Next steps in high-repetition-rate laser development for Thomson scattering

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We are beginning design of a next generation pulse-burst laser system, aiming for a maximum rep rate of 100 kHz for 1 ms. Pulse-burst laser systems with "fast burst" rep rates in the range of 10 – 20 kHz have been built for the Thomson scattering diagnostics on MST [1], NSTX-U [2], and LHD [3]. Recent measurements on LHD illustrate the new diagnostic capability to capture fast dynamics in the plasma [4, 5].

Pulse-burst laser programming is a type of heat-capacity laser operation. Heat-capacity laser operation is characterized by a burst of pulses is of limited duration, with burst length ≤100 ms and pulse rep rate ≥1 kHz. Waste heat accumulates in the laser rod during the burst. This heat is deposited evenly throughout the rod volume, with very little heat removed during the burst, such that temperature rises evenly across the rod radius. Thus beam distortion due to thermal gradients is small. Heat is removed from rod after the burst, with typically tens of seconds between bursts. Pulse-burst operation of flashlamp pumped Nd:YAG lasers is a cost-effective route to high-rep-rate capability. For Thomson scattering diagnostic application, the typical requirements are 1064 nm, 1-2 J/pulse, ≤30 ns FWHM pulse, with a top-hat beam profile. A major requirement for this next generation laser system is flexibility in burst sequence programs, ranging from 1 kHz for 100 ms to 100 kHz for 1 ms, and a variety of scenarios in between so that operation can be tailored to plasma experiment requirements.

Flashlamp pumping will be used for this next generation laser because it is inexpensive and flexible. We have tested a prototype of a new switch-regulated flashlamp driver that will provide improved flashlamp control at lower cost. We plan to scale up this prototype while additional design issues are addressed:

- Best layout of oscillator and amplifier stages
- Operation of KD*P Pockels at 100 kHz, or selection of alternative
- Optimum pumping chamber for 16 mm final amplifier rod
- Optimum flashlamp pumping spectrum and optimum Nd doping
- Feasibility of ceramic composite Cr-doped Nd:YAG to increase efficiency of flashlamp pumping

We aim to maximize the use of commercial components in this laser system, and are working with InnoLas on development and construction. Our hope is that the design and approach can be adapted to laser systems suitable for a variety of applications, including fusion research and plasma physics, fluid and combustion dynamics, and laser-plasma interactions.

[1] D. J. Den Hartog *et al.*, *Rev. Sci. Instrum.* **81** (2010) 10D513.
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[3] *Development of high-time-resolution measurement of electron temperature and density in a magnetically confined plasma* (https://www.eurekalert.org/news-releases/968127).
[4] N. Kenmochi *et al.*, *Sci. Rep.* **12** (2022) 6979.
[5] H. Funaba *et al., Sci. Rep.* **12** (2022) 15112.

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