Principles and applications of high-energy femtosecond parametric mid-IR sources

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Laser sources in the mid-infrared spectral region (3—30 μm)—both tunable narrowband ones and broadband, supporting few-cycle pulses—are of key importance for molecular applications, such as sensing techniques based on detecting vibrational fingerprints, tracing ultrafast structural dynamics and engineering of bond-selective photodissociation. There is also a rapidly growing interest in intense few-cycle mid-IR sources from the strong-field research community, related to the opportunity to control the mechanism of ionization and to exploit ponderomotive force scaling in the case of a long oscillation period of the driver laser pulse. Unfortunately, natural lasing materials operating in this wavelength region do not exist, whereas artificial structures, such as quantum-cascade lasers, are not suitable for producing intense pulses. Therefore, various techniques of optical parametric amplification (OPA) based on three- and four-wave mixing have to be employed instead. This lecture will survey the basic principles of efficient broadband parametric mid-IR conversion and showcase some prominent applications. After presenting the general considerations and surveying various methods, the talk will focus on several recent results obtained in our lab:

1) Development of a 120-GW peak power 4-μm OPA [1].

2) Phase-matched extreme wavelength conversion from 4 μm to <1 nm by high-order harmonic generation [2].

3) Observations of remotely induced nitrogen lasing; first reported generation of mid-IR femtosecond filaments in gas; and novel nonlinear optical effects induced with mid-IR pulses [3,4].

4) Solitonic self-compression of IR pulses below a single optical cycle in specialty gas-filled waveguides.

6) Generation of octave-wide femtosecond pulses around λ=6 μm and the development of a 2-μm multi-millijoule femtosecond Ho laser amplifier as a pump for the 6-μm OPA.

References:

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[4] D. Kartashov, *et al*., Phys. Rev. A., 86, 033831 (2012).