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Raman-based wavelength conversion for seeding and optical pumping of CO2 laser amplifiers

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The long wavelength of long-wave infrared (LWIR) lasers suit them to applications relying on ponderomotive interactions, such as laser wakefield acceleration and high harmonic generation. The workhorse source of such wavelengths is the CO2 amplifier, providing the ability to reach TW peak powers and sub-ps pulse lengths. Two pathways to improve the performance of these amplifiers are to increase the energy by increasing the energy of the seed and to increase the repetition rate by optically pumping the gas instead of pumping with an electrical discharge. The wavelengths required, 9.2 um for the seed and 4.3 um for the pump, are outside the range of conventional millijoule-class, nanosecond laser sources, and must be obtained through nonlinear wavelength conversion processes. One such process is known as stimulated Raman scattering (SRS), where photons are inelastically scattered by a coherent excited state of a material. In principle, ionic liquids (ILs), artificial salts that are liquid at room temperature, are an excellent choice of material for SRS, as the vibrational modes and optical properties can be tailored with the choice of ions. Relatively efficient difference frequency conversion from visible/near-infrared to the seed and pump wavelengths can be achieved with Raman shifts of 1087 cm-1 and 2200 cm-1 respectively. We find that calcite crystals offer high efficiency conversion corresponding to the first Raman shift, from 800 nm Ti:Sa to 876 nm, and an ionic liquid, 1-ethyl-3-methylimidazolium dicyanamide (EMIM-DCA), provides the second, from 532 nm Nd:YAG to 603 nm. As a proof of principle, we measure a conversion efficiency in EMIM-DCA three times higher than that of water. Future work will consist of measuring conversion efficiencies in a variety of other ILs. Beyond upgrading the CO2 amplifiers, Raman shifting in ILs provide a pathway for efficient, simple, alignment-tolerant high-energy wavelength conversion.

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