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Status and prospects of optically pumped high-pressure CO2 amplifiers

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Multiple advanced accelerator concepts such as electron and ion acceleration from plasmas, inverse FEL's, and Compton sources would benefit from the development of high-repetition-rate and short-pulse but high-energy mid-IR lasers. However, this intense-field mid-IR is still extremely difficult to access, since solid-state laser sources in this spectral region are limited in power. CO2 lasers systems are currently the most promising strategy towards the generation of such pulses, as the CO2 molecule is capable of storing Joules of energy for 10 μm amplification and does not face the damage threshold limitations that inhibit optical parametric amplifiers from reaching high peak powers at these wavelengths. Picosecond CO2 gain modules are typically pumped with an electric discharge, however, the voltage required at the high pressures (>10 atm), needed for a smooth gain bandwidth, is prohibitively high and it is extremely difficult to maintain a stable electric discharge in large volumes.
Funded by the DOE Accelerator Stewardship grant, a UCLA/BNL/UAB team launched a program towards development of a compact multiatmopshere CO2 amplifier optically pumped by pulses of a 4.3 ⊠m Fe:ZnSe laser. Switching from the traditional electrical discharge pumping to an optical pumping of a high-pressure CO2 amplifier could drastically decrease the size of a CO2 MOPA system and the pulse length to ~ 300-500 fs, simultaneously increasing the repetition rate to 10-100 Hz. To this end, a novel Fe:ZnSe laser generating ~50mJ pulses around 4.1-4.8 μm [1] was tested as a pump source. In this scheme of optical pumping, the upper laser level in the 10 ⊠m lasing channel 001-100 of a CO2 molecule is pumped directly from the ground state and in recent proof-of-principle experiments lasing was observed up to 15 atm pressure and the optical-to-optical conversion efficiency reached 10% at ~10 atm [2]. Simulations of amplification of a 10 uJ seed showed possibility to reach a few GW power level in a palm-size regenerative amplifier [3]. Current activities and future prospects will be discussed.

1. V. Fedorov et al, Opt. Express 27, 13934-13941(2019).
2. D. Tovey et al, Opt. Express, 29, 31455-31464(2021).
3. D. Tovey et al, Appl. Opt. 58, 5756-5763(2019).

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