HIgh throughPut LasER processing of Dlamond and Silicon

Reporting

Project Information

HIPERDIAS

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Project website

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Project closed

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€ 3 640 307,50

Coordinated by
UNIVERSITY OF STUTTGART
Germany

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Periodic Reporting for period 3 - HIPERDIAS (HIgh throughPut LasER processing of DIamond and Silicon)

Reporting period: 2018-08-01 to 2019-10-31

Summary of the context and overall objectives of the project

Micromachining is a strategic technology for many European manufacturers and the continuous challenge of competition is driving research and innovation efforts into technologies and solutions that will deliver higher productivity at lower cost in many industries. In parallel, the explosive progress in ultra-short pulse (USP) laser and photonic technology has afforded an opportunity for rapid acceleration of the rate of adoption of laser micromachining. HIPERDIAS will demonstrate USP laser-based material processing at unprecedented (high-throughput) levels of productivity and precision. The challenge is not only to achieve high productivity at moderate levels of precision or highest quality at low speeds, but to reach both targets at the same time. Several prerequisites have to be fulfilled to be able to accomplish this goal. First of all, an adequate femtosecond laser source with a very high average power and well-adapted beam parameters, including pulse duration, pulse energy, intensity profile, and polarization, is needed. This includes the flexible beam delivery, which will be addressed by the Kagomé fibers and allows maintaining the above given laser beam properties. Additionally, the laser beam has to be applied to the work-piece in a well-defined application-specific manner. Finally, advanced processing strategies are required to obtain optimum results at high productivity.
HIPERDIAS is strongly user-driven in order to demonstrate industrial relevance of laser micromachining at two major reference sites targeting the displacement of the current state of the art mechanical processes with 3D laser ablation of silicon, laser polishing of diamond and fine cutting of metals respectively.
The following primary objectives were targeted:
• Highly flexible high-power and high-efficiency femtosecond laser source with average output power of up to 1000 W at the megahertz (MHz) including flexible fiber beam delivery
• Cost-efficient solutions (power scaling, pulse compression & fiber transport) for a broad range of applications
• Optimization of demanding high-volume applications regarding efficiency as well as quality

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

In the 1st period of the project work progressed well in all work packages, with good collaboration and communication being established as a basis of the project work. Work focused on the three main applications, and a requirements analysis was completed for each with the major process and system specifications defined. Key Performance Indicators were established with the end-users within the consortium. All partners contributed to the work in WP1 to establish the technical fundamentals for the design of the laser machining systems to be developed within HIPERDIAS; WP1 is complete at the end of Period 1. WP2 started well, with average ablation rates of up to 2.5 mm^3/kJ achieved during Si Processing; this represents an increase in processing speed of up to 5 times. WP2 was also able to demonstrate successful cutting of metals with a thickness of 0.12 mm up to 0.25 mm. Diamond ablation tests were also performed with various fluences, investigating the removal rate and surface quality. WP3 and WP4 worked together closely to focus on the creation of a new Beam Delivery System (BDS) and the generation of femtosecond pulses, their temporal manipulation and modulation, and amplification. The first seed laser (@50 W) was delivered and installed at USTUTT. Furthermore, the first generation of grating compressors was realized. Up to 99% efficiency could be achieved. Selected grating compressors were tested in the pre-amplifier developed at AMP. In WP5 work progressed on the assembly and qualification of the thin-disk booster in order to achieve 500W of output power at a pulse duration of sub-500fs and a repetition rate of 1.25Mhz. In WP6, discussions to define the required interfaces from all involved partners took place. This includes the interfaces for the mechanical and optical components, as well as electronics and user control interface. Main results achieved in the first period of the HIPERDIAS project: Completed first design of the grating compressors; The first grating mirrors fabricated and spectroscopically characterized; Completion of first prototypes of PMC module for fiber beam delivery; Established specification for laser parameters; 50 W pre-amplifier system delivered for further amplification in thin-disk booster; Key Performance Indicators established for productivity and quality.
In the 2nd period, the project achieved good progress in all work packages. In WP2, the development of processing strategies for all three applications proceeded very satisfactorily. Indications from the work undertaken using low power laser sources suggested that the achievement of the targeted application results would be attainable as power scaling was implemented. In the first application to proceed to high powers, namely Si ablation tests, the early results showed real promise with respect to the combined achievement of material removal rates and surface finish quality. In WP3, the development of the 200W seed laser to drive the Multi-Pass Amplifier experienced some challenges. Although able to demonstrate the required power output, further development work was required to sustain long-term stability of operation. In WP4, the technology of the high PER (Polarization Extinction Ratio) fibre now featured in the BDS for testing with end-users. Similarly, the manufacturing process for large-area compressor gratings was optimised with samples tested in high power set-ups. In WP5, the Multi-Pass Amplifier was commissioned and made available for application tests. In addition, the SHG and THG generation has been completed satisfactorily but with some unavoidable limitations due to the availability of suitable crystals. In WP6, the system build-up reached a high level of maturity and in WP7 tests were underway to evaluate the processing strategies at higher powers for applications in diamond polishing and fine cutting of metals.

In the final period of the project all components necessary for the successful process development with a high-power femtosecond laser for end-users E6 and BOSCH have been integrated into a stable, flexible and versatile machine base . Furthemore a 500 W/1 kW demonstrator system has been tested and validated by the end-users BOSCH and E6 in collaboration with partner USTUTT. The desired ablation rate for the processing of silicon has been largely achieved, with the majority of the key performance indicators for the fine cutting of metals and diamond polishing also being achieved.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

The HIPERDIAS project has secured significant productivity improvements in 3D silicon processing and polishing of synthetic diamonds, both at 50-60 times greater than the state of the art, and also the fine cutting of metals at 20-25 times greater than the state of the art. Integrated high efficiency pulse compressors with losses 2-3 times lower than the state of the art have been developed and fibre delivery components with 180W and 180 µJ guided demonstrated. In addition to this the project has achieved a world first at the workpiece in developing flexible high-power and high-efficiency femstosecond sources in the MHz range with an average power up to 1kW.
The consortium have estimated in the 6 years following the project HIPERDIAS will generate additional turnover of €138.3M and create 59 new jobs within the project partners' organisations.

Project Logo

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