Development of a single shot coherent Rayleigh Brillouin scattering capable laser system

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2 Abstract

A laser system capable of performing single shot coherent Rayleigh Brillouin scattering (CRBS) was designed, constructed and tested. CRBS is a laser diagnostic capable of resolving characteristic properties of a gaseous medium such as its temperature, shear and bulk viscosity, as well as vibrational and rotational relaxation rates of the medium in question with a high degree of temporal and spatial resolution (~200ns and ~150um, respectively).

Motivation

Develop a system capable of acquiring single shot CRBS spectrum. CRBS is a four wave mixing technique capable of resolving information regarding a gaseous medium such as temperature, speed of sound, as well as shear and bulk velocity.[1,2]

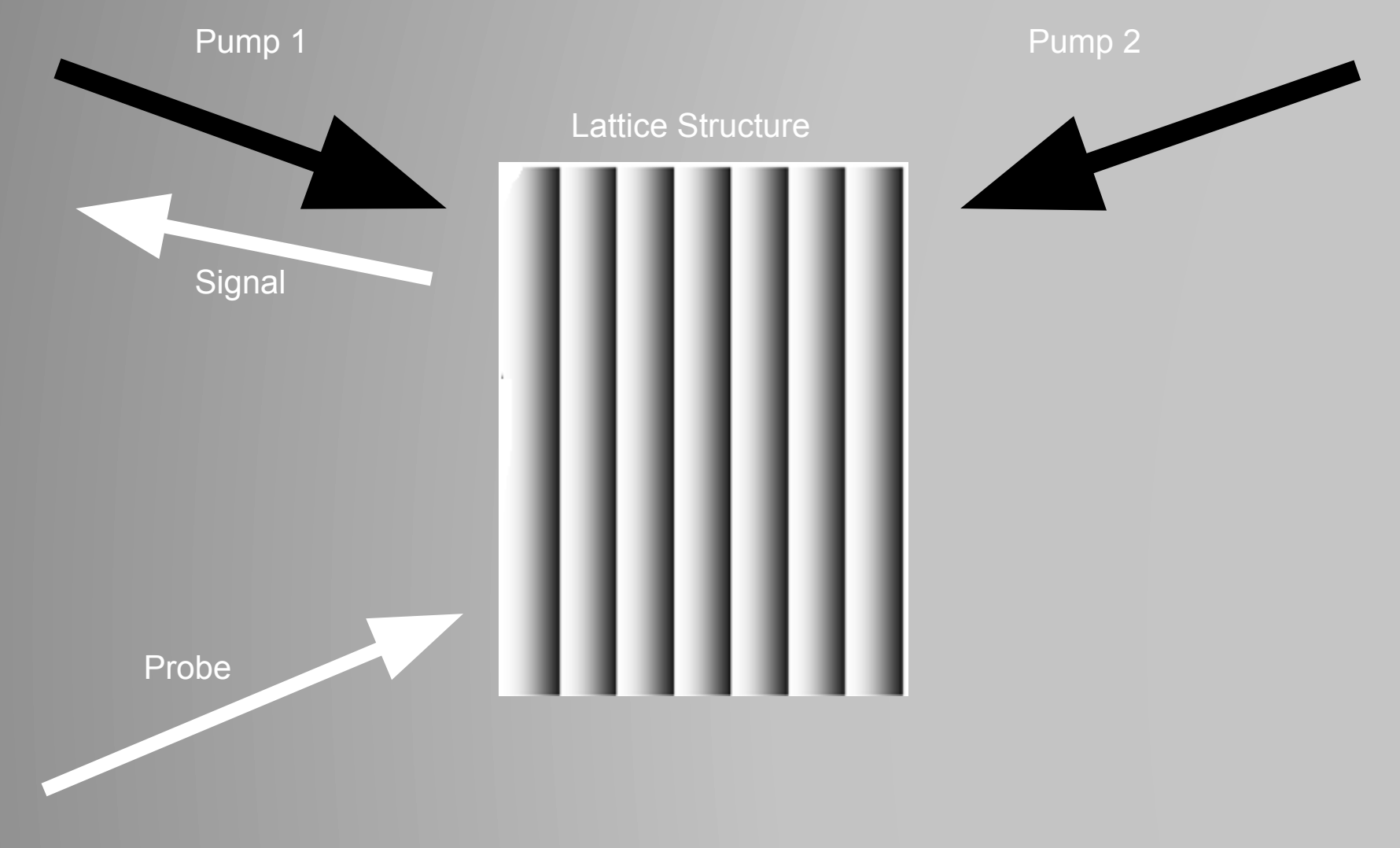

Figure 1: *Typical geometry for CRBS. Two almost counterpropagating pump beams interfere to form an optical lattice. A probe beam of orthogonal polarization to the two pump beams is then scattered from the density grating induced by the optical lattice.*

The main purpose of the system is for use as a diagnostic in the detection and *in situ* characterization of nanoparticles formed in plasmas such as arch discharges and dielectric barrier discharges. The high degree of temporal and spatial resolution makes CRBS an ideal technique for the identification of the elusive mechanisms of these interactions.

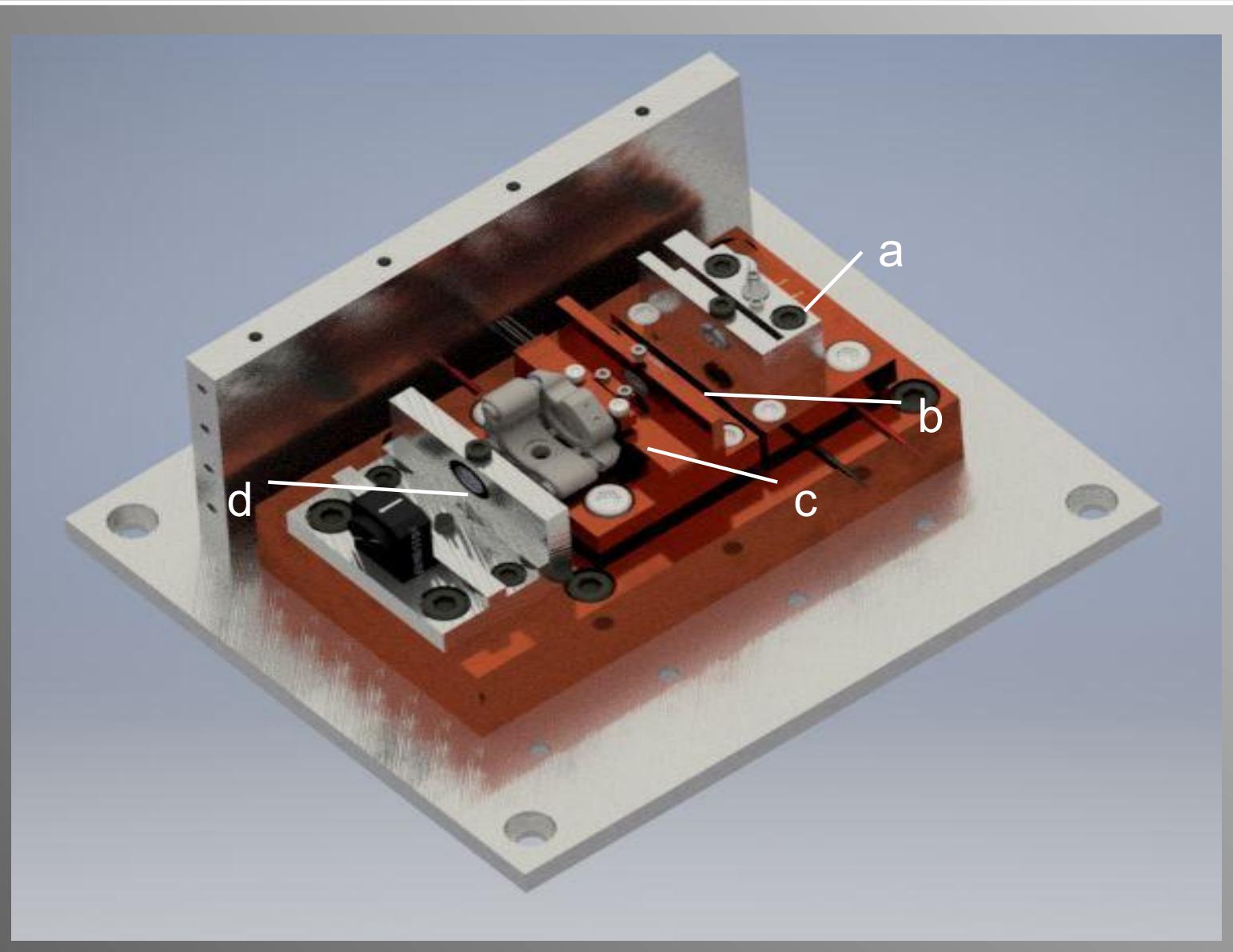

Figure 2: *The seed laser.a) Pump diode b) Collimator lens c) Focusing lens, optical cavity and electro-optic modulator d) 1064 nm filter*

The Optical Setup

The setup ultimately delivers two ~250 mJ flat-topped pulses after shaping and amplification. Here we highlight some of the unique challenges of meeting these metrics and the solutions our setup uses in order to accomplish them. The custom, in-house designed and built seed laser emits a ~10 mW continuous wave 1064 nm (CW) beam. Using an electrooptic modulator (EOM), the seed laser is capable of quickly chirping the emitted beam's frequency by 1.5 Ghz in ~200 ns. In order to eliminate intensity modulations due to relaxation oscillations in the seed cavity, the beam emitted from the seed laser is injection locked to the slave diode laser, forcing it to emit at the same frequency as the seed laser.

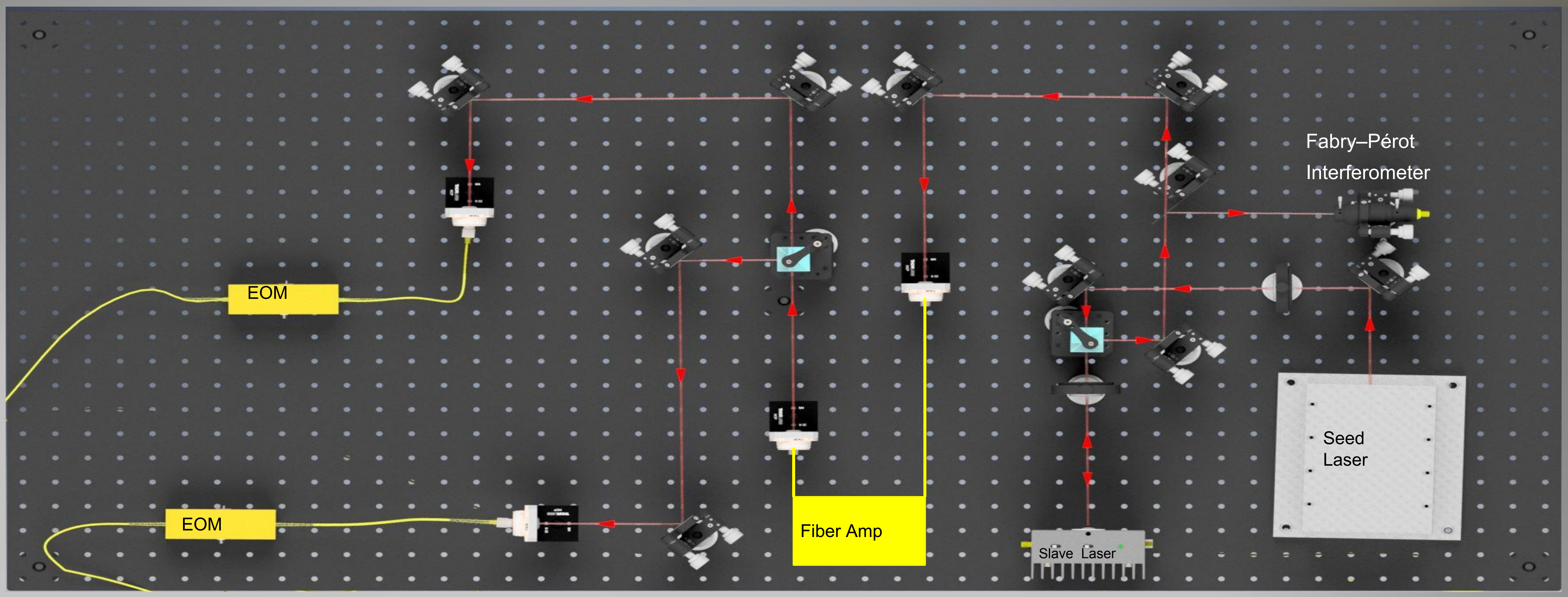

Figure 3: *The optical setup of the top shelf. The beam propagates in the direction of the red arrows. It is amplified through a fiber amplifier and split in two via a 50/50 beam splitter. The resulting beams, the temporal profile of which is modulated at the Electrooptic Modulators (EOM) are then fed into the two amplifying arms on the lower optical setup.*

A small sample of the beam emitted from the diode slave laser is guided to a Fabry-Perot interferometer to confirm successful injection locking. The majority of the beam is coupled to an optical fiber and guided into a fiber amplifier, ensuring a stable 1 W output power. The beam is then split in half, using a 50/50 beam splitter. Both beams are coupled to optical fibers and fed into two respective electro-optical temporal beam shapers. These devices allow modulation of arbitrarily shaped beam intensity pulse profiles. They are particularly helpful in compensating for the non-linearly decreasing temporal gain profile of the Nd:YAG amplifiers in the next stage. The beam is then guided to the second level through two optical fibers. This facilitates two pulses, one of constant frequency and one of frequency chirped with respect to the constant pulse, can be delivered simultaneously through the use of an additional 85m long delay line. This ultimately facilitates the acquisition of a complete CRBS spectrum in a single ~200 ns laser pulse.

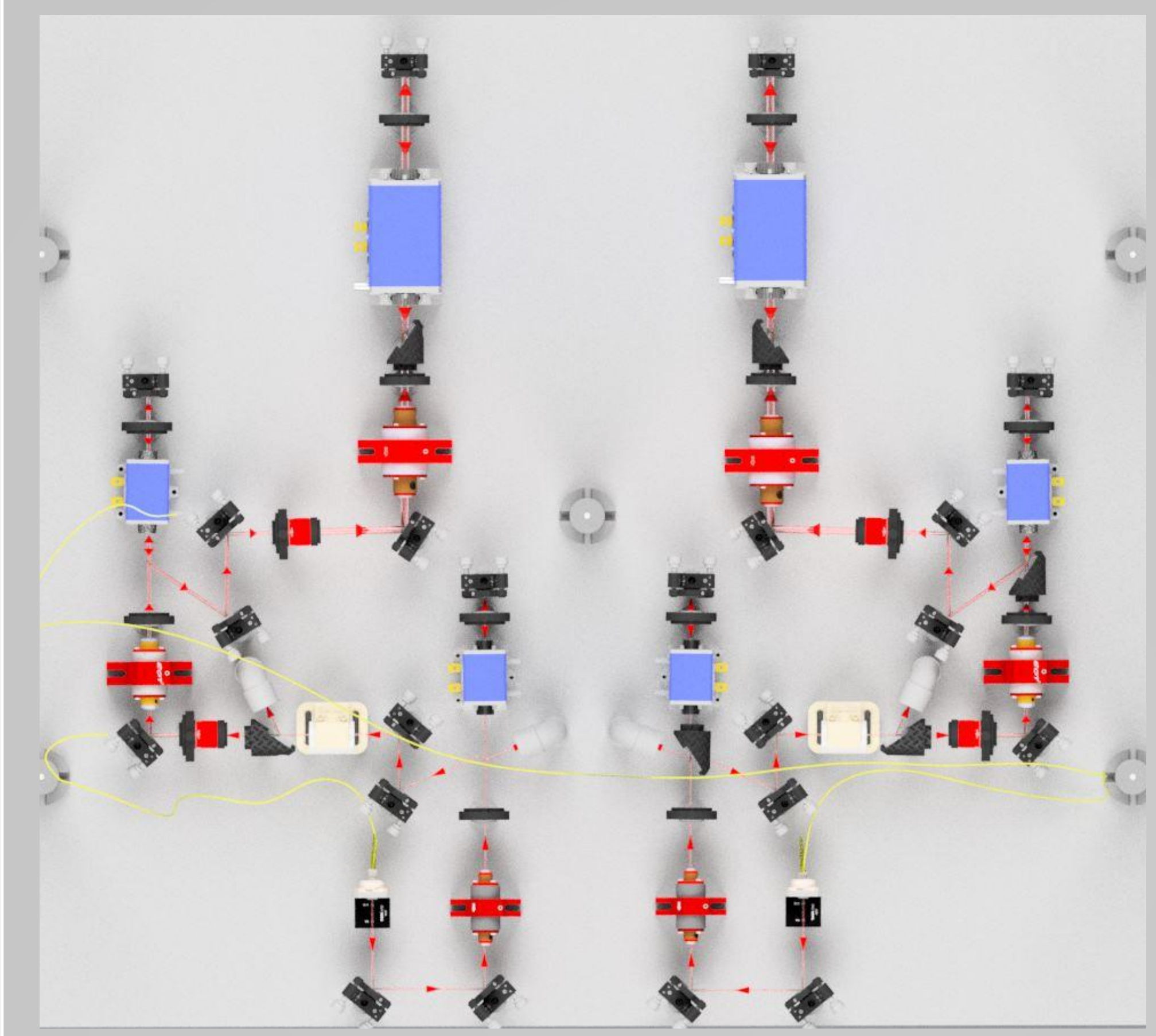

Figure 4: *The bottom shelf of the optical setup. Here the pulses are amplified in three stages (blue components) at each of the Nd:YAG laser amplifiers in blue to the desired output of 200mJ per pulse.*

Each pulse is then sent through a custom-built triple stage amplifier arm capable of amplifying a 100 nJ pulse into the 200 mJ necessary to induce the lattice.

A combination of thin film polarizers, beam shaping lenses, guiding mirrors and optical isolators separate each amplification. These devices along with half and quarter wave plates allow us to control both the nature and direction of the beams' polarizations. These measures also protect the lasing media in the amplification arms from damaging feedback. After amplification, one of the pump beams is split and orthogonally polarized relative to the pump beams to form the probe beam. At this point, the pulses are available to induce the optical lattice necessary for CRBS.

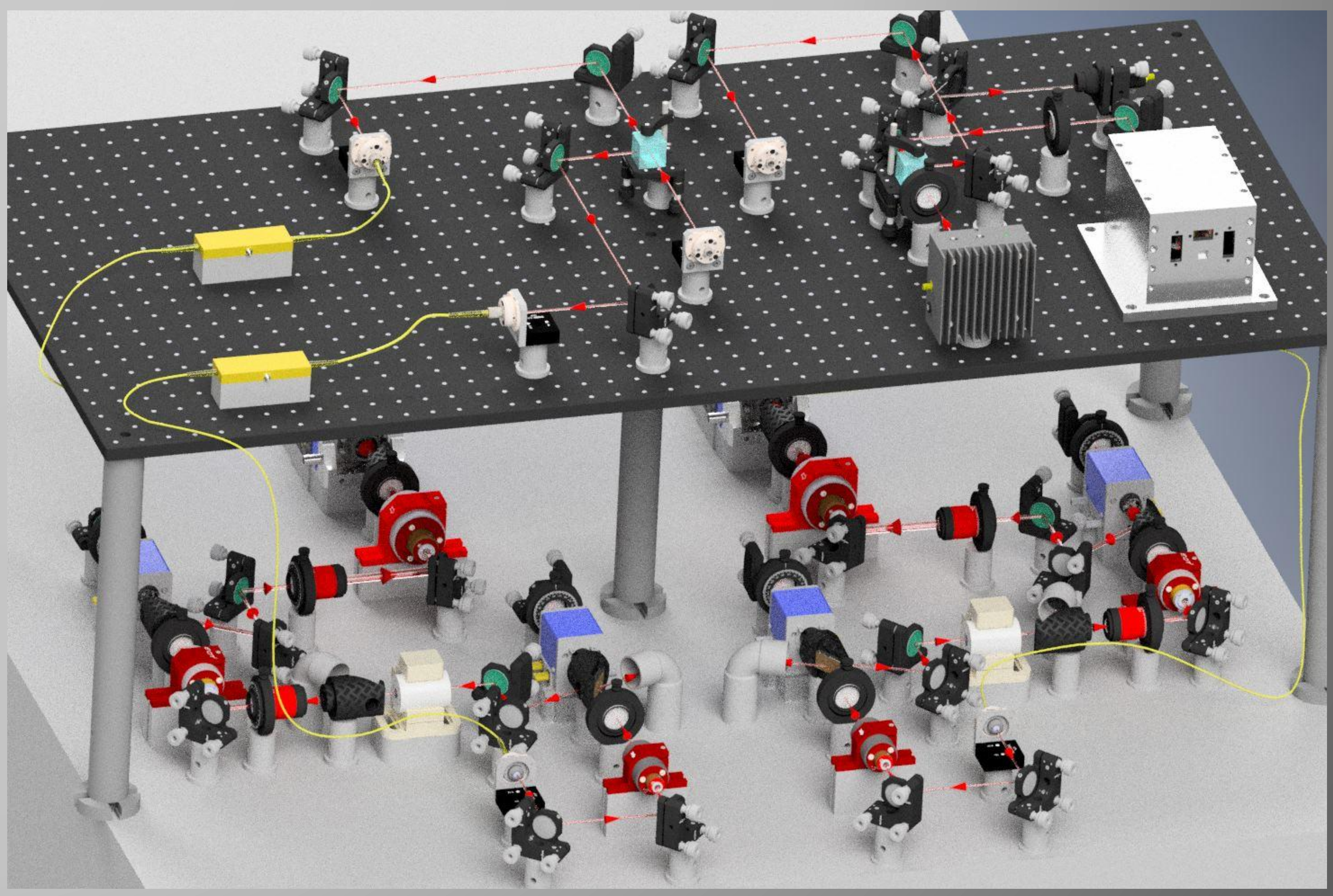

Figure 5: *Both levels of the optical setup. After shaping and amplification is complete, two simultaneous, 200 mJ, frequency chirped pulses are available for CRBS. Missing from this diagram is the 1 W Ytterbium fiber amplifier.*

Three Dimensional Model

This experiment was supported through the development of a 3D model used to facilitate the fabrication of custom parts. The model development was made possible by funding from the Department of Energy Summer Undergraduate Laboratory Internship (SULI) program.

Conclusions

A system capable of delivering the two pump beams as well as the orthogonally polarized probe beam needed for CRBS measurements has been designed and built. It is capable of obtaining an entire CRBS spectrum in a single ~200 ns pulse. This system is capable of determining temperature, shear and bulk viscosity, and the speed of sound in a gaseous medium. The system is also capable of operating on very short time scales, making the diagnostic a good candidate to characterize transient processes with a high degree of spatial and temporal resolution of 200 ns and 150 μm respectively.

Acknowledgements:

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References:

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2. **A. Gerakis, M. N. Shneider, and P. Barker, "Coherent Brillouin scattering," Opt. Express 19, 24046-24054 (2011).**