# TiSa TD Deliverable Report

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

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| **Declaration** | Any work or result described therein is genuinely a result of the TiSa TD project. Any other source will be properly referenced where and when relevant. |

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

# TiSa TD Newsletter February 2016



UNIVERSITÄT STUTTGART
INSTITUT FÜR STRAHLWERKZEUGE
STUTTGART LASER TECHNOLOGIES

The Institut für Strahlwerkzeuge (IFSW) of the University of Stuttgart (USTUTT) has realised within the Tisa-TD project the first lasing demonstration of Ti:Sa laser in a thin-disk geometry (Figure 1). The system, shown in figure 2, was based on the existing B1-pumping unit technology (developed and commercially available at the IFSW of USTUTT) which has been upgraded to allow up to 48-passes of the pump-light radiation through the disk.
The module has been transferred to partner TOSA for the sub-sequent implementation in a regenerative amplifier to extract 20W of output power at a repetition rate of 20kHz and a sub-100fs pulse duration.

The IFSW has completed the design of the TiSa "Quetschi" pumping module (also allowing 48-passes) which uses the thin-disk architecture in a transmissive configuration. The system is at present under implementation and full characterization. In order to allow early material processing experiments, the IFSW has realised a mode-locked Yb:CaF2 thin-disk oscillator delivering 1.78 µJ at a repetition rate of 10 MHz and a pulse duration of 285 fs. An accepted conference contribution based on these results will be presented in April 2016 in Brussels (Photonics Europe 2016). A paper also related to these results has recently been submitted to the Optics Letters and is awaiting acceptance.

Furthermore, the IFSW is developing a high-power CW green source based on a frequency double thin-disk laser for the lab demonstration of the high-power mode-locked thin-disk Ti:Sa oscillator. An article "Highly efficient 400W near fundamental mode green thin-disk laser" presenting the first results was presented at the Advanced Solid-State laser (ASSL) 2015 conference in Berlin (Germany) and was published in Optics Letters Vol 41.

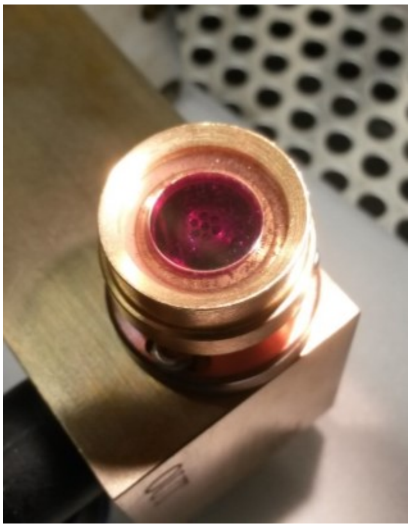

Fig. 1: Thin-disk Ti:Sa laser crystal mounted on a diamond heat sink

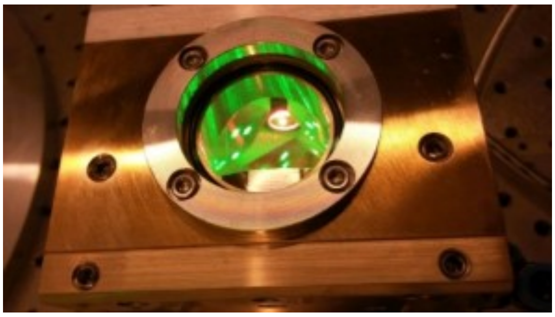

Fig. 2: 48-passes thin-disk pumping module (B1-48).

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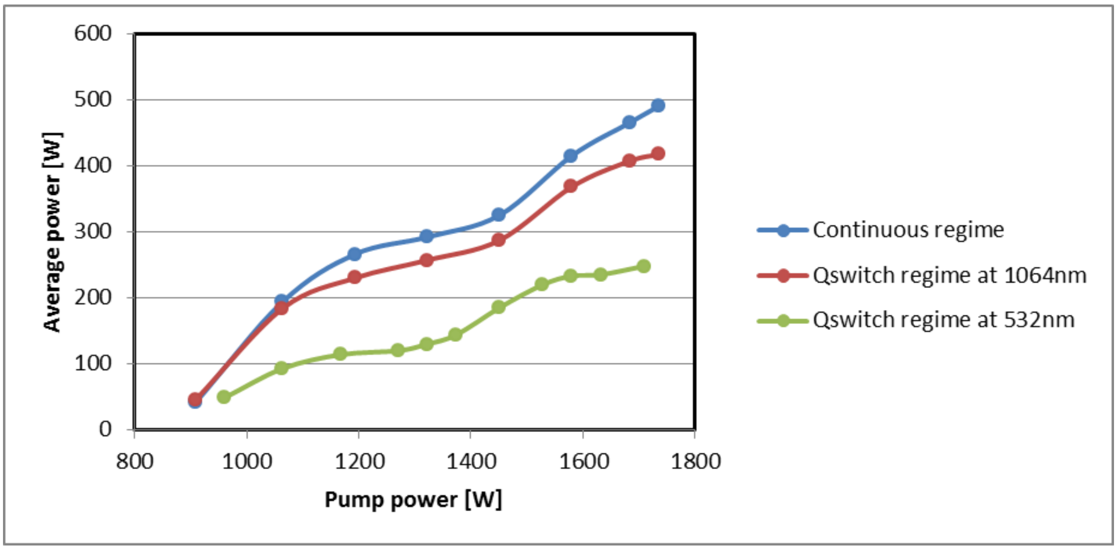
THALES

For pumping Ti:Sa crystal with high average power, new pump lasers are under development at Thales Optronique SA. Diode-pumped gain modules were designed and tested, and up to 250W average power at 532nm was demonstrated at 10kHz. The laser is working in Q-switched regime with intracavity SHG crystal. The pulse duration at high average power is typically 70ns. This new pump laser will be used for developing high average Ti:Sa system with “Quetschi” gain module developed in the TiSa TD project.




femto-st SCIENCES & TECHNOLOGIES

FEMTO-ST has investigated micro and nanoprocessing of sapphire crystal with high aspect ratio Bessel beams formed from an ultrafast Ti:Sa laser. They showed that a single shot is capable to open a void in the bulk of Sapphire with ultra-high aspect ratio. This means that micro -explosions can be created with such high generated pressure that they can compress the material around the fabricated nanochannel (several 100 nm in diameter). Generation of controlled cracks in Sapphire and applications to cutting are currently under investigation.

These results will be communicated at the conferences Photonics West 2016 (San Francisco USA) and High Power Laser Ablation 2016 (Santa Fe, USA) and will be submitted to peer-reviewed journals.

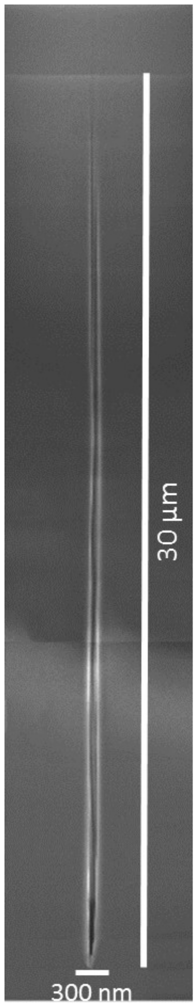



Fig. 3

Figure 3: SEM view of a high-aspect ratio nano-void inscribed by a single laser pulse in the bulk of Sapphire.

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As part of their commitment to the development of the intra-cavity cooling components for the high power thin-disk TiSa laser, Element Six has developed new CVD techniques to synthesise optical quality single crystal diamond with diameter >8 mm (see Fig. 4).

By careful control of the impurity concentrations in the material, the optical absorption was reduced to less than 0.005 $cm^{-1}$ at 1064 nm (Fig. 5).

A matched pair of 8 mm diameter round intra-cavity heat-spreader components was manufactured using novel polishing techniques to achieve a radius of curvature of 5 m on one side of the crystal disk (Fig. 6).

Additionally, a pair of polycrystalline diamond rings was manufactured to act as a high thermal conductivity mount for the single crystal diamond heat-spreaders (Fig. 7).

Fig. 4: 8mm rounds of low absorption single crystal diamond.

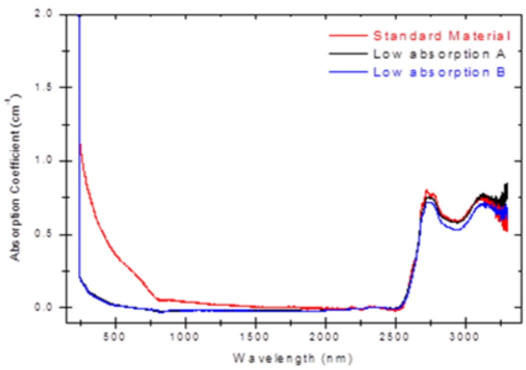


Fig. 5: Optical absorption compared to standard CVD single crystal.

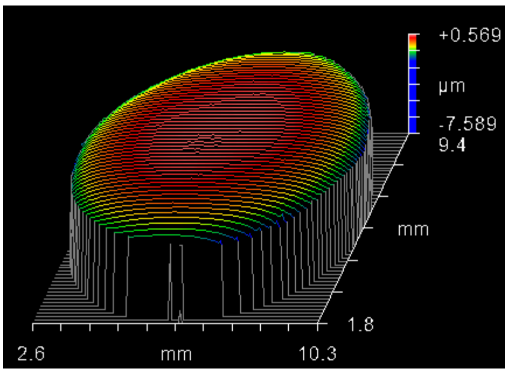


Fig. 6: Interferometry measurement of radius of curvature.

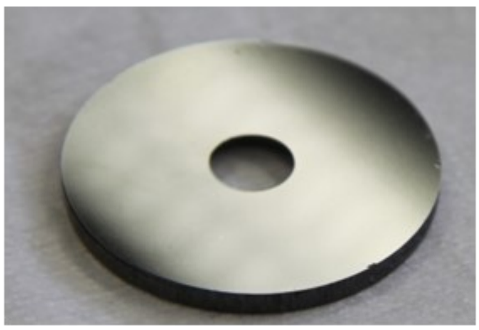

Fig. 7: Polycrystalline mounting ring.

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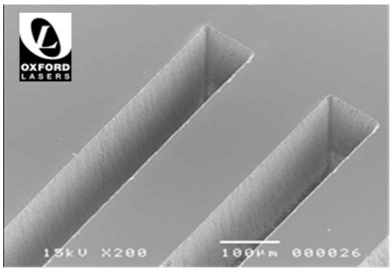
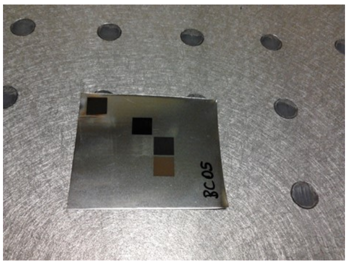
Oxford Lasers is in charge of Laser Applications Development in TiSa TD and is a lead participant in femtosecond laser process development. They will be in charge of demonstrating the project target specifications for the high average power Ti:Sapphire thin-disk oscillator. They also play a major role in the market exploitation research for the project.

As part of the TiSa TD project, OXFORD has dedicated significant resource in the form of three Laser Applications and one Laser Systems Development Engineers as well as a temperature controlled lab environment comprising an optical table, XYZ CNC table (travel 350x450mm, 2µm accuracy), digital encoded galvanometer scanner, motorised attenuator and several beam focusing options to exploit the unique properties of the TiSa TD developed thin-disk femtosecond laser oscillators. Class I laser safety is ensured.

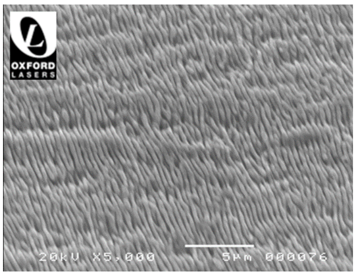
Additionally, in anticipation of receiving the high power femtosecond oscillator, OXFORD has been proactively arranging short-term laser loans in order to evaluate similar (but not as powerful or as high frequency as the TiSa TD oscillator) state of art commercial ultrafast laser sources. The processes which have been benchmarked against are: glass processing (cutting, milling) and metal surface processing at high MHz rate for surface wetting (hydrophobicity) control. Their efforts aimed at benchmarking the optical scanning equipment setup and crucially the required incident pulse energy on target, a task which was successfully demonstrated as seen in adjacent images below. (Note: a lower pulse energy to what TiSa TD would provide was used in all cases here). Based on these activities, they have recently submitted an abstract at LPM2016- Laser Precision Microfabrication, Xian China, 23-26 May 2016



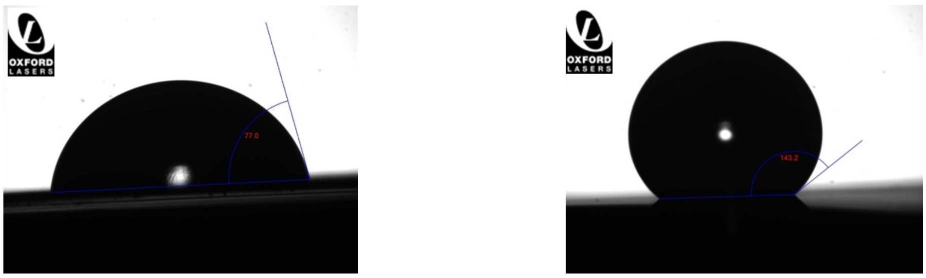

SEM image of ultra-short laser micro-milling of fused silica glass using a MHz fs source with an f-theta telecentric lens. The edge quality is exceptionally sharply defined and free from any collateral thermal damage.




MHz femtosecond laser irradiated stainless steel test part demonstrating distinct surface colour change (reflectivity change) in "square test" areas irradiated with varying laser dosage.




A close-up SEM image of the laser irradiated stainless steel modified floor area exhibiting laser-induced regular periodic features at a sub-wavelength scale period of about 350-400nm.




The difference in water droplet contact angle between the pristine non-irradiated stainless steel surface (left, 77deg) and the laser irradiated one (right, 143deg) is evident. This is OXFORD's first trial on wetting control and appears extremely promising.

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