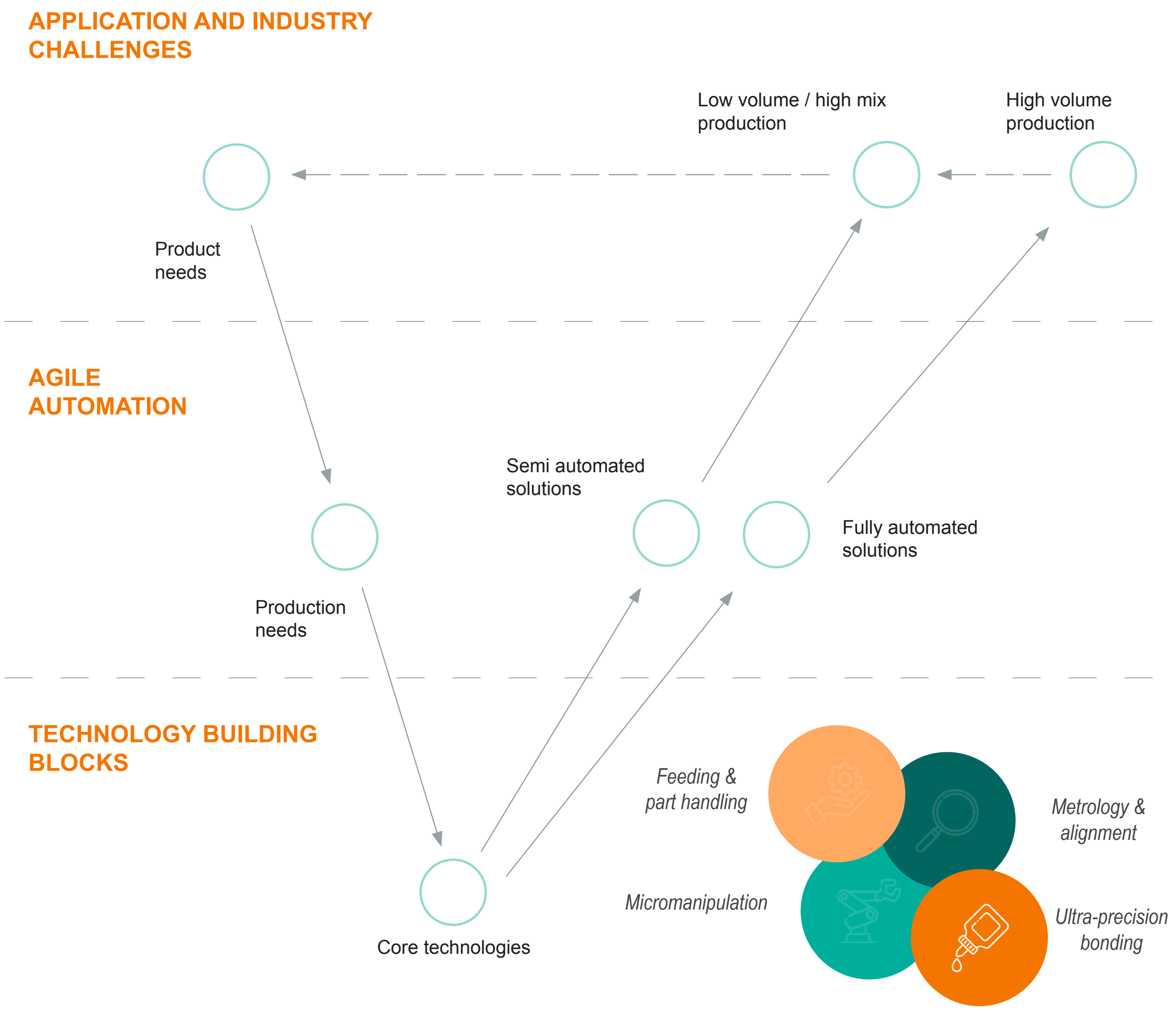
UNIVERSITY OF TWENTE. | FRAUNHOFER INNOVATION PLATFORM FOR ADVANCED MANUFACTURING

AGILE SOLUTIONS

FOR AUTOMATED PRECISION ASSEMBLY

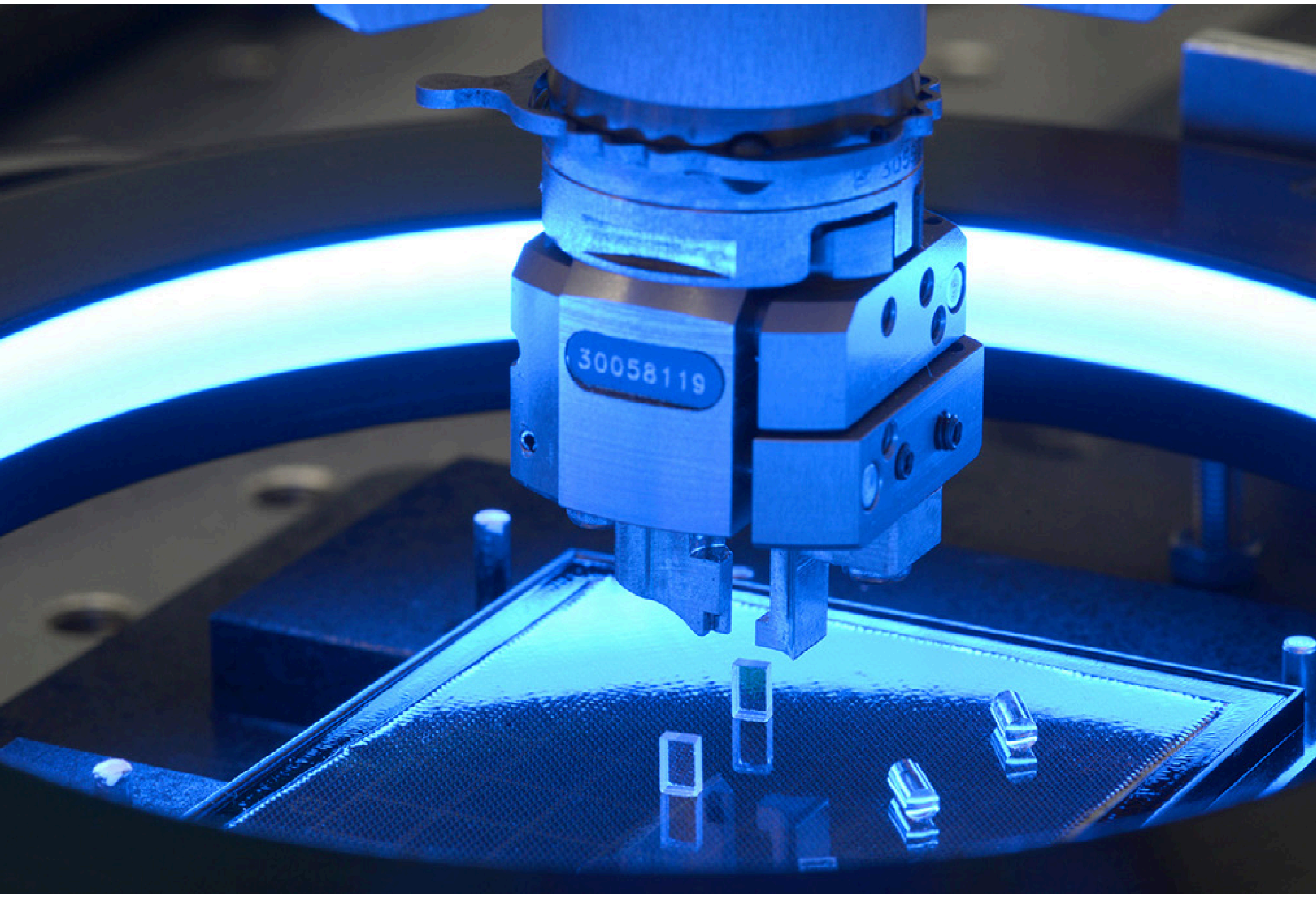

APPLICATION AND INDUSTRY CHALLENGES
Low volume / high mix production
High volume production
Product needs
AGILE AUTOMATION
Semi automated solutions
Fully automated solutions
Production needs
TECHNOLOGY BUILDING BLOCKS
Feeding & part handling
Metrology & alignment
Micromanipulation
Ultra-precision bonding
Core technologies

CONTENT

PRECISION ASSEMBLY

CHALLENGES IN INDUSTRY

Realizing and launching novel products requiring precision assembly processes creates major challenges for industry. The development of new products processes goes along with high risks, is time consuming and requires extensive expert knowledge in manifold domains. The ongoing miniaturization of components and systems, as well as increasingly small tolerances to optimize the systems function create a high demand for robust and sophisticated assembly and packaging solutions. Especially in the field of optical systems, besides the mechanical fit of components especially their optical function needs to be optimized.

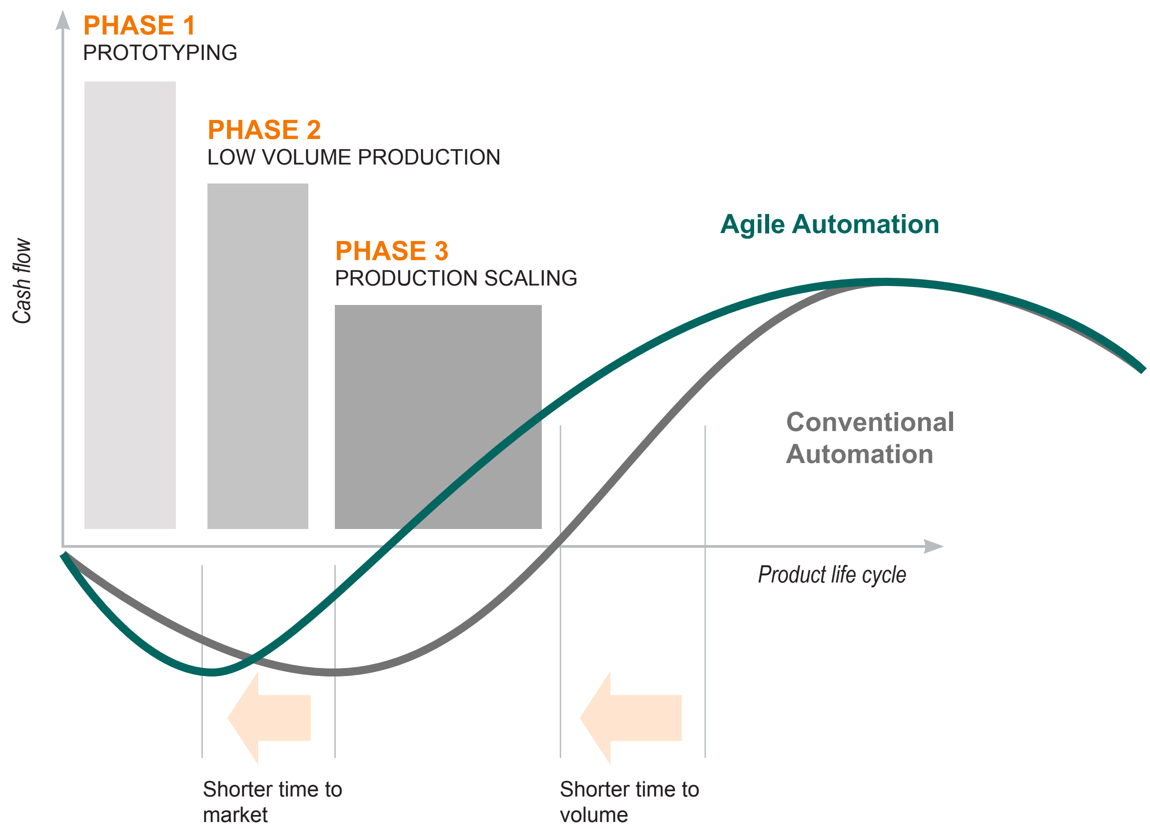


Typically, the development of the product and the production equipment are closely linked and as time is often pressing, both processes should ideally be parallelized. From an economic perspective, the acquisition of novel packaging and assembly equipment, which will also be compatible with scaling production, goes along with high investments, is risky, and thus can be a showstopper for innovative products or the automation of existing production.

We have been dealing with these questions for many years now. Together with our industrial partners we elaborated and optimized a solution, which is the answer to these questions:

— A modular project architecture based on a flexible machine platform, enabling an agile automation of precision assembly processes —

With this brochure we would like to give you an overview about our solution as well as our services. After a general introduction of automated precision assembly we would like to present you our flexible machine platform and our agile project architecture. Some case studies should enable you to classify your product with respect to our solutions or services.



PRECISION LIMITATIONS DEPENDING ON ASSEMBLY TECHNOLOGY

POSITIONING BY ACTUATOR ACCURACY	POSITIONING BY MECHANICAL ENDSTOPS	ALIGNMENT BY GEOMETRIC FEATURES	ALIGNMENT BY GEOMETRIC FEATURES	
Presentation Precision Gripping Precision				*Feeding & part handling*
	Part Accuracy Endstop Accuracy	Part Accuracy Accuracy of Measurement System	Accuracy of Measurement System	*Metrology & alignment*
Positioning Accuracy		Positioning Accuracy	Positioning Accuracy	*Micro manipulation*
Bonding Reproducibility	Bonding Reproducibility	Bonding Reproducibility	Bonding Reproducibility	*Ultra-precision bonding*

SUM OF ERRORS

Source: Beckert 2005, Ebene Keramiksubstrate und neue Montagetechnologien zum Aufbau hybrid-optischer Systeme

PRECISION ASSEMBLY

FROM HIGH-SPEED PASSIVE TO PRECISION ACTIVE ALIGNMENT

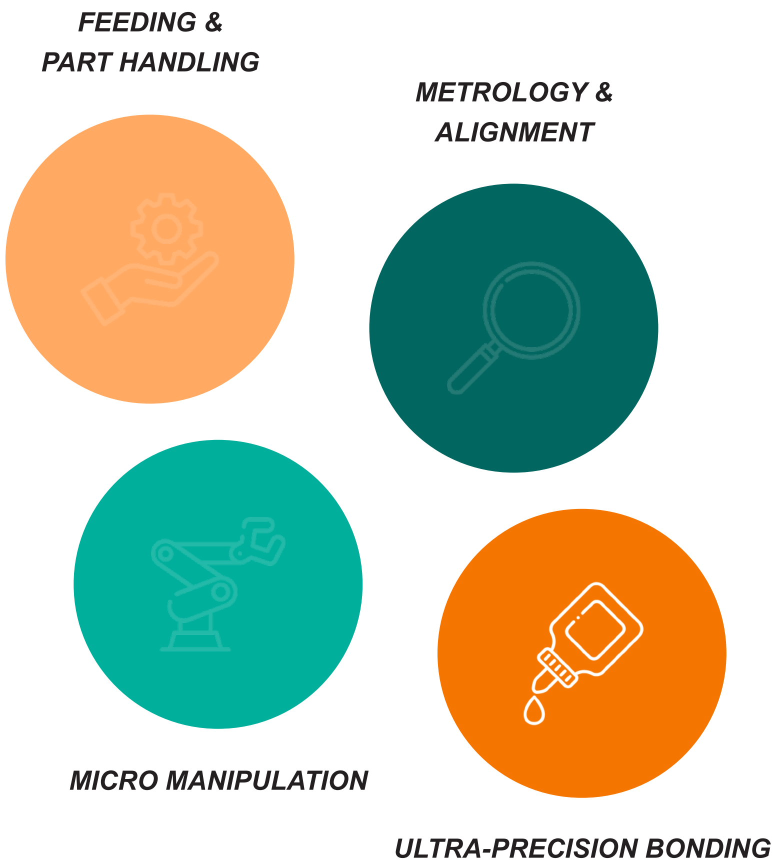
The production of modern, highly integrated and miniaturized products requires assembly processes and technologies that go beyond the classical approaches of macroscopic assembly. These highly accurate processes and technologies describe a completely separated branch of production technology: Precision assembly.

In every assembly process, the achievable accuracy is given by the overall error sum of the handling operations. In the case of a »blind« pick and place process, the sum over all errors is maximal compared to other process. By using mechanical end-stops, these errors can be compensated, but new errors occur in this case, due to the tolerances of the end-stops themselves. To achieve the required tolerances in high-precision assembly, closed-loop alignment processes, which continuously capturing and evaluating the actual situation of components, are used.

In a passive alignment process the relative position and orientation between two components is evaluated and adjusted. Typically measuring devices which are used for these alignments are distance sensors like confocal, interferometric or laser sensors. In flexible assembly systems imaging sensors like cameras are used. With the help of digital image processing component features like edges, corners or curves are extracted of the captured scenes. The accuracy of a passive alignment is influenced by the illumination of the scene and the appearance of the components. For this reason, it is important to perform a product review with respect to precision assembly prior to implementing an automated production process. With passive alignment processes, sub-micron accuracies can be achieved. Even if the components are positioned with this precision, there is still an error left which can't be compensated: the tolerances of the components themselves.
In order to minimize this last remaining error, active alignment processes are used.

In an active alignment process the function of the overall system is continuously captured and used as feedback for closed-loop positioning. This means, that the overall system is operated in an application related way while the alignment is being performed. On the example of a laser assembly, an optical component is aligned in the radiation of the active laser source during the assembly. The performance of the overall system in this example is evaluated by the beam profile or the wave front at a certain position in the optical path. For evaluation of the system performance, like in the described example, a special metrology setup is necessary.
This setup defines the sensitivity of the measurement and thus the precision which can be archived with the active alignment.

AUTOMATED PRECISION ASSEMBLY



TECHNOLOGY BUILDING BLOCKS

OVERVIEW

For the development of a robust automated assembly process, it is necessary to think in an overall process chain. Every step in this chain can influence the following steps and provides requirements to the steps before. For example, if the part feeding is performed with reduced precision, the uncertainty after gripping needs to be compensated by the following alignment process or by capturing the position of the components on the carrier before pick-up. In order to save this extra process steps, the accuracy of part feeding must be increased. This can be achieved by applying component carriers with precisely manufactured cavities that are precisely referenced to the machine. However, offering such high feeding repeatability comes with a price. Due to the precise manufacturing process these carriers are typically rather expensive.

Along the process chain various technological functions influence the product. These technological functions are realized by technological building blocks like technical equipment or software. Choosing and developing the right technological building blocks is a fundamental condition for success and is always a trade-off between process time, flexibility and price. From our view on precision assembly, we classify the variety of technological building blocks as follows:

- feeding and part handling
- metrology and alignment
- micromanipulation
- ultra-precision bonding

In the following chapters we will go deeper into the explanation of these technological building blocks and the challenges for their implementation.

TECHNOLOGY BUILDING BLOCKS

FEEDING AND PART HANDLING

In assembly automation, handling plays a central role and it has a major impact on certain key metrics of production such as autonomous production time, cycle time and yield. The crucial aspects of a part transfer process are the storage solution and the gripping operation. In some cases, also the part placement may be a challenge.

For part transfer, two levels need to be distinguished: Firstly, parts need to be transferred from the manufacturing or inspection area to the assembly area (inter-ma- chine transfer). This may even require transportation or shipping of the parts between production sites. Secondly, parts need to be transferred between work stations within one production cell or line (intra-ma- chine transfer). More distinctions needs to be made regarding the multiplicity (single part or batch-oriented part transfer) and the state of order (ordered, chaotic or in between). For inter-machine part transfer, magazining concepts need to be evaluated. Single-part transfer between machines is often considered not to be economically viable. Typically, batch-based part feeding processes for optics and electronics include form-fitting waffle trays or adhesive Gel-Paks ®, blister tapes or adhesive tapes, and wafers. For intra-machine transfer of single parts, there are two main conceptual approaches. On the one hand, parts may move through the production line on a workpiece carrier. On the other hand, single parts may be picked by a gripping tool. Using workpiece carriers, it is recommended to integrate a commercial solution and to adapt the application to the corresponding form-factor.

In micro- or optics-assembly additional requirements and challenges arise from the nature of the parts and the corresponding alignment and bonding processes. Main aspects include small gripping areas, sensitive surfaces, complex geometries. These aspects influence design criteria for magazines and grippers regarding shape, material and function. In the case of electronic parts, effects like electrostatically discharges (ESD) need be taken into account.

OUR COMPETENCIES

We and our partners on system integration level such as AIXEMTEC GmbH provide services and solutions regarding the feeding and handling of micro-parts and optics considering the above mentioned aspects and criteria. From part carrier (e.g. waffle-tray) and gripper design/manufacturing to the conception and implementation of full handling and part feeding solutions. The added value for customers working with us is our deep understanding and long-year experience of the challenges arising from micro- and optics assembly.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TECHNOLOGY BUILDING BLOCKS

METROLOGY AND ALIGNMENT

Alignment is the critical, final step in an assembly process, before the components are bonded. Based on the required tolerances, different strategies are used for this process step. In precision assembly, passive or even active alignment is a common choice. In most cases, special, customized metrology setups are necessary to achieve such processes.

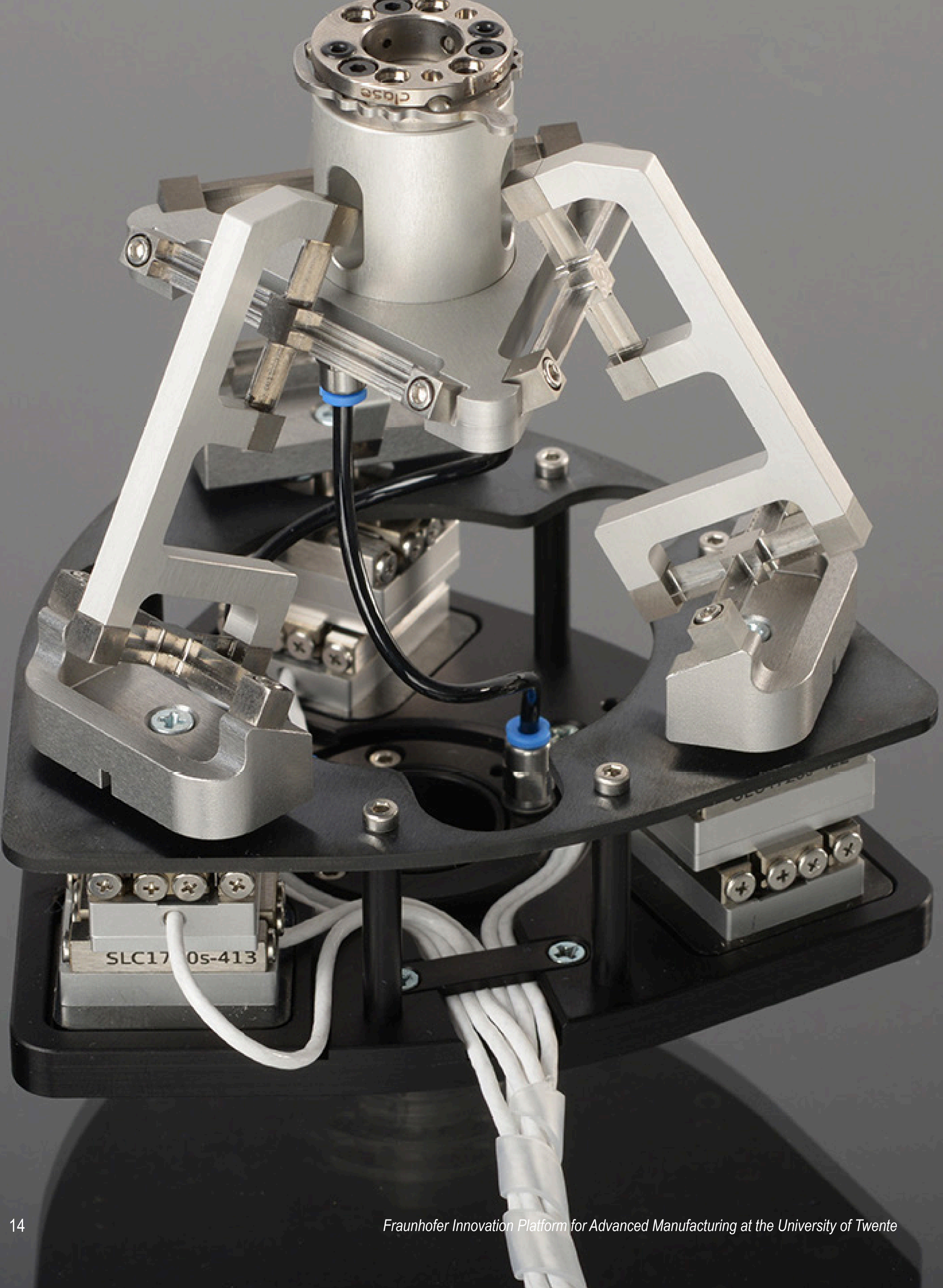
For an image-based passive alignment process, cameras are used to observe the relative position of the components. To measure distances and angles correctly, these cameras are either equipped with a telecentric lens or a standard lens which is digitally corrected. Relevant component features within the scene, like edges or corners, are extracted via image processing routines from the captured images. The measurement accuracy or the signal to noise ratio is mainly dependent on the illumination of the scene. Furthermore, a good illumination makes life easier for the image processing. Thus, the selecting of the right direction, color and shape of the illumination beam is one of the important tasks while implementing a metrology setup for a passive alignment.

In an active or function-oriented alignment process, the function of the overall system is continuously evaluated. That means, the overall system is operated in an application related way during alignment. For evaluation of the system performance, a special, customized metrology setup is necessary. This setup defines the sensitivity of the measurement and thus the precision which can be archived with the active alignment. The algorithms that are used for active alignments are either model-based or non-model-based.

Model-based alignment algorithms with linear controllers are robust and can perform precise alignments in just a few seconds. For non-model-based approaches methods of the classically multidimensional optimization like gradient decent are used. Nowadays, brute-force approaches are often used in production. Because this methods scanning and evaluating a whole range of positions and orientations, the process time is unnecessarily large and gives an enormous potential for optimization.

OUR COMPETENCIES

Our core competency are sensor-guided passive and active alignment processes for precision assembly. We have implemented and optimized a lot of image- based passive and active alignment processes including the necessary equipment and metrology setups. Our services range from feasibility studies and system analysis, which we perform with our self-developed tools, to the design and integration of turnkey machine modules for metrology, comprising sophisticated processing algorithms. Benefit from our extensive know-how and upgrade your equipment through our metrology and alignment solutions.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TECHNOLOGY BUILDING BLOCKS

MICROMANIPULATION

Micromanipulation of components is one of the basic tasks in micro-assembly-processes. The increasing automation of the assembly of ever smaller optical systems often requires, that highly accurate alignment instruments, so called micro-manipulators, are applied for aligning the components. In order to fulfill these requirements, we developed a high-precision and flexible micro-manipulator.

The »Commander6« (C6) micro-manipulator is the key component of most of our automated micro-assembly processes. With its six degrees of freedom, the compact C6 covers large traversing ranges combined with very high motion resolution and repeatability. The kinematics of the C6 manipulator consists of a parallel structure and is based entirely on solid-state flexures. As actuators piezo stepping motors are used, which combine an extremely high motion resolution of a few nanometers with relatively large travel ranges. Due to this setup, the whole structure of the »Commander6« is elastically deformed as the piezo actuators move. This makes it possible to transfer the smallest lossless to the end effector and avoid unwanted effects such as backlash or hysteresis.

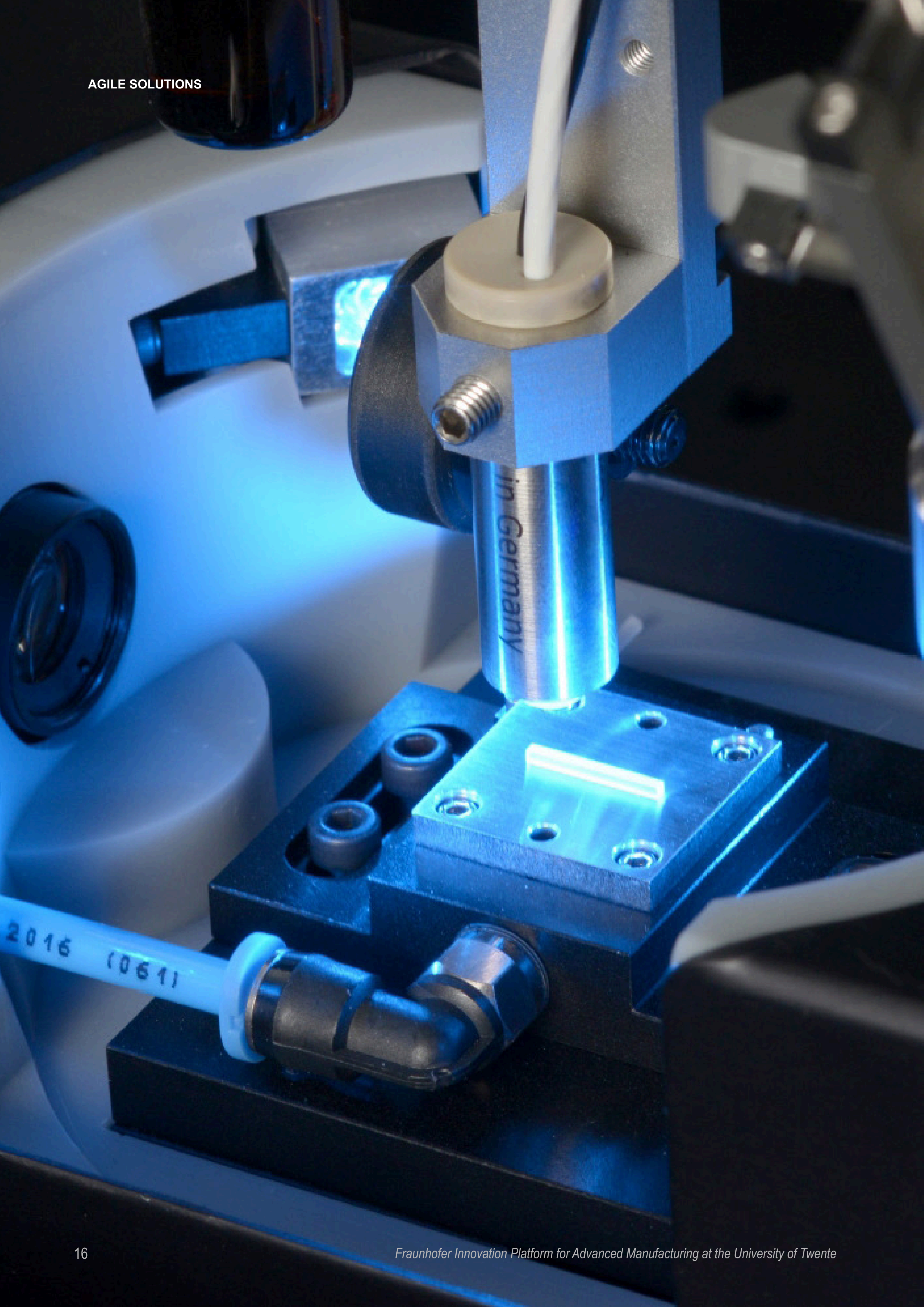
The C6 is the result of a joint project with the Fraunhofer Institute for Laser Technology ILT, in which various aspects of automated laser assembly were being researched. The main outcome of this project is not the C6 in its standard form, which covers the most alignment tasks. It is the mathematical design rules which allows us to apply the basis structure of the C6 for solving different alignment problems. For LiDAR or DOE assembly, the C6 was designed in a special dome setup in order to be able to capture radiation with a large opening angle via measuring systems to perform an automated active alignment.

Technical data of the Commander6 micromanipulator:

- » Six degrees of freedom
- » Compact design (<100 x 100 x 100 mm3)
- » Large travel ranges (> ± 3 mm)
- » Very small increments, high motion resolution (closed-loop <50nm, <5 µrad)
- » Very high repeat accuracy (<0.3 µm)

OUR COMPETENCIES

Due to its rigid structure and precision, the »Commander 6« is the ideal micromanipulator for closed-loop-alignment processes. Based on virtually all kinds of requirements (concerning assembly space, working space, output and performance) we are able to customize and extend the C6 with grippers, as well as UV-hardening units to provide our customers a highly integrated, all-round assembly-tool.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TECHNOLOGY BUILDING BLOCKS

ULTRA-PRECISION BONDING

Micromanipulation and measuring techniques allow for the highly accurate positioning of smallest components and optics within a few nanometers. However, the bonding process sets limits to the repeatability which can be achieved in industrial and automated production of precision systems. In automated micro-assembly, controlled metering of the adhesive is essential to the quality of reproducible bonding processes.

Alongside high-precision metering and positioning, curing is one of the key elements in ensuring reproducible joints with UV-hardening adhesives. Different manufacturers of adhesives use various measuring methods to determine adhesive shrinkage. As a result, it is impossible to compare shrinkage on the basis of the data provided by the manufacturers.

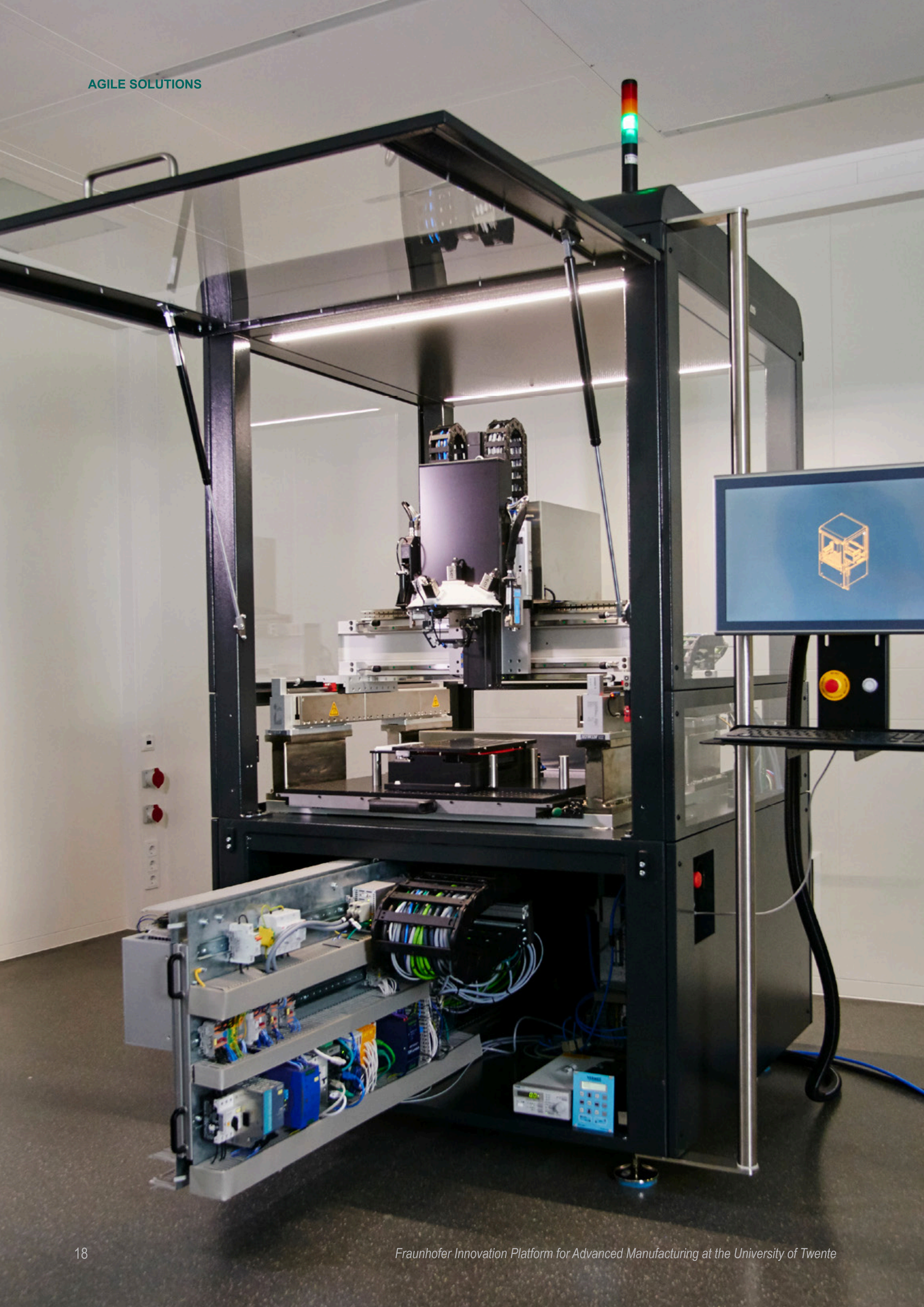
If components are attached via soldering, thermal stress is applied to the compound, leading to mechanical deformations after cooling. A classic example for this is the so called »smile« of a high-power-diode laser-bar. To deal with uncertainty's of the bonding process, different strategies are used in practice. By applying controlled misalignments before bonding, the shrinkage effect can be taken into account, so that the components reach the desired positions after bonding.

OUR COMPETENCIES

We have acquired in-depth expertise in the adhesion process in the course of numerous projects related to prototype assembly and fully chained assembly processes. We apply this knowledge to control the properties of the adhesives and to develop robust bonding processes for automated precision assembly.

To ensure that the adhesive is dispensed with precision, we developed a characterization and calibration station which can be integrated in existing equipment to determine the volume of individual drops of adhesive as they fall, down to a droplet volume of only a few picoliters. Additionally, the position of the dispenser can be determined with an accuracy level of only a few micrometers. As a result, the correct amount of adhesive can be delivered to exactly the right point.

In addition to the development of concrete solutions, we perform own characterization of available adhesives. We measure adhesive shrinkage in linear and volumetric operations, record the measurements in an internal database and compare them. Furthermore, we are able measuring shrinkage kinetics over time and evaluate minimal curing times by characterizing shrinkage behaviour with different curing parameters. Our adhesive characterization allows us to identify the most suitable adhesive for each application. We will be happy to measure your sample – because knowledge as to the behavior of the material used makes it manageable and enables automated assembly with highest precision.



OUR APPROACH — *AGILE AUTOMATION*

FLEXIBLE PRECISION ASSEMBLY PLATFORM

Building a customized machine tool does not mean having to re-invent the wheel. However, the cost-effective micro- and high-precision assembly of small and medium-sized batches or even single prototypes requires flexible assembly solutions. This is why we developed a system construction kit for recurring challenges of sophisticated assembly technology. This kit features a modular machine setup and an open software architecture for control.

— One machine platform serving R&D and production —

The key problem we want to address with this solution is the following: The production of first prototypes in precision assembly requires closed-loop alignments with customized or third-party metrology, ultra-precision bonding and precise manipulation. For ramp-up, the tools and the novel process know-how from this semi-automated prototype manufacturing as well as first implemented software routines need to be transferred from a lab-setup to a production machine. Our solution eliminates this technology transfer by enabling the prototypical and small and medium-sized production to take place on the same machine platform. This makes the platform an ideal tool to guide and assist manufacturers from the early R&D phase to the automated series production.

The machine platform comprises a gantry with four degrees of freedom, a modular industrial control system and mechanical, pneumatic and electric interfaces. Loading, handling, manipulation and alignment solutions as well as systems for the dispensation and curing of the adhesives complete the assembly unit. The machine platform and the software have been designed in such a way that our clients can extend and upgrade it according to their evolving needs and requirements. This allows manufacturers to react quickly and flexibly to the changing demands of their markets.

— The worlds first open- source assembly machine —

Based on the modules that we develop, we can quickly and cost-effectively build up customized micro-assembly and high-precision assembly facilities, providing our clients with the machine components and the controlling systems that they require to manufacture newly designed as well as existing (but until then manually produced) systems. We continuously develop new and reusable tools as well as process modules to provide a wide range of technological building blocks for our customer's applications.

OUR APPROACH — *AGILE AUTOMATION*

MODULAR PROJECT ARCHITECTURE

Our flexible machine concept enables new approaches for projects aiming at precision assembly automation. Its modular and reconfigurable architecture enables us to parallelize product, tool and process development and offer our customer a reliable solution from lab scale to fabless volume production. With a unique phased approach, named »agile automation«, we accompany our customers over the entire product implementation process while teaming-up with industrial system integrators to ensure a flawless industrialization of the developed solutions.

Starting with project phase 1 at TRL 3 with an automation friendly product design and realizing first prototypes in our labs we can help to accelerate the product development phase and avoid costly iteration cycles. The qualification of new tools and principles like metrology equipment, component-handling tools like magazines and grippers over the engineering of precision bonding and quality assessment routines can be scope of feasibility studies which we carry out before high investments into equipment need to be taken. Taking into account required productivity, yield, autonomous production time, etc. we identify potential dealbreakers in the earliest possible development stage.

In the following project phases 2 and 3 we first develop a detailed automation concept, design and realize require tools and demonstrate core functionalities. By subsequent integration into our flexible machine platform, we can then achieve a full prototypical setup that enables us to prove feasibility of the chained

PHASE 1 (TRL 3 - 4)
FEASIBILITY STUDY

- » Assessment of dealbreakers
- » First (scalable) concepts -
- » Prototypical demonstrator

GOAL
Show feasibility of automated assembly of novel system, eliminate high risks at low costs.

FREEZE OF REQUIREMENT SPECIFICATION

- » Quantity
- » Variants
- » Quality level
- » Yield
- » Service level
- » ...

PHASE 2 (TRL 4 - 5)
CONCEPT AND TOOL DEVELOPMENT

- » FMEA
- » Elaborate different concepts
- » Assess and select best concept
- » Realise key enabling tools
- » Demonstrate key processes
- » Perform first process tests

GOAL
Develop final automation concept and demonstrate key processes, realisation of key enabling tools

PHASE 3 (TRL 5 - 6)
PROCESS DEMO

- » Implementation of new tools
- » Chaining of process blocks
- » Final evaluation and revision of concept
- » Test production of zero series or small series

GOAL
Design specifications for industrial grade assembly tools

production processes, and reach first test production of zero series meeting TRL 6. An iterative evaluation and optimization of this prototypical production finally delivers a detailed requirement specifications for the industrial grade solution.

For the industrialization in project phase 4, we typically hand over the developed solution to one of our system integration partners like AIXEMTEC GmbH. They help to launch the novel product, mature processes and eventually proceed to a next generation of these tools, which are industrial grade and move to TRL 7. The industrialized system can be transferred to our customer for further integration into the production environment. Alternatively, our integration partners can offer job shop manufacturing of first series, minimizing investment costs.

In project phase 5 we focus on process optimization with regard to process capability, productivity or even system adaptivity for product variation. Some customers prefer to perform this phase by themselves in order to secure product specific processes know-how. We and our system integration partners support the optimization process with efficient methodologies and best practice experiences. Our track record for successful projects is long and includes projects from automotive industry, medical applications, consumer electronics, industrial and defense related high-power diode laser applications or even tele- and datacom applications with fiber-optical systems.

Our main advantage is speed - due to the modularity and our experience we manage to leverage technologies from TRL 3 to 7 in some cases in 12 months. At the same time, the risks for our customers are limited - the efforts of each project phase are kept at a minimum and clear milestones pave the path to the successful automation of novel or existing product assembly.

PHASE 4 (TRL 6 - 7)
INDUSTRIALISATION FOR REACHING REQUIREMENTS

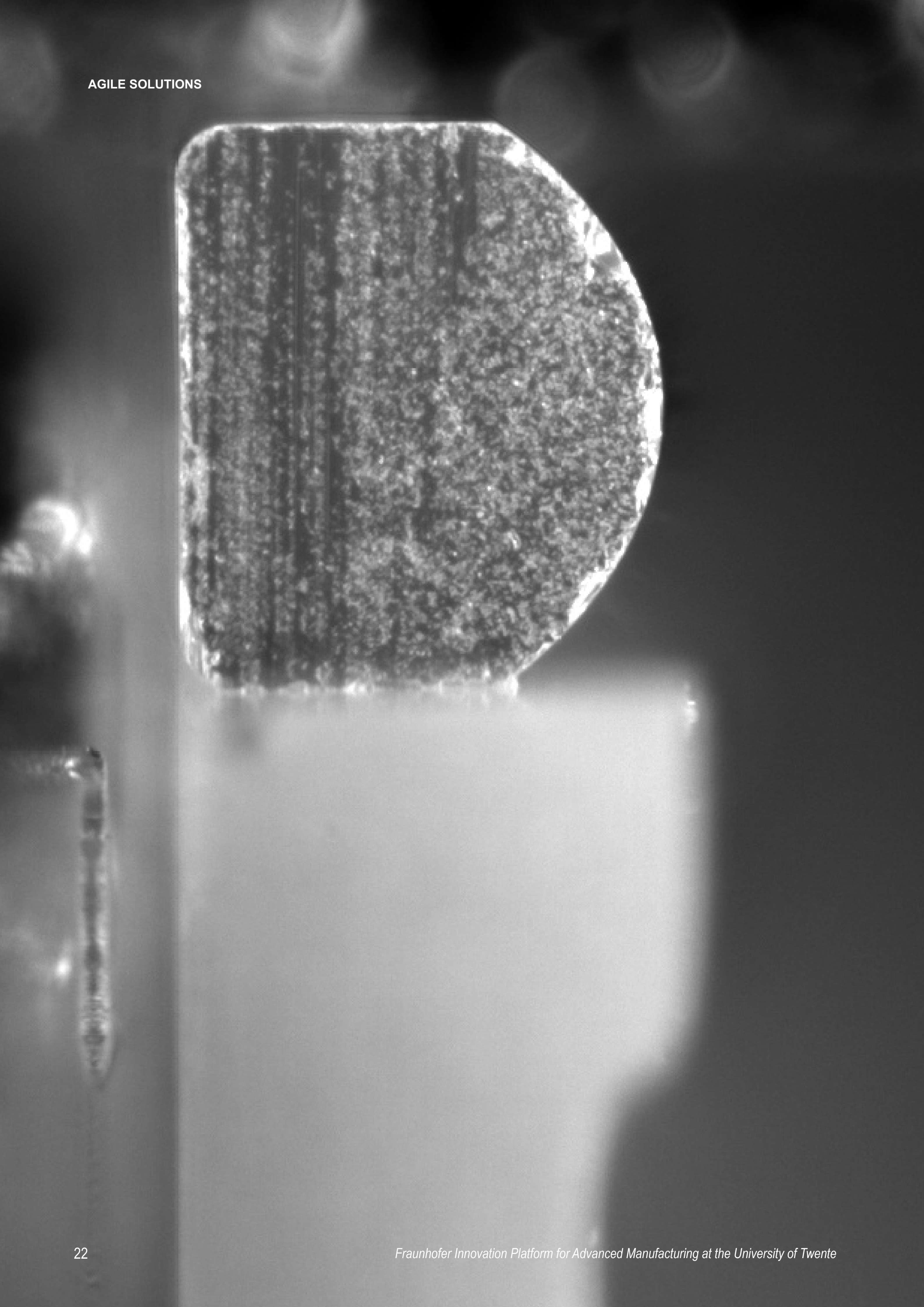
- Creation of industrial grade tools, acquisition of key components
- Process maturing of prototypical processes to meet the specified requirements
- Implementation of job-based operating system/HMI
- Transfer of machine to customer or job-shop manufacturing by industrial partner

GOAL
Pass defined process capability index

PHASE 5 (TRL 7 - 8)
PROCESS OPTIMIZATION

- Improval of productivity, yield, new variants, etc.
- Self sustained machine adaption to products by customer
- Training of engineers for process tuning and product adaption
- Training of operators for production

GOAL
Reach defined sigma-level / increase productivity / implement reconfigurability or variants

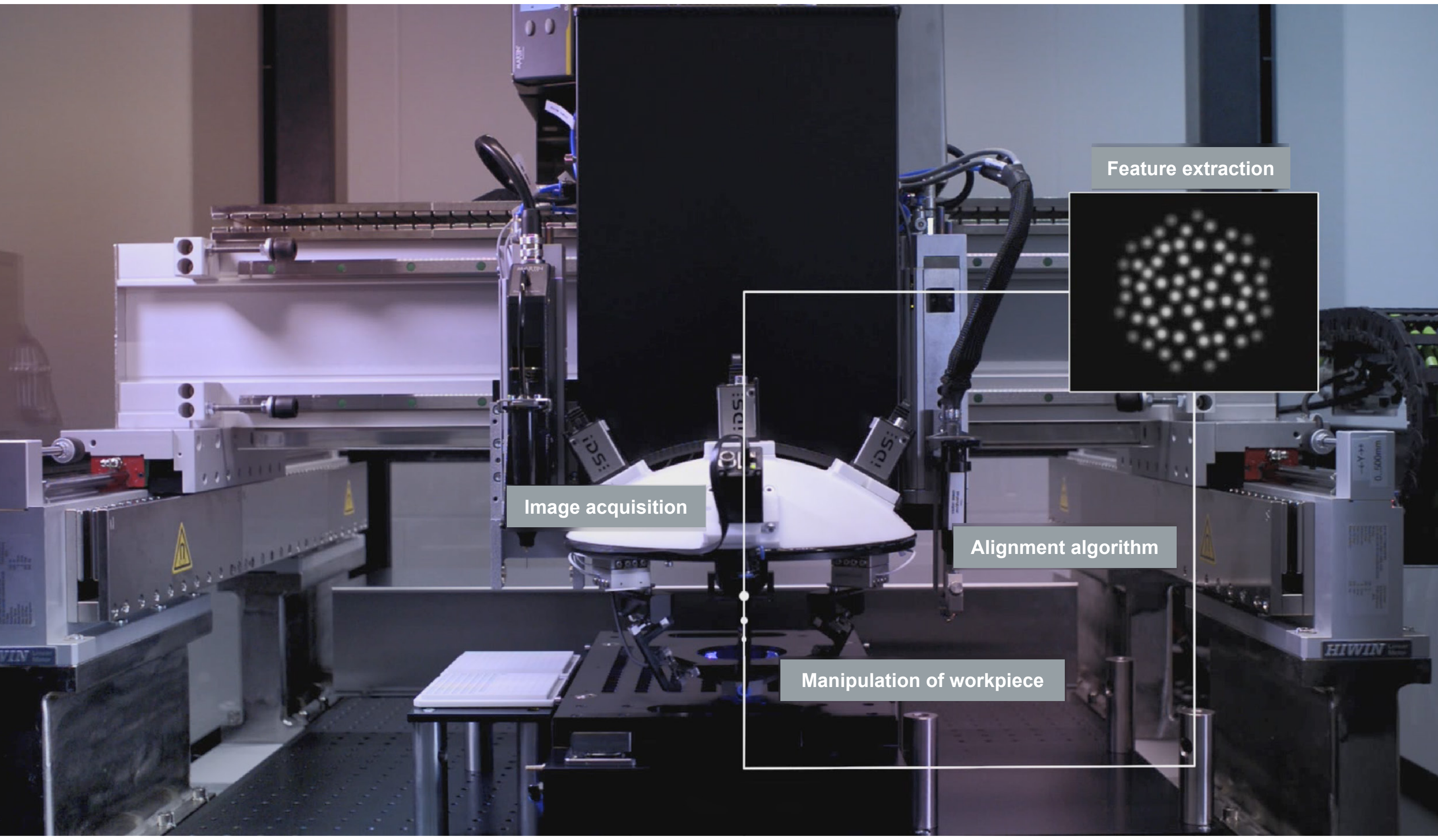


CASE STUDIES

AUTOMATED FAC ASSEMBLY

In the design of high-power diode lasers, micro-optical lenses are used to capture and parallelize (collimate) the highly divergent radiation in the so-called »fast axis«, right after exiting the laser. These fast-axis collimator lenses (FAC) are fixed in front of the semiconductor facet of the diode laser using carrier-elements (bottom tabs) by means of UV-curring adhesive. FAC lenses are thin lenses with lengths of a few millimeters and heights/widths of a few hundred micrometers. The largest component surfaces are in most cases surfaces of optical relevance, so they are not available for handling or gripping. Due to their short focal lengths, FAC lenses are the most critical components of high-power diode laser systems and significantly influence the performance of the overall system. In addition to shape and surface quality, high demands are placed on the assembly accuracy of these micro-optical components. In order to optimally align and position the lenses despite varying properties (e.g. focal length), active alignment strategies are used. The automation of the active FAC alignment process for production offers enormous potential. Compared to manual alignments, the reproducibility and accuracy of the final result are greatly increased. While precise manual active alignments take several minutes, optimized automated process take just a few seconds, which significantly increases productivity.

In several projects and in close cooperation with our partners in micro optics industry as well as system integrators like AIXEMTEC GmbH, we continuously developed and optimized our solutions for the active alignment of FAC-lenses. Our model-based 4-DOF active alignment algorithm converges in less than 8 seconds to the optimal positioning with a reproducibility in nanometer range (depending on the focal length of the FAC-lens and the amplification of the metrology setup). With our standard machine module, the beam diagnostic system (BDS), we are able to characterize the »true« back-focal-length (BFL), in addition to information on the focusing quality and the deflection of the FAC lens (smile). Besides a customizable optical metrology system for the active alignment, the BDS contains side cameras for the BFL-measurement. These cameras are also used for passive pre-alignment, which upgrades the BDS to a 6-DOF closed loop alignment system. Integrated into our flexible machine platform, our algorithms and metrology systems for FAC-alignment are used either for automated assembly as well as quality assessment.


Feature extraction
Image acquisition
Alignment algorithm
Manipulation of workpiece

CASE STUDIES

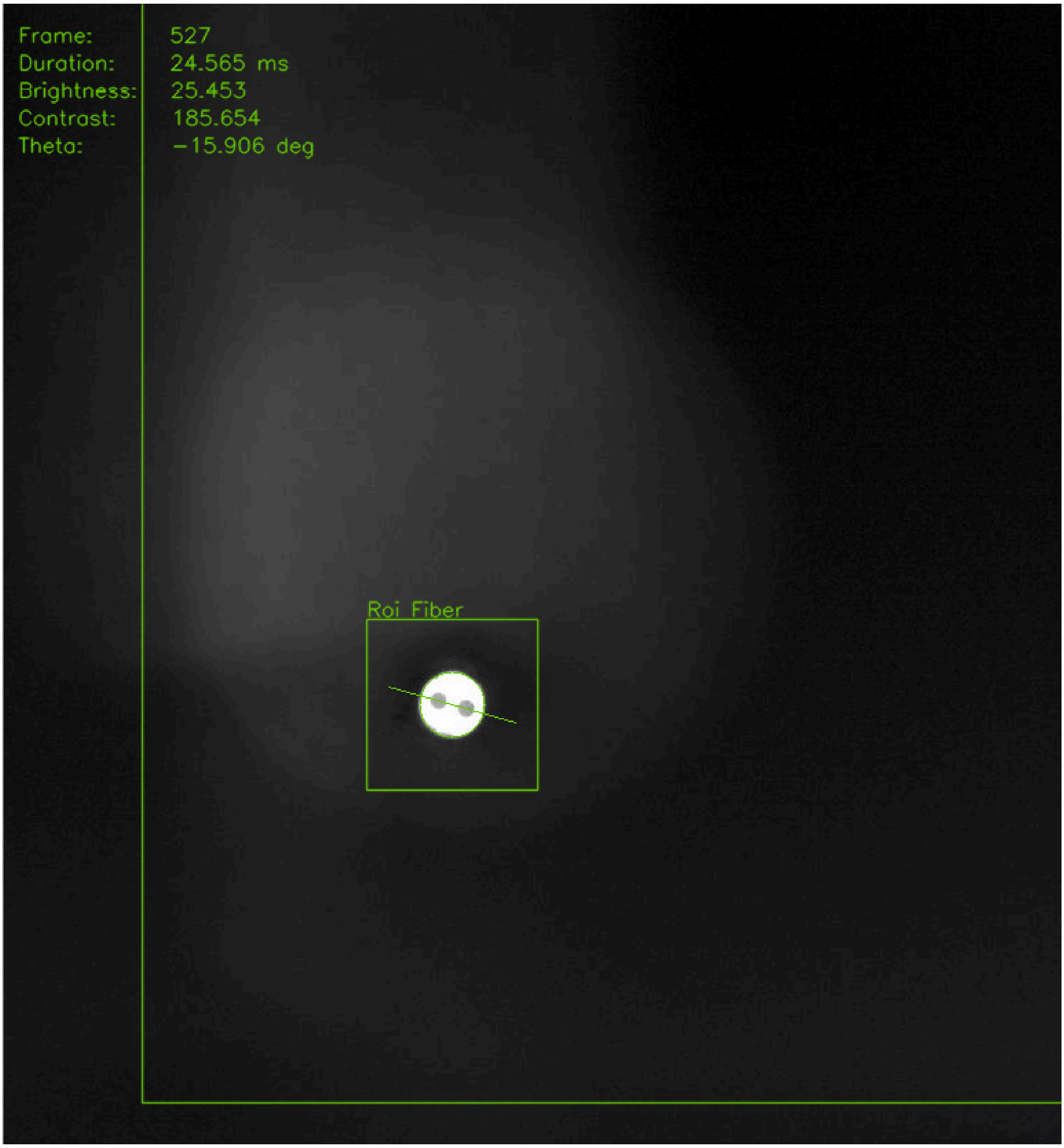
AUTOMATED DOE ASSEMBLY

Diffractive Optical Elements (DOEs) are periodic micro- structures, which can shape and split laser beams very effectively. DOEs are used to create for example dot patterns used for gesture recognition. Microsoft's Kinect motion sensor or the face recognition sensor of IPhone X are prominent examples for DOE applications. Typically, such optical systems consist of a (laser) light source, a beam-shaping optic and the DOE. All components need to be aligned relative to each other with very tight tolerances in the range of a micrometer. Especially in automotive or consumer applications single components must not be very expensive and inherit larger manufacturing tolerances in many cases. For the industrialization, this means that these tolerances need to be compensated in the assembly process to achieve highest quality optical systems from low-cost components.

We have developed a batch-based assembly machine configuration capable of creating such high-end DOE based systems in an automated production environment. The basis for this production machine developments was our flexible and reconfigurable machine platform. Due to the modular architecture of our machine we were able to parallelize the commissioning of the base machine and the development of the novel tools and were capable of creating the new machine configuration in only 6 months time giving our customers the opportunity to launch his product in the quickest way possible.

In the development phase we qualified the key-enabling technology building blocks of the metrology setup and the alignment algorithm as well as the precision bonding process using UV-curing adhesive. We equipped our machine with tailored special purpose tools to perform the novel assembly task. Our micromanipulator Coomander6 was customized to handle DOEs, measure the alignment state of the DOE and the light source with large fields-of-view of up to 80° and also integrated high-end UV-curing equipment. Furthermore, we implemented a probing-unit capable of probing 144 individual systems.

After feeding the both lasers and DOEs on two trays into the machine the operator starts the assembly job and the machine produces 144 systems with a cycle time of roughly 30 seconds autonomously. The individual laser is turned on and in a closed-loop alignment, the metrology system (integrated into the micromanipulator) detects the misalignment of DOE and light source. In multiple steps the DOE is aligned in 5 degrees of freedom with a translational precision of roughly 1µm to relative to the light source. Since January 2015 this machine is operating at our customers facilities in a 3-shift industrial environment. In the meantime we created multiple novel configurations for our customer and helped him to most effectively launch additional products.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Roi Fiber

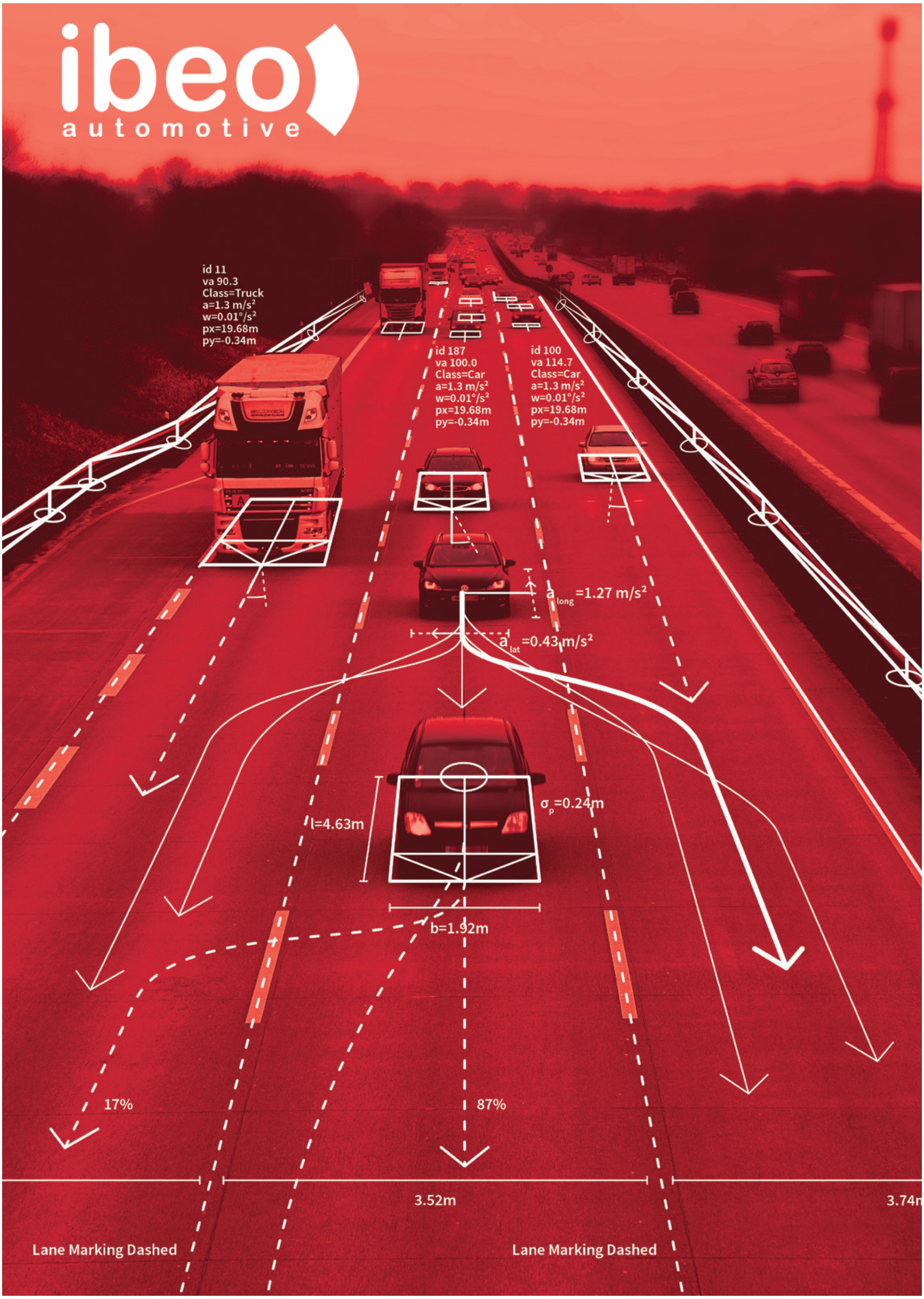
CASE STUDIES

AUTOMATED FIBER ARRAY ASSEMBLY

Photonic integrated circuits open a vast field of novel applications. Yet, these systems require highly flexible and precise fiber assembly routines. Fibers need to be densely packed and aligned in 6 degrees of freedom relatively to each other. The basis of a single fiber array assembly is a glass block with multiple v-shaped cavities, so called v-grooves. During assembly, single fibers must be aligned and placed with micron precision into the v-grooves. After positioning, a single fiber is fixated with UV-curable adhesive. The last step of the process chain is the precise positioning and bonding of a lid glass plate on top of the assembled array. Due to the increasing demand, solutions for the automated assembly of fiber arrays have to be developed. However, the compact design and the flexible fiber material represent a challenge for automation.

Together with our partner PHIX Photonics Assembly, we developed a novel manipulation tool for optical fibers and a metrology setup for the automated passive assembly. The manipulation tools consists of multiple grippers which are holding the fiber in position after gripping. With the help of two piezo-driven claws at the front end of the fiber, the rotational degree of freedom of the fiber can aligned precisely. The manipulation tools is equipped with multiple LEDs for illuminating the gripped fiber. This side illumination ensures, that the so called stress rods getting visible at the front end of the fiber, which enables the image processing to detect the angle in the rotational degree of freedom. For the closed loop alignment and positioning process, we implemented the necessary image processing routines to detect the position of the fiber with a translational precision in micron range and a rotational accuracy below ±0.5 deg. Parallel to feasibility studies and the development of customized tools and processes our partner for system integration AIXEMTEC GmbH, has setup the base machine and developed a carrier concept for feeding of the fibers into the machine.

At the customer's request, the machine was delivered for prototypical semi-automated assembly, but with the future possibility of full automation. The customer is enabled to produce small series and to independently develop further processes. By this approach, the customer himself builds the core know-how for the assembly without involving any third-party.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py=-0.34m
id 187
va 100.0
Class=Car
a=1.3 m/s²
w=0.01°/s²
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py=-0.34m
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va 114.7
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l=4.63m
b=1.92m
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87%
3.52m
3.74m
Lane Marking Dashed
Lane Marking Dashed

CASE STUDIES

AUTOMATED LIDAR ASSEMBLY

Solid-state LIDAR systems are one of the most trending topics in optics industry as they will be key-enabling tools for autonomous driving. Yet, before solid state LIDAR systems will penetrate the market also into the lower priced car segments, major challenges in production need to be overcome to enable cost-effective production.

In only 7 months after first contact with out customer Ibeo Automotive Systems GmbH, we installed a machine to assembly solid-state LIDAR systems at their facilities. This extremely short development time was possible by parallelizing the machine commissioning and the concurrent development of special purpose tools. In intense collaboration with Ibeo Automotive Systems GmbH, we first validated our technical approaches in laboratory setups to prove that for example the alignment of both lenses for sender and receiver side can be detected and aligned relatively to each other.

After proving feasibility of these »dealbreakers«, we customized our existing tools like the micromanipulator Commander6, equipped it with the novel metrology equipment and developed a tailored curing solution for the adhesive bonding process. At the same time, our system integration partner AIXEMTEC GmbH built the base machine configuration into which the novel assembly tools were integrated. Only 6 months after project start our customer could start to produce first small-series of their novel LIDAR systems and deliver systems to developers and end customers.

The realized machine is capable of assembling two lenses to two chips while establishing a functional relation between both imaging systems. A key feature of the machine is the tailored passive precision alignment system. As we are able to detect the alignment state of lens to chip without turning on the LIDAR system, we gain two significant advantages over active alignment systems. Firstly there is no need to operate the LIDAR System. Electrical probing is not necessary, the alignment routing is not limited by the sensor speed as for conventional MTF-based alignment systems. Second advantage is the compact and highly precise alignment of sender and receiver beam-path. The entire metrology system fits onto our micromanipulator base which has a diameter of 250mm. A major challenge in to perform this alignment and bonding task for two lens-chip systems with micrometer precision. Both sender and receiver side need to be aligned relative to each other without actually »seeing« each other.

Having solved this major technological challenge we now have an assembly machine at hand to perform similar tasks besides the assembly of solid-state LIDAR systems. This could be the assembly of multi-camera systems without using a target. Also a high-speed alignment of lens to chip without operation of the CCD-chip and yet analyzing on- and off-axis MTF becomes possible.

ABOUT US

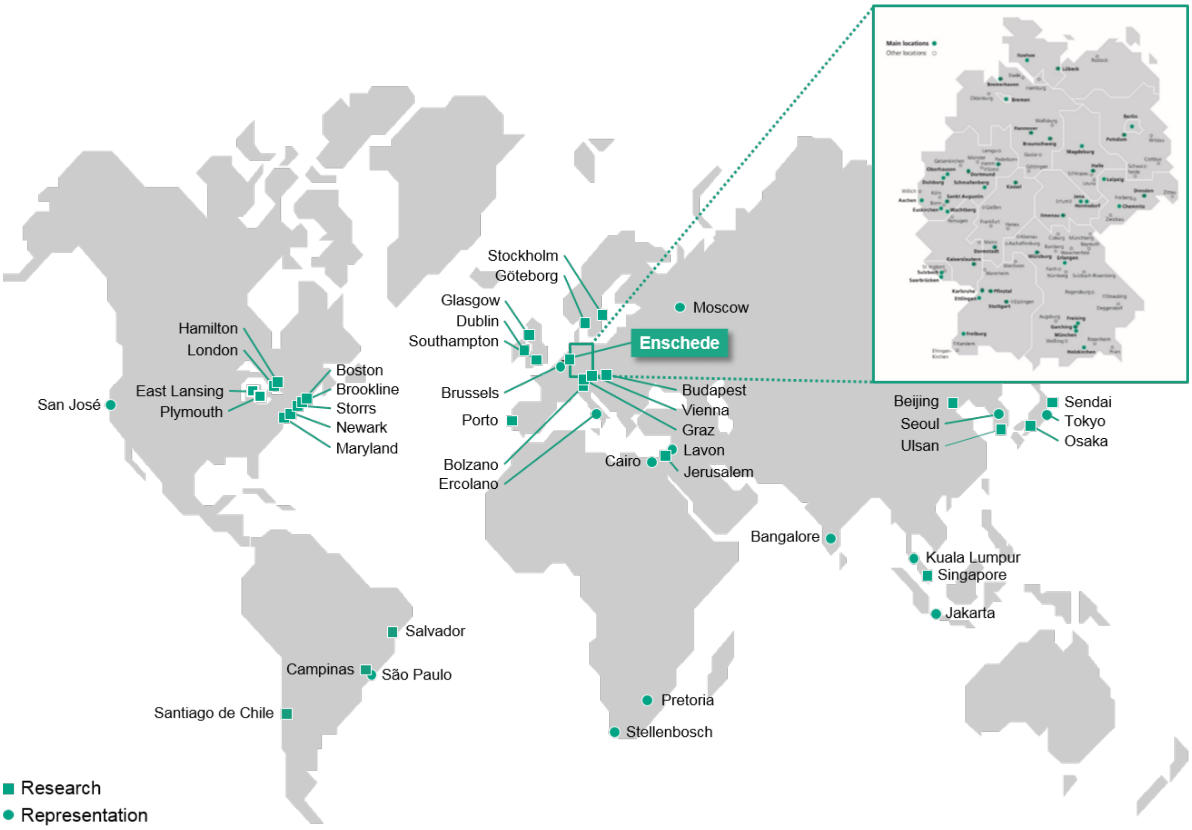
Originally known as the Fraunhofer Project Center at the University of Twente, the Fraunhofer Innovation Platform for Advanced Manufacturing emerged in 2022, continuing the strong collaboration between the Fraunhofer Institute for Production Technology IPT in Aachen and the University of Twente in the Netherlands.

The Fraunhofer Innovation Platform for Advanced Manufacturing at the University of Twente (FIP-AM@UT) is a research centre that collaborates with manufacturers to develop innovative and integrated solutions to serve and strengthen the industrial manufacturing community and benefit society as a whole.

FIP-AM@UT's primary goal is to strengthen and diversify the manufacturing sector in the Netherlands to ensure ongoing adaptability, competitiveness and efficiency. This can be accomplished by bringing highly skilled researchers and supporting staff to the region.

Their secondary goal is to source and develop innovative thinkers by engaging them in cutting-edge applied research for both industrial and public clients, and by promoting technology transfer through the joint exploitation of results.

FIP-AM@UT is part of the University of Twente (UT), the only campus university in the Netherlands. Divided over five faculties, it provides more than fifty educational programmes. In addition, UT has a strong focus on personal development, aiding and encouraging talented researchers to conduct groundbreaking research.



PARTNERS

UNIVERSITY OF TWENTE

The University of Twente is a modern, entrepreneurial university, with 3,000 researchers and professionals and over 10,000 students, leading in the area of new technologies and a catalyst for change, innovation and progress in society. The university's strength lies in its capacity to combine and work on future technologies. The University of Twente is home to powerful research institutes at the forefront of nanotechnology (MESA+), ICT (CTIT), biomedical technology and technical medicine (MIRA), governance and behavioral sciences (IGS), geo-information sciences and earth observation (ITC), and science based engineering.

FRAUNHOFER NETWORK

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000, who work with an annual research budget totaling 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

FRAUNHOFER IPT: INSTITUTE FOR PRODUCTION TECHNOLOGY

The Fraunhofer Institute for Production Technology IPT in Aachen has decades of experience in the production technologies it utilizes to provide companies with a strong basis for the digitization of production processes, machine tools and equipment. Technological expertise is complemented by new production organization methods and by the design of industrial software systems. The institute currently employs around 460 people who are dedicated to applying their creativity to methods, technologies and processes for a connected, adaptive production.

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fip@utwente.nl

fip.utwente.nl