

Congratulations to New ICFO PhD graduate

Dr. Callum O?Donnell graduated with a thesis entitled "Novel Femtosecond Optical Parametric Oscillators in the Infrared"

April 29, 2019

Dr. Callum O?Donnell received his Master in Physics from the University of Manchester (UK) before embarking on his PhD studies between the laboratories of ICREA Prof. at ICFO Dr. Majid Ebrahim-Zadeh and ICFO spin-off Radiantis, where he centered his work on exploiting new nonlinear materials to improve the spectral coverage and output power of optical parametric oscillators. Dr. O?Donnell?s thesis, entitled "Novel Femtosecond Optical Parametric Oscillators in the Infrared", was supervised by Prof. Majid Ebrahim-Zadeh and Dr. Chaitanya K. Suddapalli.

Abstract

High-repetition-rate femtosecond laser sources are essential laboratory tools for spectroscopy, microscopy, amongst other applications. With the relative length of one femtosecond to one second being similar to the length of 1 second compared to the age of the universe, such lasers enable scientists to probe physical processes at unimaginably short timescales. Furthermore, the high peak powers can excite strong nonlinear response in delicate material samples without delivering potentially damaging levels of energy. The infrared (IR) spectral region across 1-12 mis rich in molecular absorption features, but i general poorly served by conventional coherent light sources. Optical parametric oscillator (OPOs) represent the most viable solution to this long-term issue, due to their table-to nature, and unparalleled tunability and spectral brightness in the near- and mid-IR. Recen breakthroughs in nonlinear crystal technology have opened the door to the generation o laser light in the previously difficult to access region above 4 m, using high power lase s near 1 m. Exploiting these new nonlinear materials to improve the spectral coverage nd output power of OPOs has the potential to provide important societal benefits, particularly in the fields of frequency metrology, security, and medical imaging. In addition, theoreti al modelling and exploration of devices with novel cavity designs can lead to technologi al advances which improve OPO affordability and increase their appeal to a wider scienti ic audience.

In this thesis, we have demonstrated three OPOs across 1-8.4 m in the infrared, which ar pumped using well-established Ti:sapphire laser technology. The first is a compact an cost-effective device tunable across 1051-1700 nm in the near-IR, producing sub-100 f pulses at 80 MHz. The incorporation of an optical fibre into the cavity leads to excellen passive power and wavelength stability, and enables soliton formation to be observed together with other interesting nonlinear effects. We have also demonstrated an efficient low-threshold mid-IR OPO exploiting group-velocity match effects in MgO:PPLN, whic enables the use of a long (42 mm) nonlinear crystal. In doing so, we report quantu conversion efficiencies as high as 48% from the near-IR (s1 m) pump to the mid-IR (3.1-4 3 m), and use the source to perform basic spectroscopy.

The third device uses Ti:sapphire light at s1 m to directly pump the new nonlinear crystal CdSiP2, generating up to 20 mW average power across 6.6-8.4 m in the deep mid-IR. As t e first demonstration of a single-stage Ti:sapphire-pumped deep mid-IR OPO with practic l output powers, it has potential for medical imaging applications in the important amide II a d III.

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