39 W narrow linewidth Raman fiber amplifier with frequency doubling to 26.5 W at 589 nm

Yan Feng, Luke R. Taylor, Domenico Bonaccini Calia, Ronald Holzlöhner, and Wolfgang Hackenberg
European Southern Observatory (ESO), Karl-Schwarzschild-Str.2, D-85748 Garching bei Muenchen, Germany
yfeng@eso.org

Abstract: We report on a 39 W SBS-suppressed narrow-linewidth (<1.5 MHz) Raman fiber amplifier at 1178 nm, which is frequency doubled to 589 nm for laser guide star application (26.5 W generated in a preliminary test).

OCIS codes: 140.3510 Lasers, fiber, 140.3550 Lasers, Raman, 140.7300 Visible lasers

For large ground-based astronomical telescopes, laser guide star adaptive optics is crucial to reduce blur by compensating wavefront distortions induced by atmospheric turbulence. ESO has been pursuing fiber laser based technology for next-generation laser guide star systems for several years. Recently, we have developed a high-power narrow-linewidth Raman fiber amplifier technology [1,2], which allowed us to obtain a 14.5 W continuous-wave 589 nm laser by second harmonic generation in an external resonant cavity with an LBO crystal [3]. Later, we extended this result to 25 W at 589 nm by frequency doubling of two coherently combined Raman fiber amplifiers with 86% conversion efficiency [4,5]. This power level is more than that required by the 4LGSF project currently carried out at ESO. However, obtaining similar power from a single-channel amplifier is highly desirable, in view of the substantial reduction in engineering complexity of the laser system.

With that in mind, we have first upgraded our 1120 nm pump laser. With a short 30 m piece of standard single mode fiber and a fiber laser cavity design, asymmetric in the sense of FBG reflectivity and bandwidth, more than 150 W at 1120 nm has been obtained with a 200 W-class 1070 nm Yb fiber laser. This is, to the best of our knowledge, the highest power Raman fiber laser ever reported [6].

The 1120 nm laser is used to pump a single Raman fiber amplifier, which is seeded by an external cavity diode laser (~100 kHz linewidth) at 1178 nm. Applying our proprietary stimulated Brillouin Scattering suppression methods [1], up to 39 W of continuous-wave 1178 nm radiation with linewidth < 1.5 MHz (device resolution limited) is obtained, as shown in Fig.1. Also shown in Fig.1 is the return light that is due to stimulated Brillouin scattering. This output power actually exceeds our previous result from the two coherently combined Raman fiber amplifiers.

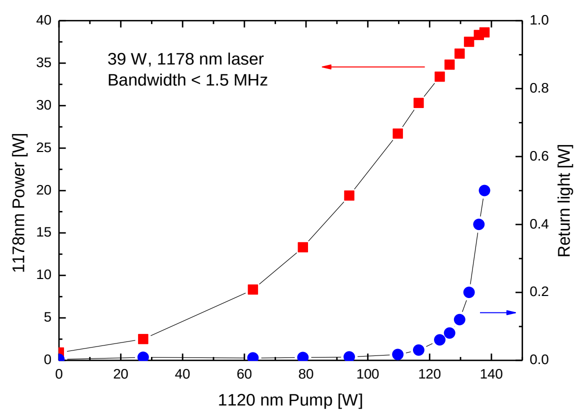

Fig. 1 1178 nm laser power and return light as a function of 1120 nm pump power.

The 1178 nm laser is then optically isolated and mode-matched to a bowtie-configured SHG cavity with a 30 mm LBO crystal, thermally controlled to 40°C. Up to 26.5 W 589 nm laser is obtained in an initial SHG test, as shown in Fig.2, corresponding to a conversion efficiency of 81%. We are in the process of optimizing the mode matching of the 1178 nm laser to the doubling cavity, and believe that we may obtain more orange power, given that 86% conversion efficiency has been achieved in our lab before at similar power level [3–5].

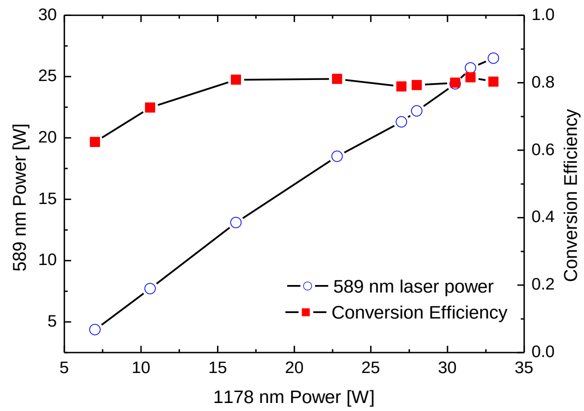

Fig.2 589 nm laser power and conversion efficiency as a function of 1178 nm power.

Our result is an import step towards compact fiber based sodium guide star laser systems, which meet not only the optical specifications, but also the tough requirement of robustness imposed by fact that these lasers have to operate at remote telescope sites. Industry will be involved intensively throughout the process.

Also note that since Raman fiber lasers are wavelength versatile, the technology can be used to generate high power narrow linewidth lasers at other wavelengths for various applications.

References:

[1] (WO/2009/090096) NARROW BAND FIBER RAMAN OPTICAL AMPLIFIER, International Application No.: PCT/EP2009/000275, http://www.wipo.int/pctdb/en/wo.jsp?WO=2009090096, pending

[2] Yan Feng, Luke Taylor, and Domenico Bonaccini Calia, "20W CW, 4MHz linewidth Raman fiber amplifier with SHG to 589nm," Photonics West 2009 post-deadline paper, Proc. SPIE, 7195, xvii-xviii (2009).

[3] Luke Taylor, Yan Feng, and Domenico Bonaccini Calia, "High power narrowband 589nm frequency doubled fibre laser source," Opt. Express **17**, 14687-14693 (2009).

[4] Yan Feng, Luke R. Taylor, and Domenico Bonaccini Calia, "25 W Raman-fiber-amplifier-based 589 nm laser for laser guide star," accepted by Opt. Express.

[5] Luke R. Taylor, Yan Feng, and Domenico Bonaccini Calia, "25 W narrowband CW 589 nm Radiation obtained via frequency doubling of two coherently combined Raman fibre lasers," submitted to IEEE J. Quantum Electronics.

[6] Yan Feng, Luke R. Taylor, and Domenico Bonaccini Calia, "150 W highly efficient Raman fiber laser," to be submitted.