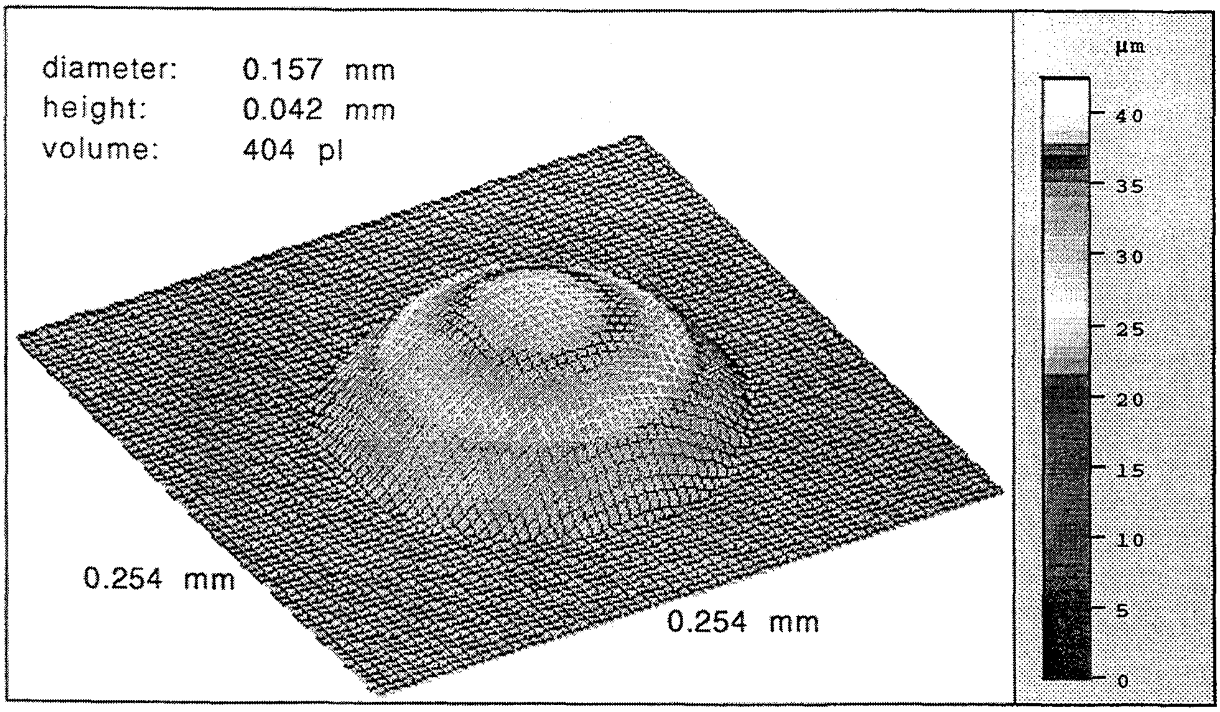

Fig. 4. Adhesive drops, produced by DOD-procedure

The named methods were tested using various materials and procedures. Determination of drop-volumine is a special problem. If the molecular density was known the bigger drops were weighed, but most of the volume measurings were by microscopic image formation or by mechanical feeling of the cured adhesive-drops with a contact stylus apparatus. A noteworthy result was the presentation of very regular drops with the DOD-procedure (fig. 4). The accuracy of the DOD-drop-volume is < 2%. The DOD-procedure is now only useful for solvent-free adhesives with a small viscosity, but with the stamp-transfer-method (fig. 5) it is possible to transfer other adhesives.

The volume of transfered adhesive is dependent on

- the size of the stamp (fig. 5)
- the viscosity
- the surface tension from the adhesives
- the immersion depth of the adhesive-reservoire.

The tolerance of the adhesive volume which is transfered by stamp-transfer is 20 %. A possible cause is the high temperature-dependence of the viscosity of the liquid adhesive. The boundary-tension and the contamination of the sample-surface is temperature dependent, also.

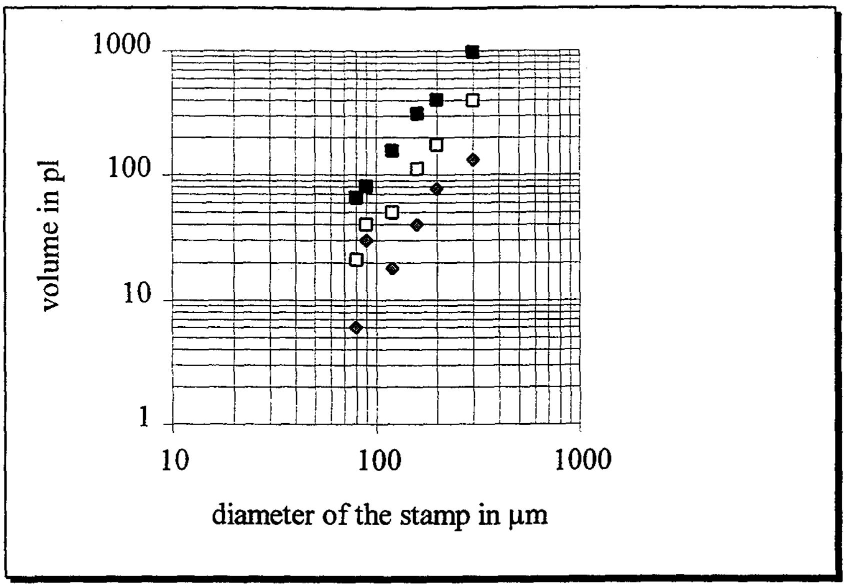

Fig. 5. Stamp diameter related to drop volume
$V(r) \sim r^n$ with $n \approx 2{,}3$

4. ACKNOWLEDGEMENTS

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