20 W Upgrade to the ULTRA Facility

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Introduction

ULTRA provides time-resolved spectroscopy facilities to academic and industrial users. The experiments are typically based on pump – probe techniques, exploring molecular structure and dynamics.

The core laser system of the facility, since 2009, has been a dual (fs/ps) cryo-cooled, 10 W titanium sapphire (TiS), 10 kHz repetition-rate, < 50 fs chirped pulse amplifier [1]. Since becoming a facility around 9 years ago, this system has generated more than 130 publications, across mainly chemistry and biology subject areas, including many high impact results [2-7]. This core system is now enhanced by a new TiS amplifier (ULTRA B). This laser provides higher energy output, relative to the current system (ULTRA A) and dedicated target stations to allow parallel operations of ULTRA A and B, with less reconfiguration of the layouts between different experiments.

ULTRA A, ULTRA B and the LIFEtime [8] systems now support parallel operations of the ULTRA facility. This provides a good foundation for the recent increase in access to the facility, now 60 weeks academic access, plus additional industrial user time.

Laser system

The new ULTRA B laser system, shown in fig. 1, is a high power TiS chirped pulse amplifier, manufactured by Coherent. A mode-locked TiS oscillator provides 65 MHz, 400 mW seed pulses to the amplifer, with > 80 nm bandwidth. A Peltier-cooled regenerative amplifier and single pass amplifier are pumped by a > 50 W, 10 kHz, Nd:YAG laser. These first two amplifier stages provide ~ 10 W average power output, post-compression. This power is boosted to 20 W by a third amplifier stage, which is cryo-cooled and pumped by a second Nd:YAG laser. The final output is < 40 fs, 2 mJ, 800 nm.

Figure 1. ULTRA B, 20 W Titanium Sapphire laser system.

This output is immediately split into two 10 W beams as we notice perturbations in the output due to non-linear absorption in the air when propagating the full 20 W, ~ 20 mm diameter beam for more than 1 m. This non-linear absorption is small (< 1 %), but the high average power leads to a thermal fluctuation which is measureable in our experiments. In any case, the splitting of the beams is necessary to generate the required multiple beams for experiments.

10 W of the output pumps a home-built dual optical parametric amplifier (OPA) seeded by a single white-light source, shown in fig. 2. The OPAs are wavelength tunable with computer-control, each generating up to 1.5 W signal and idler (1.1 to 2.6 μm). These outputs can be used as pump and/or probe in experiments. Currently, we have a difference frequency generation stage on the end of one OPA, to generate mid-IR (> 4 μm) output (up to 4 μJ).

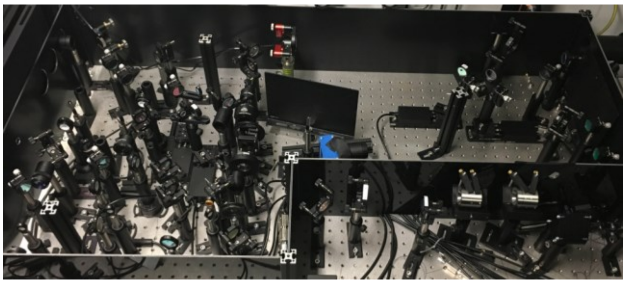

Figure 2. Home-built dual OPA.

The second 10 W output has been used to generate bandwidth narrowed output via etalons, which can be combined with the synchronized mid-IR output for SFG experiments [9].

In the near future we intend to boost the output of one OPA using the second 10 W, to provide high energy, > 100 μJ, idler output for temperature jump experiments [10].

Experimental setups

Throughout the last 10 years, the number of different experiment types offered has gradually increased and now includes: time-resolved UV – IR [2,3,5-7], two-dimensional IR (2D-IR) [11, 12], Kerr-gated time-resolved Resonance Raman [13], femtosecond stimulated Raman [4], time-resolved multiple probe [14] and sum frequency generation (SFG) [9] spectroscopies, with more on the way. ULTRA B currently has dedicated 2D-IR and SFG experiments, which will no longer be performed on ULTRA A.

The current 2D-IR configuration uses an interferometer on the pump arm for photon-echo measurements [15]. Further upgrades to this capability are now ready to be integrated in the form of an IR pulse shaper [16] and fast scanning interferometer [17].

Conclusions

The ULTRA facility has been upgraded by addition of a new 20 W TiS amplifier. Higher energy and better shot-to-shot stability of the new laser can provide improved signal to noise in experiments. Dedicated 2D-IR and SFG beamlines have so far increased the range of capabilities in the facility and enable additional parallel operations capability, to increase the throughput of number of weeks access available.

Acknowledgements

We would like to acknowledge STFC for funding upgrade.

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