Project presentation

Ultrafast High-Average Power Ti:Sapphire Thin-Disk Oscillator and Amplifiers

The TiSa - TD project has received funding from the European Community's Seventh Framework Programme under Grant Agreement No. 619177

Beneficiaries – Call Topic Objective ICT-2013.3.2 Photonics iii) Laser for Industrial processing

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Motivation

Current state-of-the-art

Based on Yb-doped crystals, high-power ultrafast thin-disk lasers with pulse durations down to approx. 700 femto-seconds and average output powers of up to 150 W are commercially available. Even higher powers (up to 1.3 kW at 8 ps) and shorter pulse durations (down to 62 fs at 5 W) have been reported for Yb-based ultrafast thin-disk lasers in the lab. Similar output powers have been reported from Yb-based ultrafast slab and fiber lasers also.

Limitations of the state-of-the-art

Due to the limited spectral gain bandwidth of Yb-doped crystals, a massive trade-off between average output power and pulse duration is observed for the current thin-disk lasers. Below approx. 300 fs, the efficiency as well as the power drop off quickly, reaching maximum values in the 10 Watt range only for approx. 100 fs pulse duration.

Beyond the state-of-the-art

Lasers with average powers of several 100 W and pulse durations in the 100 fs range will enable a broad range of high-volume precision materials processing applications. For example, they will allow cutting and drilling of glass (e.g. Gorilla® glass for smart phones and tablets) and other transparent materials (e.g. sapphire and diamond) with high precision and unprecedented speed. To achieve these laser parameters, Ti:sapphire, which offers a unique spectral gain bandwidth enabling the generation of pulses with durations as short as 5 fs, will be employed as laser active material. To be able to extract the high heat flux generated inside the Ti:Sa disk efficiently, a new symmetrical cooling concept based on transparent diamond heat spreaders will be employed.

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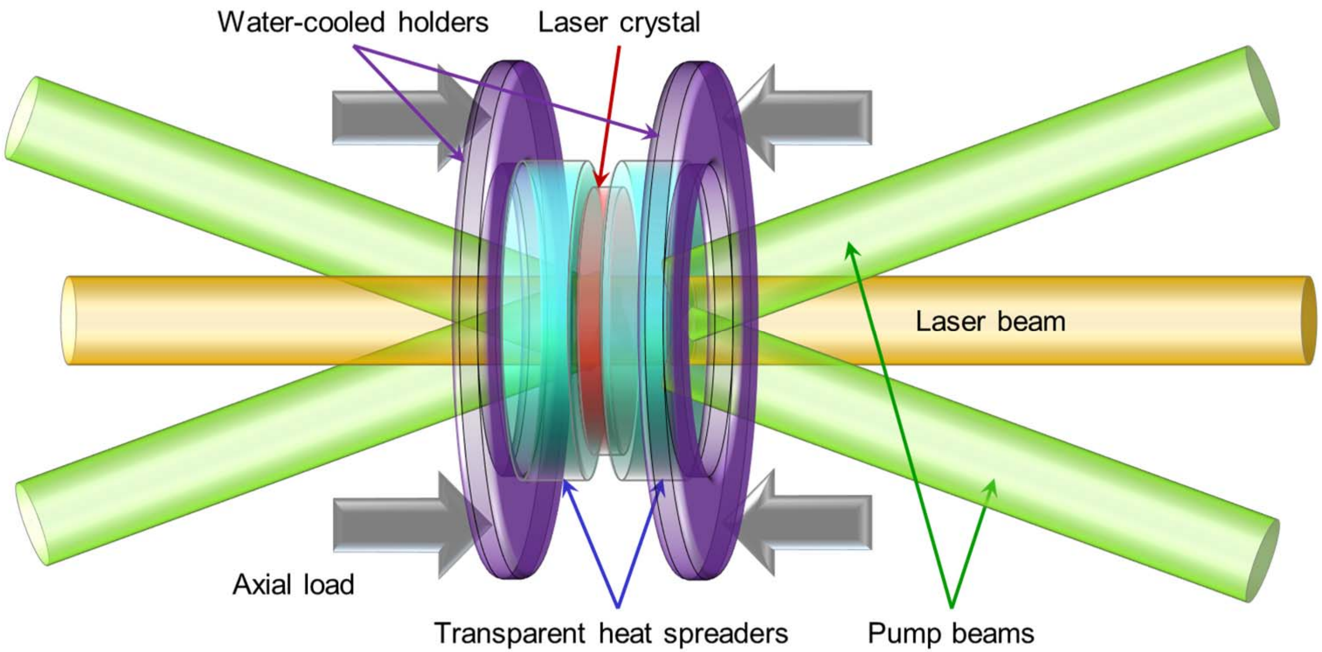
Project central objective

The basic idea of the project is to substantially improve the thermo-optical effects occurring in a Ti:Sa laser crystal by implementing the thin-disk concept with symmetrical cooling using two transparent diamond heat spreaders for efficient axial cooling of the crystal



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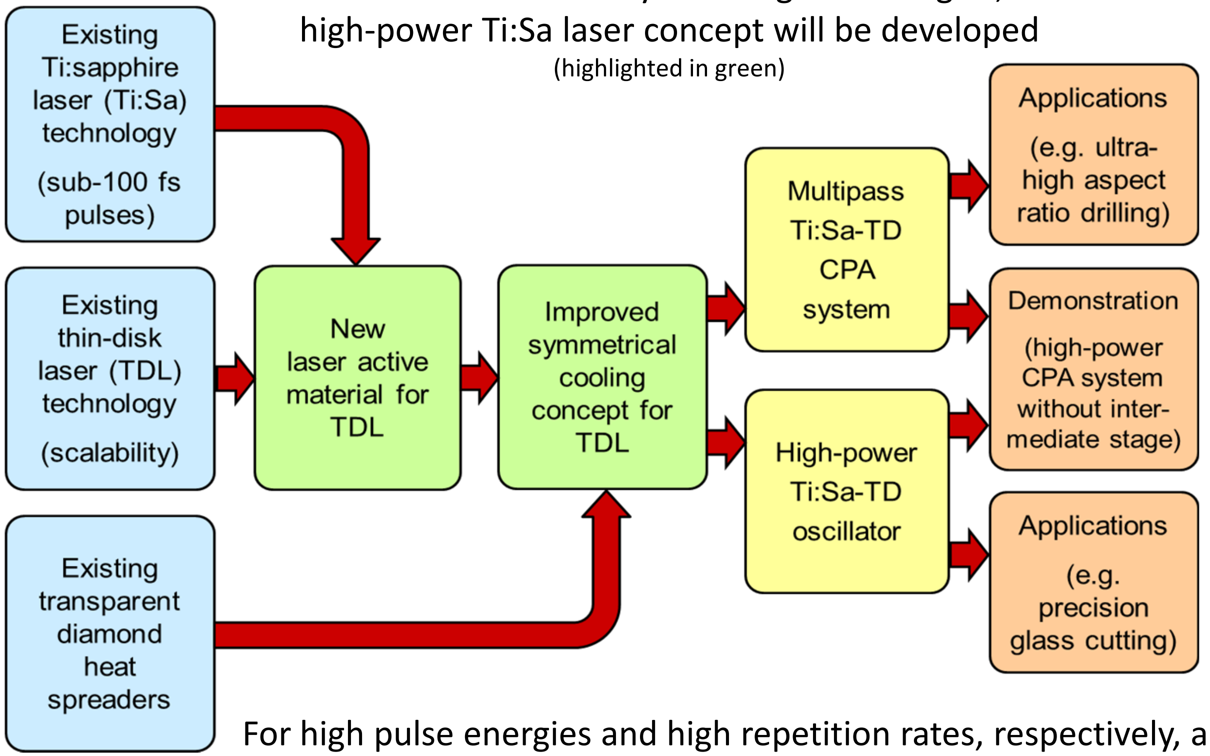
Overview project structure

The starting point of the project is the three key enabling technologies (highlighted in blue)

A world leading partner of the consortium is associated to each one of these technologies.

Based on the three key enabling technologies, a high-power Ti:Sa laser concept will be developed (highlighted in green)



For high pulse energies and high repetition rates, respectively, a CPA system using a multipass TD amplifier and a high-power TD oscillator will be realized (highlighted in yellow)

The Ti:Sa-TD laser systems developed within the project will enable to: (highlighted in orange)

- Investigate novel material processing applications
- Demonstrate a high-power CPA system without intermediate amplifier

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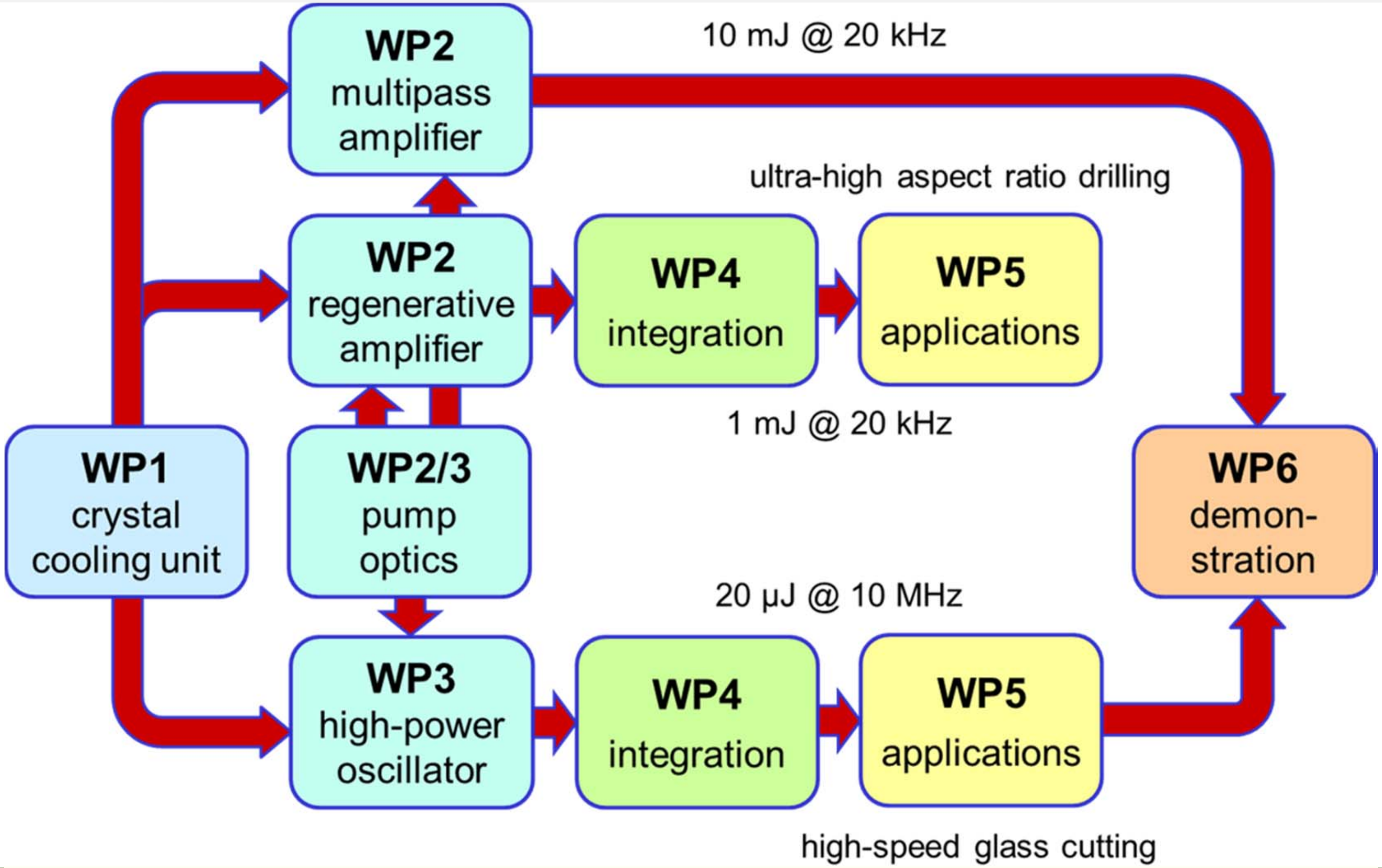
Project overview of work package structure



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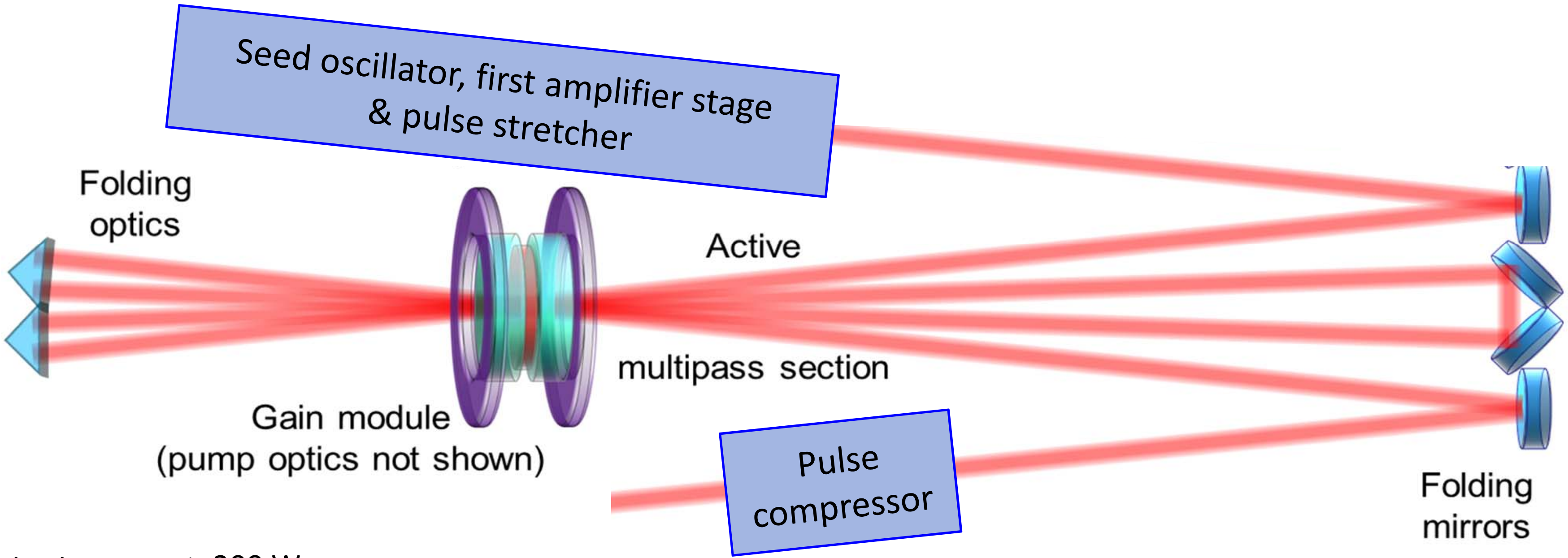
Project concept: Multipass amplifier

The final amplification stage of the high-average power Ti:Sa CPA system will be realized using a multipass TD amplifier which does not need active optical switching and thus enables high pulse energies and average powers



Output power: ≥ 200 W av.
Pulse duration: < 100 fs
Pulse energy: ≥ 10 mJ

The multipass amplifier will be pumped using two frequency-doubled nano-second pulsed lasers with an average output power of 300 W each at 532 nm

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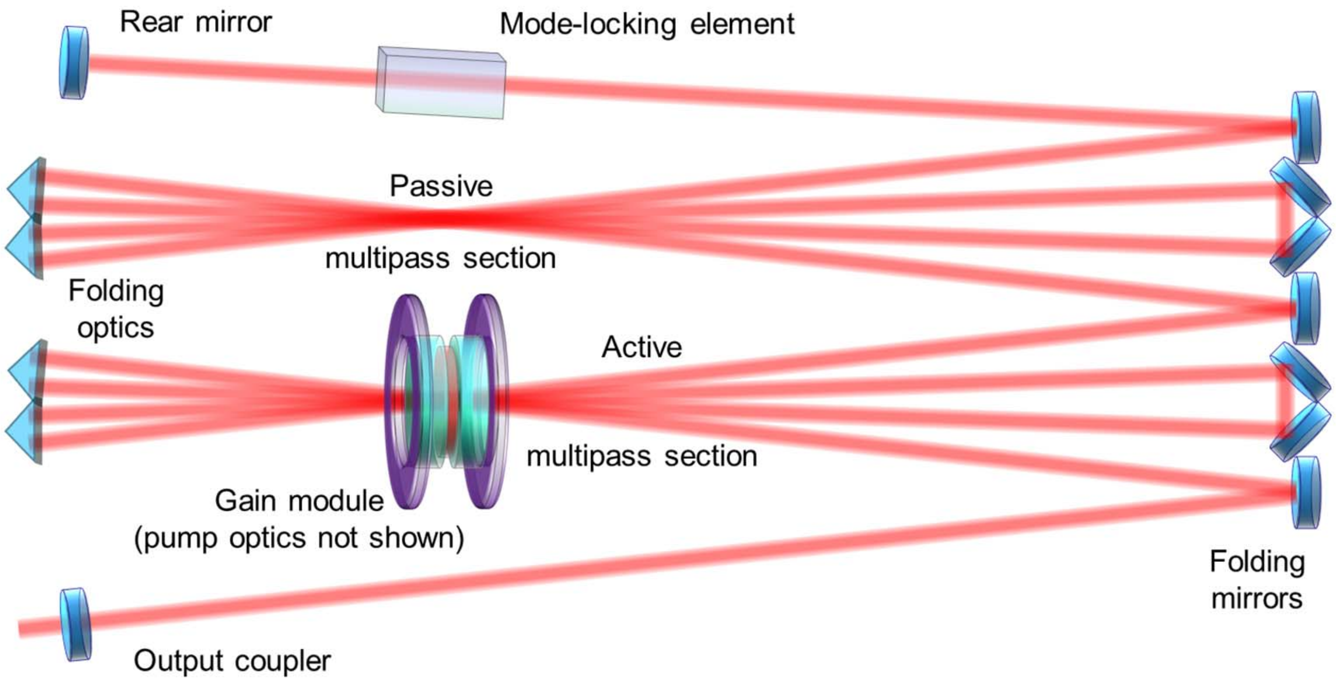
Project concept: High-power oscillator

Beside the conventional modelocking techniques (SESAM & KLM), alternative methods (e.g. based on cascaded nonlinearities) will be investigated to minimize losses and maximize stability

The high-power femto-second TD oscillator will be realized using an active and passive multipass section to generate sufficient gain per round-trip (which minimizes self-phase modulation in the atmosphere) in order to achieve a repetition rate of 10 MHz



Output power: ≥ 200 W av.
Pulse duration: < 100 fs
Pulse energy: ≥ 20 µJ @ 10 MHz

The high-power femtosecond TD oscillator will be pumped using a frequency-doubled Yb:YAG TD laser with an output power of 500 W cw at 515 nm

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Project expected results

- The realisation of a Ti:Sa think-disk regenerative amplifier using CPA with maximum pulse energy of at least 1 mJ, a pulse duration below 100 fs, and a repetition rate of 20 kHz, corresponding to 20 W average power.
- The realisation of a Ti:Sa thin-disk multipass chirped pulse amplifier with a maximum average output power of at least 200 W, a maximum pulse energy of at least 10 mJ at 20 kHz and a pulse duration of less than 100 fs.
- The realisation of a modelocked Ti:Sa thin-disk oscillator with a maximum average output power of at least 200 W, a maximum pulse energy of at least 20 µJ at about 10 MHz and a pulse duration of less than 100 fs.
- Demonstrating a Ti:Sa thin-disk CPA system having a maximum average output power of at least 200 W, a maximum pulse energy of at least 10 mJ at 20 kHz and a pulse duration of less than 100 fs.
- Demonstrating drilling of ultra-high aspect ratio holes in transparent materials, targeting a uniform damage in glass over 500 µm propagation length having a transverse diameter of less than 20 microns.
- Demonstrating high-speed precision cutting of transparent materials, targeting a cutting speed of at least 200 mm/s for 0.2 mm thick glass with a good quality.

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