High Average Power 589 nm generation in LBO

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Abstract: We report on a 589 nm source from sum frequency mixed 1064 nm and 1319 nm in LBO. An output power of 22 W at 589 nm was obtained with an M^2 of 1.3.

1. Introduction

The development of yellow laser sources at 589 nm for sodium guidestar applications has been pursued by several researchers[1-3]. System requirements for the adaptive optics on the telescopes used by the astronomy community have resulted in the need for high average power 589 nm sources with outputs over 50 W for multi-conjugate adaptive optics (MCAO) systems. There are many techniques available to obtain 589 nm output, however not all of them are readily scalable to 50W with high reliability. We are developing Nd:YAG based 1064 nm and 1319 nm laser systems for pumping a Lithium Triborate (LBO) crystal cut for noncritically phase matched sum frequency generation of 589 nm. Nd:YAG and LBO [4] are well developed materials that have a high optical damage threshold and a demonstrated ability to produce high average power output.

In this presentation we discuss a laser configuration that provided up to 105 W of infrared power for pumping the LBO crystal. The infrared output was a CW, mode-locked, pulse train with a 77 MHz repetition rate and the resulting 589 nm output obtained was 22W.

We plan to add additional amplifiers at 1319 nm and 1064 nm to increase the available infrared power to over 160W, which we expect to produce over 50W of 589 nm power. This laser guidestar system is being developed for use at the Gemini South Observatory in Chile and the W. M. Keck Observatory in Hawaii.

2. Experimental set up

An overview of the overall laser system has been presented previously[5] and a schematic of the experimental layout is shown in Figure 1. The system is built on a 10 by 3 foot optical table. The 1064 nm laser source consists of an oscillator with a double passed re-imaging waveguide amplifier [6]. The oscillator, based on an end pumped Nd:YAG rod gain medium, provides 22W in a 77 MHz mode locked pulse-train. An intracavity etalon is used to limit the laser bandwidth to generate pulses of 400 ps FWHM. The output beam quality is near diffraction limited with a measured M^2 of 1.05.

The 1319 nm laser source consists of a Nd:YAG rod oscillator with two double passed re-imaging waveguide amplifiers. The oscillator provides 12W in a 77 MHz mode locked pulse-train. An intracavity etalon is used to limit the laser bandwidth to generate pulses of approximately 420 ps FWHM. The etalon is also used in the system to control the output wavelength of the laser to maintain the 589 nm light near the peak of the Sodium line absorption. The output beam quality is near diffraction limited with a measured M^2 of 1.05.

The 1064 nm re-imaging waveguide[6] has an active aperture of 80 microns by 1 cm. The input beam is focused to a line focus and double passed through the amplifier. The re-imaging effect in the 80 micron height of the waveguide creates a Gaussian beam after amplification. The unfocused, collimated beam in the 1 cm width of the waveguide which has no guiding effect, becomes non-Gaussian after amplification due to saturation effects. The output beam is re-collimated and a weak cylindrical lens is used to correct for astigmatic lensing effects in the amplifier. The 1064 nm amplifier provides an output power of 75W.

The 1319 nm re-imaging waveguide has an active aperture of 85 microns by 1 cm. The 1319 nm amplifier consists of two waveguide amplifiers in series. The 1319 nm amplifier provides an output power of up to 45W. The 1064 nm and 1319 nm beam power was controlled using a polarizer waveplate combination.

The relative timing of the mode-locked pulse train from the two sources is critical for efficient sum frequency generation. The radio frequency (RF) drive for the acousto-optic mode-lockers is used to control the relative phase relationship of the two pulse trains. The RF phase can be adjusted to within one percent for the two RF drive signals, which provides a temporal relative timing stability of approximately 10 ps.

The SFG process requires optimization of the co-linearity, spatial overlap, spot size and polarization orientation of the input beams. The components in the 1319 nm optic chain limited the power available to the LBO crystal to 35 W.

The LBO crystal used for the SFG experiment was 50 mm in length with a 3x3 mm aperture. The crystal had a triple band anti-reflection (AR) coating on both faces. The LBO crystal was adjusted for optimum operating temperature and position relative to the beam waist. A commercial oven in a tip-tilt mount was used for the LBO crystal. The thermal control of the oven is critical as the crystal length of mm reduces the effective thermal bandwidth of the sum frequency generation process to 1.5 degrees C. The oven controls to ± 0.1 degrees C.

3. SFM experimental results

The 1319 nm and 1064 nm beams were focused to a spot size of 55 micron FWHM and the foci positioned in the center of the LBO crystal. The input powers from the 1319 nm and 1064 nm lasers to the LBO crystal were adjusted using a waveplate and polarizer. The input power from both lasers was adjusted to provide a photon balanced input condition except for the final data point were the 1064 nm power was increased to full power which was in excess of the 1319 nm available power. The 589 nm conversion results are shown in Figure 2. The system produced 22 W of 589 nm output in a non-photon balanced condition with a total input infrared powerof 104 W. This corresponds to a 21% conversion efficiency. The highest photon balanced input power was 74 W. This input power provided 14.8 W of output with a conversion efficiency of 20%. The output beam quality of the 589 nm output beam was measured to have an M^2 of 1.3. An image of the far field beam profile is shown in Figure 3. The 589 nm spot created by the system is acceptable for guidestar appications. After warm up the system operated with a power stability of better than ± 5%; measured over several hours. We observed that the LBO oven temperature had to be re-optimized as infrared power was increased. An increase in IR power from 10 to 105 W required an oven temperature change of 0.4^0C due to absorption of 1064 nm, 1319 nm and/or 589 nm light.

4. Conclusion

We designed and built a laser system to provide mode-locked IR pulse trains for sum frequency generation in LBO to obtain over 20 W of output at 589 nm. An output power of 22 W was obtained with a beam quality M^2 of 1.3. The output beam power was stable to better than 5% long term. The LBO crystal did exhibit absorption from the transmitted beams but thermal performance was within values published by the suppliers.

We plan to extend the power of the system to over 160 W in the IR by late 2007 and investigate scaling the 589 nm power to 50 W. the laser system will be installed at the Gemini South facility in Chile in 2008.

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6. References

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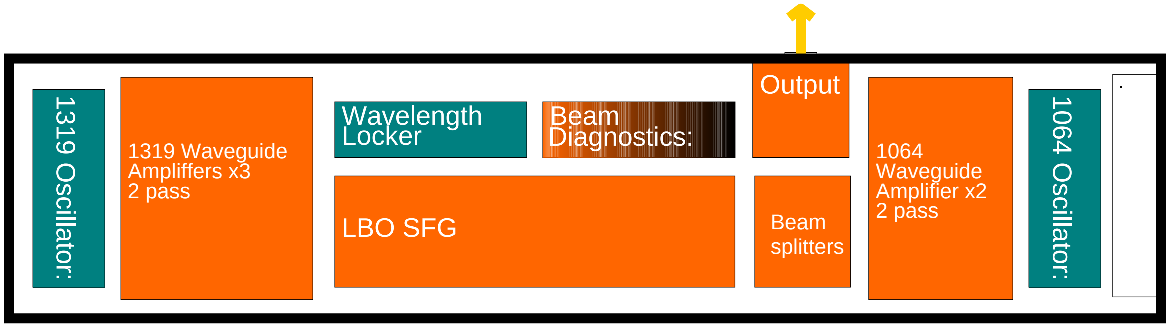

Figure 1: Schematic layout of the laser system components

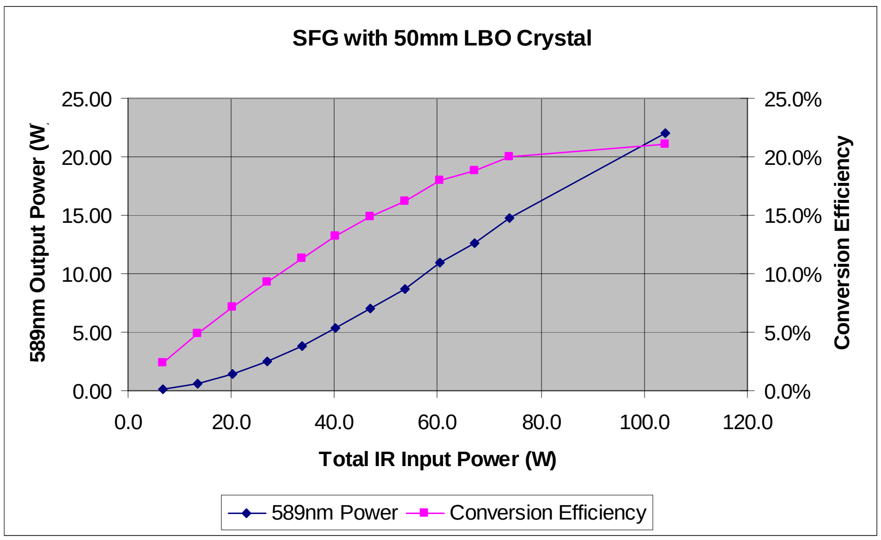

Figure 2: Experimental conversion efficiency and 589 nm power vs IR power

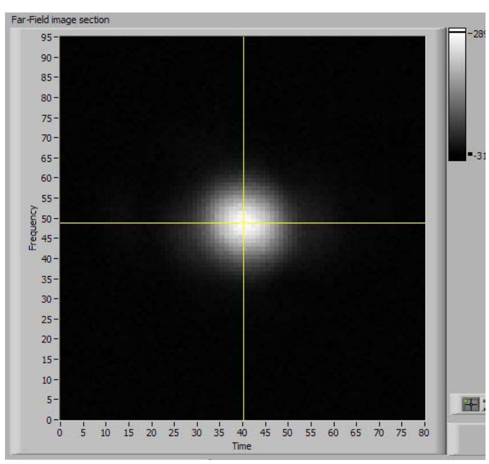

Figure 3: Far field beam profile at 589 nm