DURIP: Fast Oscilloscope and Detectors for Air Laser Research

Office of Naval Research

N00014-13-1-0683

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1. Type of equipment

The equipment purchased under this DURIP provides the capability to detect in real time events on very fast time scales, as low as 10 picoseconds. Fast real-time oscilloscopes and fast detectors were needed for this purpose.

2. Manufacturer of equipment and model number

TEKTRONIX

DPO73304D, 33 GHz Digital Phosphor Oscilloscope; 4 analog channels
DPO70604C, 6 GHz Digital Phosphor Oscilloscope; 4 analog channels

NEWPORT

2x 1454-50 DET, 18.5PS, detector, VIS- IR, K/FC coupling, multimode

3. Cost of the equipment
$245,452.00

4. Quantity

Two fast real-time oscilloscopes (one at 33GHz and one at 6GHz) and two fast detectors (18ps response time).

5. No changes

6. A concise discussion of the use of the equipment including (a) any research work described in the proposal and (b) any other research of interest to DOD.

The equipment allows for real-time direct measurement of laser pulses on picosecond time scale. In particular, this equipment allows us to time-resolve the fast pulses obtained in air lasing. The air laser is the forward and backwards coherent emission we observe

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when we focus in air intense UV pulses resonantly with two-photon transitions in atomic oxygen or nitrogen. The UV pump pulse (or an earlier pulse from another laser) dissociate the molecular oxygen and nitrogen, creating atomic species. Following this laser-induced molecular dissociation, near-IR emission at 845nm or 745nm is obtained via two-photon pumping the resulting atomic oxygen or nitrogen, respectively.

Specifically, two-photon UV pumping at 226nm for oxygen, and at 207 or 211nm for nitrogen is followed by the near-IR emission. A strongly asymmetrical high gain region created by the focused UV pump can lead to coherent emission in both forward and backward direction, where the stimulated emission gain is the strongest.

The backwards lasing in particular is of interest for remote detection of trace species, because we are creating a laser source at or behind the target plume. This laser source provides a coherent beam that can be easily detected from long distances, extending the detection capabilities to ranges much beyond the capabilities of detecting an incoherent, isotropic emission.

Due to its properties related to the gain medium length and coherence length, we have previously estimated the air laser pulses to be on the order of picoseconds, or tens of picoseconds. The main purpose of this DURIP acquisition was to provide us the capability of directly measuring the air laser pulses.

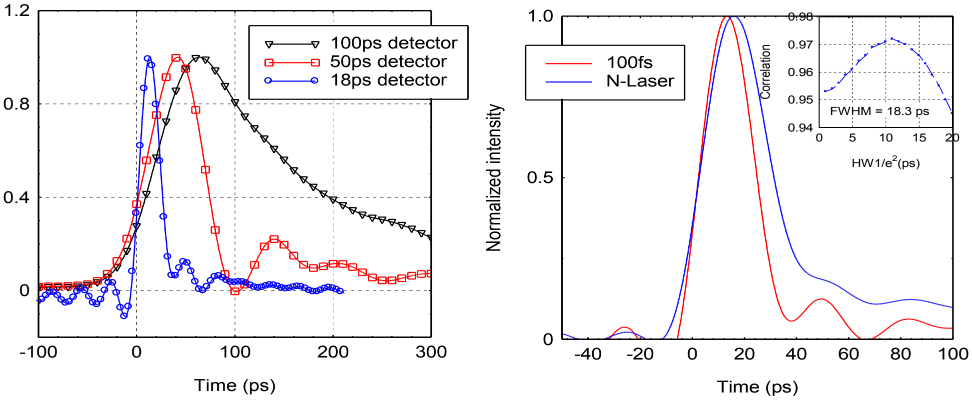

Fig. 1. Left: Backwards lasing pulse from atomic nitrogen in air measured with several fast detectors. Right: Deconvolution of the measured pulse and the detector/oscilloscope response function show a nitrogen laser pulse of 18.3ps.

In Fig. 1 we show the temporal characteristics of the nitrogen laser emission in air. Using the fast detectors and the 33GHz Tektronix DPO73304D oscilloscope acquired under the DURIP grant we can measure directly the fast emission of the nitrogen laser (Fig. 1, left). By measuring the response function of the detection system with a 100fs laser pulse, we can deconvolute the air laser pulsewidth from the detector response by maximizing the correlation with a varying laser pulsewidth (Fig. 1, right). This procedure allows us to measure a pulsewidth of 18ps.

The direct pulsewidth measurements, together with separate interferometric measurements showing coherence time on the order of 10-20ps, demonstrate that the stimulated emission leading to air lasing provides a coherent source with bandwidth limited pulses.

Because of the fact that the UV pump laser we are using delivers 100ps pulses, it was expected that several air laser pulses can be obtained during a single pump pulse, provided high enough optical gain. Fig. 2 shows that indeed, during the pump pulse (red dotted lines), several air laser pulses (black solid lines) can be achieved. These measurements were performed using the same fast detection capability provided by the DURIP grant.

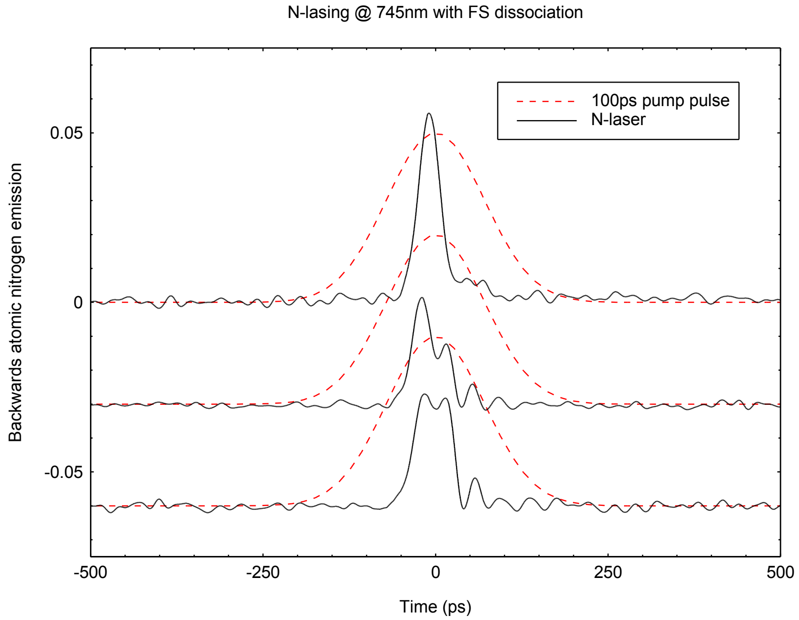

Fig. 2. Examples of multiple air laser pulses (solid lines) obtained during the 100ps UV excitation pulse (dotted line).

The capability of measuring pulses on the picosecond time scale is proving to be beneficial to other projects of interest for DOD. For example, working on another ONR sponsored project we have achieved strong stimulated emission in atomic xenon for the purpose of generating a beam resonant with an emission line in the target xenon atoms.

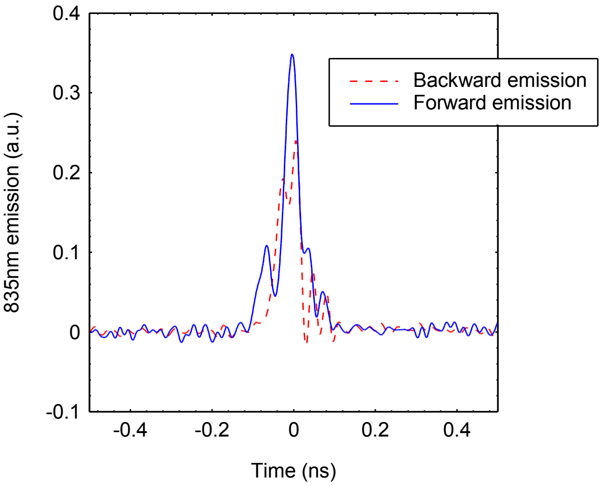

Fig. 3 The 835nm emission in the forward and backward direction from a cell filled with Xe pumped by femtosecond laser pulses at 252nm.

We have also obtained emission on the same 10-20ps time scale from pumping argon atoms. This development is again of interest to our air lasing project sponsored by ONR, because argon is the third most populous air constituent, after nitrogen an oxygen.