ULTRA/ARTEMIS - 100 kHz High Power OPCPA Progress Report

Emma Springate
CLF- Artemis

Mike Towrie
CLF-ULTRA
Research Complex at Harwell

Greg Greetham
CLF - ULTRA
Research Complex at Harwell

Adam Wyatt
CLF - Artemis

Contact *Emma.Springate@stfc.ac.uk*

Introduction

ULTRA and Artemis are state of the art ultrafast dynamic and spectroscopy facilities supporting interdisciplinary research of the highest quality from the biosciences to condensed matter physics. The facilities address the scientific priorities of BBSRC (illustrated by its capital investment to both ULTRA and LIFEtime) and EPSRC. There is a strategic desire to exploit the synergy and added value of bringing ULTRA and Artemis together and begin a timely development of the next generation of UK large scale ultrafast pump-probe facilities. Following a review of current available technologies, the high repetition rate, high average power and mid-IR output with < 50 fs from recently developed optical parametric chirped-pulse amplifiers (OPCPA), has been identified as a key technology for ULTRA and Artemis.

This report highlights progress in the first phase of the project. Through STFC and BEIS Capital funding, the CLF will introduce a custom Fastlite 100 kHz high power mid-IR OPCPA laser system (Fig. 1) in June 2018, as the pump source for XUV and Mid IR pump probe facilities. High average power OPCPA developments are gaining momentum with the advent of power-scaling of picosecond ytterbium pump lasers and integration in projects such as ELI-ALPS (Extreme Light Infrastructure, Hungary). This "3rd Generation femtosecond laser technology" enabes scaling in power and repetition rate that is set to produce light from mid IR to XUV of unprecedented brightness and facilities that will span measurements from attosecond to seconds timescales. The ultimate aim of the CLF is to create instruments producing the

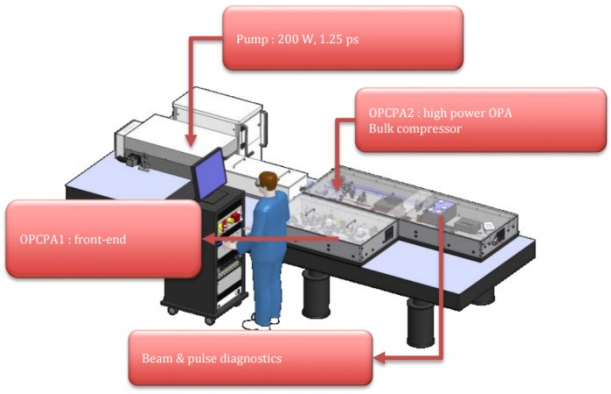

Figure 1:- The Fastlite OPCPA system.

The 100 kHz Laser

Over the last two years the CLF has been closely reviewing OPCPA technology for application in pump-probe spectroscopy and companies have now emerged that will supply 100 kHz high average power OPCPA lasers. Fastlite in particular has

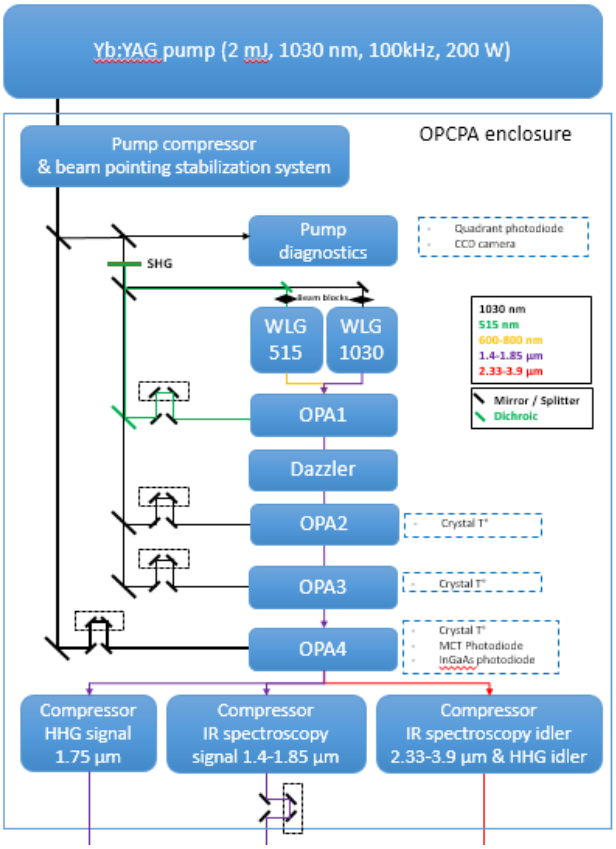

Figure 2:- The OPCPA arrangement with compressed 1.75 and 3 µm HHG and IR spectroscopy options.

focused on mid-IR output (system shown in fig. 1) generated from signal/idler of direct 1030 nm pumped OPCPAs. Of note, is the Fastlite AOM-PDF approach [Dazzler] with remarkable flexibility in computer-control of seed pulse spectrum and phase for rapid manipulation of output parameters that for spectroscopists creates greater opportunity for pump- probe technique developments. Figure 2 shows the flexible OPCPA configuration being built for the CLF. The near to mid IR OPCPA is pumped by a stable TRUMPF 100 kHz, 200W, 1.5 ps laser and the OPCPA is expected to have high stability of ~0.4 % rms and high beam quality important for HHG generation and pump probe spectroscopy. The laser system will be delivered from Fastlite in June 2018.

Laser Description

Fastlite's flexible OPCPA design will allow operation in two modes, HHG mode and IR mode. It will provide < 50 fs, CEP stable, > 50 µJ, broadband, 100 kHz, tunable 1 – 4 µm wavelength light. The OPCPA system (Fig. 2) will have automated control and incorporates the Dazzler system with unique and rapid control of the OPCPA pulse length and

wavelength characteristics, that allow rapid wavelength tuning, fast switching between pulse ps and fs pulse length modes. It will also provide control of pulse dispersion for compensation of optical dispersion and pulse shaping for optimal instrument response, CEP, control (allowing ± π) measurements and feedback. This, with driver software and integrated diagnostic systems, will allow integrated control of output parameters of the laser.

OPCPA in HHG Mode

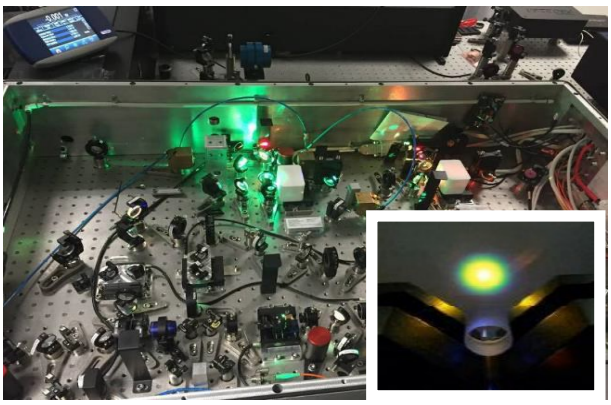

Figure 3:- The OPCPA with white light continuum seed beam depicted in the insert.

For use in High Harmonics Generation applications the OPCPA has optimised centre wavelengths of 1750 nm (Signal) and 3000 nm (idler) with pulse duration of < 50 fs and energy > 170 µJ and > 60 µJ respectively.

Both 1750 and 3000 nm outputs will be passively carrier enveloped phase (CEP) stable. Fast feedback control will enhance stability (> 100 Hz feedback bandwidth) using CEP diagnostics with a ≥ 10 kHz single shot measurement device.

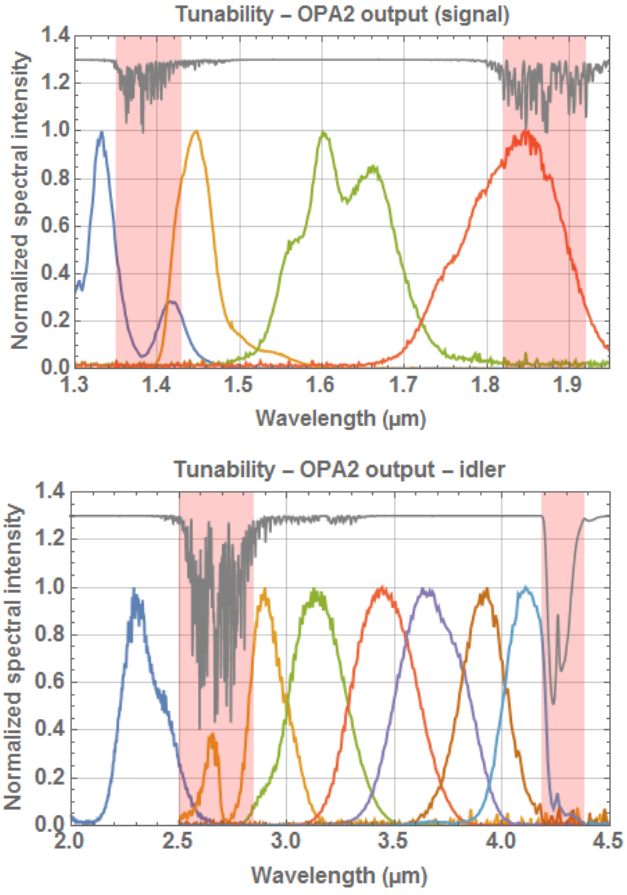

Figure 4:- OPCPA tuning range in the femtosecond mode.

OPCPA in IR Spectroscopy Mode

The OPCPA will have computer-controlled wavelength tunability from a signal output of 1400 – 1850 nm and idler output of 2330 – 3900 nm, with energy ≥ 50 µJ and ≥ 30 µJ respectively across these tuning ranges. Pulse duration is either < 100 fs (Fig. 4) or between 1 – 2 ps at < 30 cm^{-1} spectral bandwidth (Fig. 5).

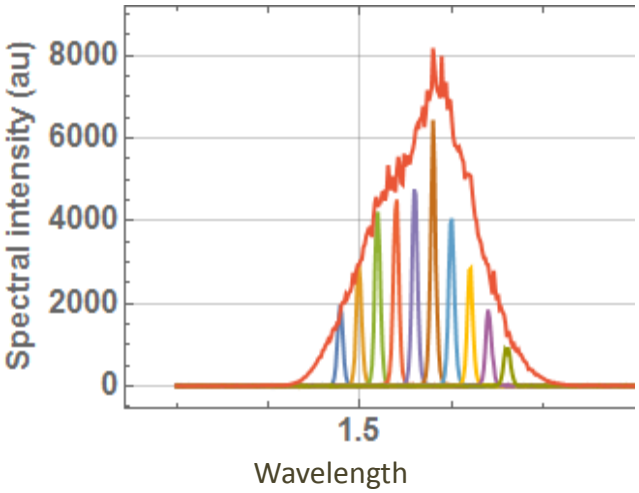

Figure 5:- The tuning of the OPCPA in the picosecond mode, with <30 cm^{-1} spectral bandwidth.

The CLF will develop a high power non-linear optical mixer to generate tunable light in the 3.9 – 10 micron spectral range required for broadband high, repetition rate, time-resolved IR and multidimensional IR spectroscopies. UV-VIS outputs will also be provided to allow a choice of pump wavelengths in combination with XUV probe.

The expected spectral intensity of the IR Spectroscopy OPCPA measured for the femtosecond and picosecond mode of operation is shown in Figs. 3 and 4.

Conclusions

This report provides the technical specification of the Fastlite 100 kHz high power OPCPA system to be delivered to the CLF in June 2018. The CLF will use and develop the laser and OPCPAto generate light from the XUV to mid IR in the first phase in the bringing together of ULTRA and Artemis and the provision of world leading pump probe facilities into the future.

Acknowledgements

We would like to thank STFC for support in the purchase and future commissioning of the laser with contribution from BEIS Capital funding in 2016.