Modular System Concept for Ultra-Precision Assembly

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Abstract

This article describes the successful implementation of a modular system concept for ultra precision assembly tasks by means of the accurate alignment of light emitting and receiving modules in front of buried waveguides in optical circuit boards. The constitutive result of a Saxon research project FGM [1] is a modular designed assembling system, that enables vertical fine positioning and gripper integrated angle adjustment in opposition to conventional Surface Mount Technology.

Today these sensitive components are mounted and adjusted predominantly manually under special laboratory conditions. The technical challenge is to develop new methods and assembling components for high-precision and reproducible packaging in an automated assembling process. This is an important step to reduce the fabrication costs drastically and to smooth the way from a pure laboratory method to an industrial solution concept.

1 Problem formulation

1.1 The assemby task

Vertical-Cavity-Surface-Emitting-Laser (VCSEL, see fig. 1) represents a latterly established class of semiconductor-lasers designed for transmission sections from centimeter- to meter-ranges. For transforming the light signal into an electric signal Positive-Intrinsic-Negative-Diodes (PIN) are employed. A key problem in assembling is the accurate alignment of the light emitting or detecting modules in front of the parallel arranged waveguides inside the circuit board. The hot-embossed buried waveguides for that application feature a cross section of 45 x 45 μm^2. The VCSEL surface has a diameter of 10 µm. The pitch between the 12 single waveguides is 250 µm. The surfaces of the detecting side (PIN) are approximately 70 µm in diameter. The tolerance in vertical and horizontal direction is taken as ± 2 µm.

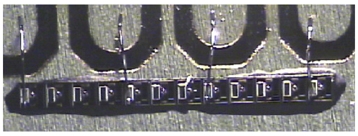

Figure 1: camera view on a VCSEL

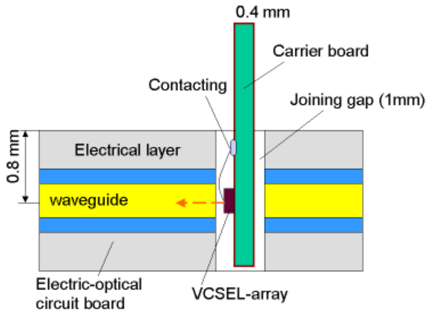

Figure 2: direct light coupling principle

The most far away VCSELs (in this case number 1 and 12, fig. 1) should be able to launch the complete optical output into the waveguide. The outcome of this is a narrow angle tolerance with ± 0.05 degree. The major technical challenge is arising thereby, that the center of rotation for correcting the angle is on the gripped component and that the center of the axis of rotation is mechanically not available. The assembly strategy provides a multi-stage catching and adjusting of the emitter and detecting modules with following measurement and correction of the current position.

1.2 State of the art

Today's commercially available Surface assembly systems are not able to countersink accurately defined components in vertical direction. There exist no packaged VCSEL-arrays with guiding structures. As part of a current german BMBF project NegIT [2], a design of an optical coupling in the daughter card and board backplane interfaces was developed for first tests. This Negit-Pin is not available on the market now. Commercially available 6-axis-roboter accomplish a repeatability of ± 50 µm, partially as well ± 20 µm. Special cartesian or portal robots with a accuracy < 5 µm are offered by Sysmelec, SPI and LPKF [3]. A precision gripper with integrated tilt function is not available for this devices on the market. Goniometers rotate an object around a point located above the center of the top platform (www.newport.com). The heaviness of goniometers is not usable for precision gripper units.

2 The modular micro-assembly system

The master concept of the precision assembly system is based on a 4-axis positioning system, similar to a measuring device that guides the modular gripper unit.

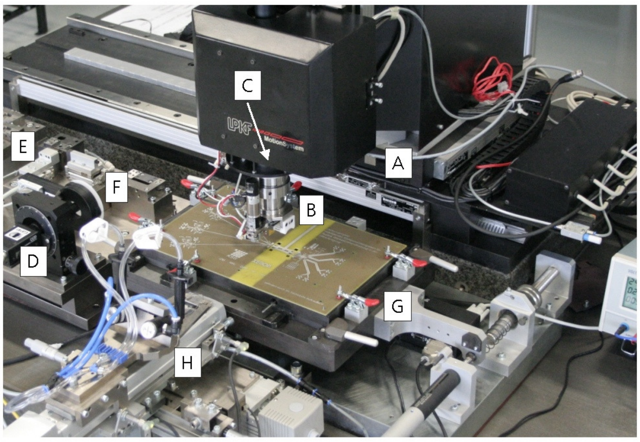

Figure 3: Test rig at Fraunhofer IWU

The photo above shows the main components like precision-axes (A), the tilt-gripper (B), an integrated camera (C) and a second, fixed measuring camera (D). In front of the assembly system, magazines for the modules (E), a fine alignment station (F) and a circuit board chuck (G) are arranged. Also a new developed dispensing station (H) by *Xenon* with 3 precision-axes is placed there. A new developed position correction control system is embedded in the motion control of the assembly system. The gripper unit consists of two pneumatical micro finger grippers, which are adjusted in a V-shape to keep the center free for a camera view. The novel tilt-module's kinematic bases on a special designed solid joint structure (made of POM=polyoxymethylene) at a pipe-shaped segment [4]. This tilt-module is used to transform a linear actuator stroke into a rotation with a tool center point outside the kinematical structure. A mini-servo drive working with the HarmonicDrive ® principle enables a high resolution positioning in an automated assembly procedure.

3 Results of experimental work

Based on the described system concept a test rig was built up at Fraunhofer IWU in Chemnitz to demonstrate the micro-assembly process. In several equated experimental series complete assembly-flows were proven and altogether 10 samples of the electric-optical circuit board could be finished successfully (fig. 6) [5]. The following high-frequency tests resulted performances in light transmission with a data-rate of 2.5 Gigabits per second. The assembling accuracy (including dispensing and hardening) could be verified with 5 micrometers. The accuracy of positioning the VCSEL- or PIN-modules was demonstrated with $\pm 2\ \mu m$. The targeted precise solution in angle adjustment was solved with a repeatability of $\pm 0.003°$.

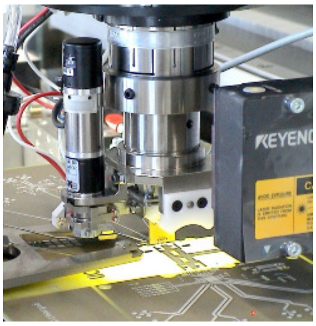

Figure 5: Assembling a VCSEL-module

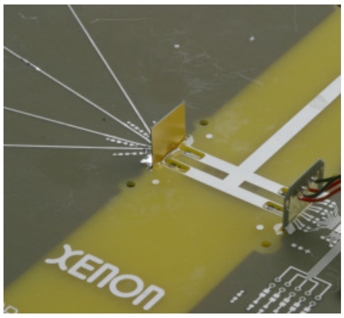

Figure 6: Finished optical board

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