Congratulations to New ICFO PhD Graduate

Dr. Omid Kokabee graduated with a thesis entitled ï¿½High-pow r ultrafast optical parametric oscillators from the visible o mid-infraredï¿½

December 17, 2025

We congratulate Dr. Omid Kokabee who defended his thesis this morning in ICFO's Elements Room.

Dr. Kokabee obtained his MSc in Photonics at the Universitat Politecnica de Catalunya and he joined the Optical Parametric Oscillators team at ICFO.

ABSTRACT:

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In a synchronously pumped optical parametric oscillator (SPOPO), the pump laser pulses are timed to arrive at the OPO crystal in synchronism with the circulating signal pulses, enabling efficient energy transfer and the generation of high-power, high-repetition-rate, widely tunable, ultrashort pulses. This synchronization allows SPOPOs to achieve high conversion

efficiencies and excellent temporal, spectral and spatial characteristics. The research presented in this thesis focuses on the development of high-power ultrafast SPOPOs at repetition rates from 76 MHz to as high as 1 GHz covering the visible to mid-infrared spectrum.

First, we presented a method for efficient generation of femtosecond pulses with wide tuning in the red spectrum using a periodically-poled LiNbO3 (PPLN) as the nonlinear gain crystal combined with bismuth triborate (BIBO) for internal frequency doubling. High nonlinear gain in both PPLN and BIBO, combined with collinear pumping, results in a conversion efficiency of 17.2%, providing tunable coverage across the 665-785 nm range. The large spectral acceptance in PPLN and BIBO facilitates convenient wavelength tuning by adjusting the SPOPO cavity delay, without modifying other parameters such as PPLN crystal temperature, BIBO phase-match angle, or pump wavelength.

Further, we reported the implementation of a femtosecond SPOPO operating at an approximate repetition rate of 1 GHz using a novel technique to enhance the MHz pump repetition rate. The system uses PPLN as the nonlinear medium and features an innovative cavity design exceeding the fundamental synchronous cavity length. Driven by a Kerr-lens mode-locked (KLM) Ti:sapphire laser operating at 76 MHz, the system generates near-transform-limited pulses at the 13th harmonic of the pump laser frequency, corresponding to 988 MHz. Internal dispersion compensation using a pair of SF11 prisms in the linear cavity configuration achieves stable near-transform-limited output signal pulses up to the 14th harmonic of the pump laser repetition rate, corresponding to 1064 MHz.

Later, we introduced a universal method for maximizing output power from optical oscillators through interferometry. By incorporating an antiresonant ring interferometer into one arm of the oscillator cavity, continuously variable output coupling is achieved over a broad spectral range and under any operating conditions. Demonstrated using a femtosecond SPOPO, this technique enables continuously adjustable output coupling from 1% to 60%. At an optimized output coupling of approximately 30%, around 200 mW of power is extracted, more than double the output compared to a conventional output coupler with around 4%. The method maintains a Gaussian beam profile and near-transform-limited pulse durations.

Additionally, we detailed the development and characterization of a highly efficient and stable picosecond SPOPO system based on magnesium oxide-doped PPLN (MgO:PPLN), pumped by a ytterbium (Yb) fiber laser. The system achieves exceptional performance in power output and conversion efficiency, with a total average power extraction of 11.7 W. This includes 7.1 W of signal radiation at 1.56 ?m and 4.6 W of idler radiation at 3.33 ?m, with a remarkable extraction efficiency of 73%. This performance is accompanied by superior spectral and spatial beam characteristics, exhibiting exceptional output power stability.

Thesis Committee:

Prof. Dr. Albert Ferrando Cogollos, Universidad de Valencia

Prof. Dr. David Artigas Garcia, ICFO
Prof. Dr. Jordi Gomis Bresco, Universitat de Barcelona