Contribution ID: **2187** Contribution code: **THPA177** Type: **Poster Presentation**

Multi-terawatt, sub-picosecond long-wave infrared laser for next-generation particle accelerators

Thursday, 11 May 2023 16:30 (2 hours)

Lambda-squared scaling of the ponderomotive potential makes long wavelengths preferable for certain regimes of laser-based particle acceleration, including the laser-wakefield acceleration of electrons at low plasma densities and the acceleration of ions from gaseous targets. Currently, multi-terawatt levels of peak power at long-wave infrared (LWIR) wavelengths around 10 μm can only be achieved via the amplification of a picosecond laser pulse in high-pressure CO2 laser amplifiers. Our state-of-the-art LWIR laser system employs chirped-pulse amplification in a mixed-isotope CO2 active medium (Oxygen-16 : Oxygen-18 ≈ 50:50) at a pressure of ~10 atmospheres to deliver up to 5 TW peak power in 2-picosecond pulses. This laser system has enabled several promising parameter-space optimization studies and proof-of-principle demonstrations of advanced techniques of particle acceleration and x-ray generation in recent years.
A next-generation LWIR laser is currently under active development. It will provide a sub-picosecond pulse duration (100 fs and 500 fs with and without post-compression, respectively) and ≥15 TW of peak power. Theoretical models predict that these laser parameters will enable new acceleration regimes, such as the blow-out regime of laser-wakefield acceleration with millimeter-scale accelerating plasma structures.

Funding Agency

U.S. Department of Energy, Office of Science (DE-SC0012704)
U.S. Department of Energy Accelerator Stewardship Program grant, B&R #KA2601020, KW010102

Footnotes

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Session Classification: Thursday Poster Session

Track Classification: MC7: Accelerator Technology and Sustainability: MC7.T25: Lasers