1064 nm injection mode-locked Nd:YAG laser optimized for guide star applications

by

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Contents

Abstract

In recent years, the emergence of powerful, sodium-resonant laser sources has led to a dramatic improvement in resolution at many of the world's large aperture observatories. The lasers are used to create artificial beacons (or guide stars) by fluorescing atmospheric sodium. Light from the beacon, returning from altitude, probes the intervening turbulence and the phase distortions detected are subsequently corrected using adaptive optics. Near-diffraction limited imaging has now been achieved on observatories with diameters up to 8 m using this technique. Future 30-100 m diameter telescopes will require new laser sources having higher average powers and innovative pulse formats to implement new forms of atmospheric tomography and correction. In this thesis I present the design and development of a new laser system for this purpose.

The laser design that I describe uses sum frequency generation (SFG) of 1064 nm and 1319 nm Nd:YAG lasers to produce the sodium wavelength, and introduces the novel application of injection mode-locking as a robust method to control the lasers wavelength and bandwidth. The high peak power and low timing jitter of the mode-locked (micro) pulses allows for efficient SFG of the 1064 and 1319 nm beams. Each slave laser is Q-switched and the duration of the Q-switched (macro) pulses are optimised to reduce star elongation and bleaching of the sodium.

The experimental work presented in this thesis is focused on the realization of a 1064 nm injection mode-locked slave laser, whose performance is optimised for use in the SFG guide star system. The work can be roughly divided into two sections. Firstly, results are presented from a low average power proof of principle laser which was used for risk reduction experiments, then secondly, a higher average power laser using a new laser head design is presented.

With the proof of concept laser it is shown that the injection mode-locking technique is robust and can be used to generate an ideal pulse burst with both wavelength and bandwidth control. A new method of Q-switched pulse stretching was implemented and the results show that the Q-switched pulses can be extended by a factor of 4.5 without a reduction in pulse energy.

The later part of the experimental work consists of a description of the design, construction and testing of a new high average power laser head used to generate the power levels required for the final guide star system. The laser head uses a zigzag Nd:YAG slab, pumped from each side by high average power laser diode arrays. This laser is shown to be capable of generating one of the highest average powers reported in the literature for an electro-optically Q-switched, diffraction limited Nd:YAG laser in a stable cavity.

Publications resulting from this work:

- T. P. Rutten, P. J. Veitch, C. d'Orgeville and J. Munch, "Injection mode-locked guide star laser concept and design verification experiments," Opt. Express vol. 15 (5), pp. 2369-2374 Mar. 2007.

- T. P. Rutten, N. Wild and P. J. Veitch, "Fast rise time, long pulse width, kilohertz repetition rate Q-switch driver," Rev. Sci. Instrum. vol. 78, 073108 Jun. 2007.

- T. P. Rutten, P. J. Veitch and J. Munch, "Efficient pulse stretching of Q-switched lasers," IEEE J. Quantum Electron. vol. 44 (10), pp. 911-915 Oct. 2008.

- J. Munch, T. P. Rutten, N. Simakov, M. Hamilton, C. d'Orgeville and P. Veitch, "A new guide star laser using optimized injection mode-locking," Proc. SPIE, vol. 7015, June 2008

SIGNED: ....
DATE: ....

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