TiSa TD Period 1

Publishable Summary

The “TiSa-TD” project aims to demonstrate ultrafast high-average power Ti:Sapphire thin-disk oscillators and amplifiers. Such ultrashort laser pulses affect everyday life as they enable precision micro-machining and are therefore used in a wide variety of medical and industrial applications. While for micro-machining of metals ps-pulse durations are sufficient, for transparent materials (e.g. glass covers for smartphones) pulse durations in the range of 100 fs are required. To achieve these pulse durations, Ti:Sapphire is very suitable and the aim of the project is to increase the available output powers, and therefore productivity, by combining Ti:Sapphire lasers with thin-disk laser technology.

In the TiSa-TD project two TiSa-based laser systems are built up. The first system employs chirped-pulse-amplification (CPA) and a multipass amplifier to achieve high pulse energy at a low repetition rate (200 W, 10 mJ at 20 kHz). This low-repetition rate is well suited for ultra-precise-drilling with ultra-high aspect ratio, especially for transparent materials, which is investigated in the project. The second system focusses and a high-power TiSa-TD oscillator at high repetition rates (200 W, 10 µJ at 10 MHz). This is very suitable for cutting of transparent materials, e.g. of Gorilla® glass, which will be investigated as a reference application.

An overview of the project is depicted in Figure 1. The different partners involved in the project can offer key competences to establish Ti:Sapphire as a new laser active medium for thin-disk lasers. This includes a lot of experience on existing TiSa laser technology to achieve pulse durations of sub-100 fs, as well as experience on thin-disk technology which enables power-scaling. Due to large thermal loads in the disk at high power pumping an improved symmetrical cooling concept (“Quetschi”) is developed in the project employing transparent diamond heat spreaders. Based on this TiSa thin-disk gain module, the two laser systems (multipass CPA-system and high-power oscillator) are developed. Using these systems different applications will be demonstrated.

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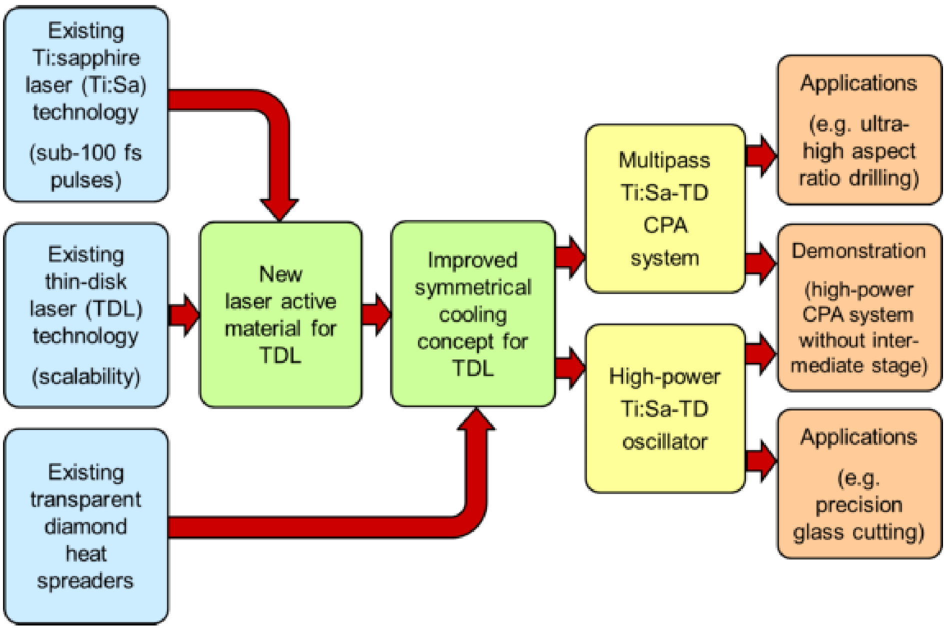

Figure 1: Schematic overview of the project TiSa-TD.

The main achievements within the first 18-months of the project can be summarized as follows.

- Component and material technologies

The mechanical and thermal models of the TiSa thin-disk gain module (crystal cooling unit and pumping optics) were completed at USTUTT and based on this, specifications for the single crystal diamond (SCD) and the TiSa parts were determined, e.g. dimensions, doping concentrations, and radii of curvature (ROC). The first diamond parts have been produced at E6 and hit most key specifications which allowed building up the first mechanical trial version of the crystal cooling unit. The work also focused on further reduction of absorption losses and the increase of the area of the SCD samples under production.
The required TiSa crystal material has been specified, manufactured, processed and is currently undergoing optimization steps.

- High-power ultrafast Ti:Sa TD CPA system

The first part of the chain to reach the goals for the CPA system is a TiSa regenerative amplifier with 20W of average power. The design of this system is finalized. All necessary parts have arrived and the assembly of the gain module is currently being finalized by USTUTT, leading to the beginning of first experiments with this new TiSa gain module concept at TOSA.
The output beam of the regenerative amplifier will be used as a seed for a 200W TiSa multipass amplifier. For pumping this amplifier new pump lasers are needed. Those pump lasers are under development at TOSA with the goal to reach an average power of 300W at 532nm in pulsed (ns) regime.

- High-power mode-locked Ti:Sa TD oscillator

A symmetrical pump optic based on two parabolic mirrors having 48 passes of the pump light through the laser crystal has been successfully designed and will be used in the CPA multipass amplifier as well as in the high-power oscillator. The mechanical and optical components have been produced and assembled.

To enable the application development to start their investigations, an Yb-based oscillator has been designed and experimentally tested at USTUTT with different laser active media.
The integration tasks for both oscillators (Yb-doped and TiSa-TD systems) are ongoing at M2.

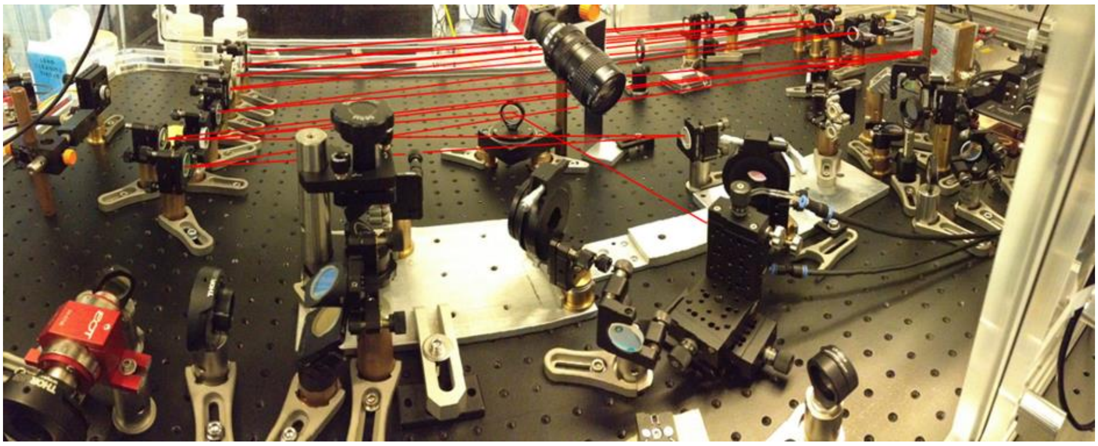

Figure 2: Resonator beam path for Yb-based oscillator.

- System integration

To integrate the developed laser systems in material processing machines, all requirements had to be identified and defined in a first step. This has been accomplished by all partners.
Furthermore, the laser machining platform is designed and a prototype is already built at Oxford. This prototype will be further modified as needed depending on experimental needs.
At CNRS-FEMTO, a first convincing setup suitable for laser processing with high energy Bessel beams has been designed.

Figure 3: Workstation for the TiSa laser systems.

- Application development

In a first step, suitable test materials for the TiSa laser systems were defined. The material properties, required thicknesses, process requirements and analysis techniques have been documented (different transparent dielectrics, metals, etc.).
In a further step, suppliers and sourcing of such materials and hardware vendors had to be identified for all relevant laser processing trials and characterisation techniques.
Preliminary laser processing trials were carried out at Oxford and CNRS-Femto with multi kHz and MHz ultrafast laser sources in strengthened and unstrengthened display Gorilla glass, sapphire, borosilicate, borofloat and sodalime glasses at different thickness up to 2mm (plasma filament cutting). Additionally, selective removal of thin films was demonstrated using a preliminary 20 W and 310 fs laser, as well as preliminary selective surface functionalization of metal surface with increased wettability (contact angle from 86° to 89°).

Valuable preliminary information was extracted on key laser process requirements (pulse energy, pulse overlap, process speed) for MHz ultrafast laser processing applications (mainly on glass processing).

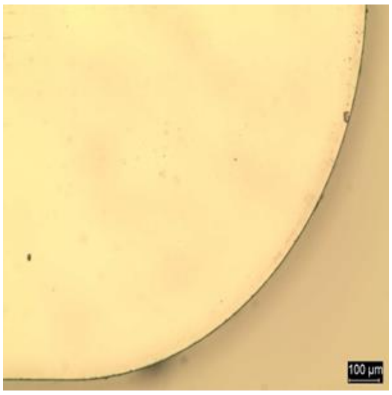

Figure 4: Preliminary laser processing trials on 1.1 mm thick Sodalime glass with Bessel beam technique.

- Demonstration

The demonstrations of material processing with the TiSa laser systems will be carried out when these systems are completed.