20W CW, 4MHz linewidth Raman fiber amplifier with SHG to 589nm

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ABSTRACT

Up to 20.7 W CW, 3.5 MHz linewidth, 1178 nm continuous-wave laser has been obtained at ESO laser labs by Raman amplification of a distributed feedback diode laser. To our knowledge it is the highest power obtained at such a narrow linewidth with Raman fiber amplifiers. The 1178nm laser has a linear polarization-extinction-ratio of 25dB. Frequency doubling with an LBO-based SHG commercial cavity has given 83% conversion efficiency and 14.5W CW at 589nm. The source is suitable to produce mesospheric laser guide stars as reference stars for adaptive optics. The presented narrow-band, high power Raman amplification technique might be used for a large number of different wavelength ranges.

Keywords: Lasers, fibers, Raman lasers, laser amplifiers, laser guide stars, Second Harmonic Generation

1. INTRODUCTION

This post-deadline paper, which has to be limited to two pages, reports on the recent breakthroughs of our research activities done in the frame of the ESO R&D programs to generate 589nm CW sources for laser guide stars. In future large telescopes instrumentation, 20-25W CW at 589nm are necessary, with linewidths ideally ≤50 MHz. Toward this goal our Laser Systems Dept is working on the development of high power, narrow band fiber Raman lasers at 1178nm, to be then frequency doubled to 589nm.

Fiber lasers are an asset and probably the best choice in remote and difficult operation sites like astronomical observatories. They are typically compact, maintenance-free, turn-key and ruggedized devices. Moreover their output beam quality is extremely good. The lasers which we are aiming at are part of Laser Guide Star Facilities; the laser beam is projected at 90 km in the Mesosphere, producing laser guide stars by excitation of mesospheric sodium atoms. Our in-house development is done in close touch with industry, with the goal to have the final laser packaged and finally engineered by industry, as a product. We are progressing with the research taking care of course of the IP protection.

2. THE LASER

A MOPA scheme is followed in our 1178nm fiber laser source, in which an 1178nm, ~10s mW DFB fiber coupled laser is used as seed for a Raman fiber amplifier. The pump wavelength is 1120nm. Both seed and pump fiber lasers are commercially available. We have found first a way to obtain narrow-band Raman amplification, with the linewidth limited so far only by the seed linewidth; then recently we have been successful in efficiently suppressing SBS in the Raman amplifier, obtaining up to 20.7 W CW at 1178 nm. The technique will work in many other wavelength ranges.

Although in our experiment still a non-polarization-maintaining fiber is used, the laser can be adjusted to emit linear polarization, with a polarization-extinction-ratio of 25dB, using waveplates in the free space beam before the SHG unit. The observed long-term stability of the output polarization is of the order of few degrees/C, at regime operation. The measured linewidth of our system is about 3.5 MHz, suitable for highly efficient resonant external cavity doubling to 589 nm for laser guide star applications.

The output of the fiber amplifier is optically isolated and then mode matched to a compact, commercially available SHG cavity. The cavity uses a 20mm LBO crystal for the SHG. Thanks to the extremely good optical quality of the input beam, we have reached a very good mode matching with the cavity. Also, the spectral phase noise properties of our high power fiber Raman amplifier are extremely good, since a SHG conversion efficiency up to 83% has been achieved.

3. RESULTS

Figure 1 shows the measured 1178 nm output as a function of the 1120 nm pump power. With the suppressed SBS amplifier we obtain up to 20.7 W at 1178nm with 67 W CW of pump power at 1120nm. This means we have obtained ~10 times increase of SBS threshold in power, with respect to a normal fiber of similar length.

To further increase the output power of the single stage amplifier, we will test in the coming months further SBS suppression schemes as a function of fiber length and pump power. The frequency conversion has produced up to 14.5W CW at 589nm, with 17.2W CW at 1178 in input. This is better than 82% conversion efficiency.

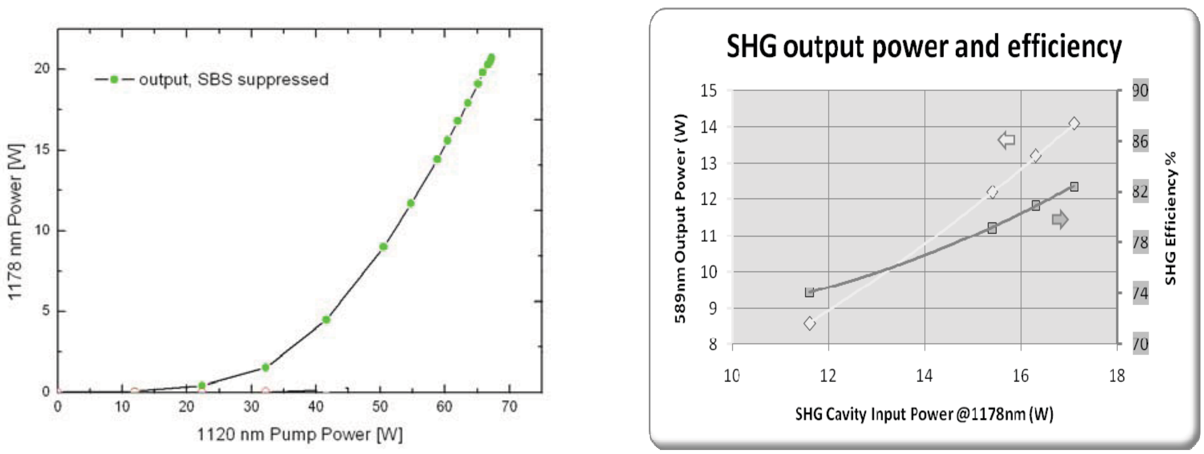

Fig. 1 Left: output power of the 1178nm fiber Raman amplifier as a function of pump power;

Right: measured SHG output power at 589nm, up to 14.1W CW in this plot, with conversion efficiency up to 82%

An Ando optical spectrum analyzer is used to check the spectral purity of the 1178nm fiber laser output. The result is shown in Figure 2. We see more than 40 dB contrast of the background noise versus the signal.

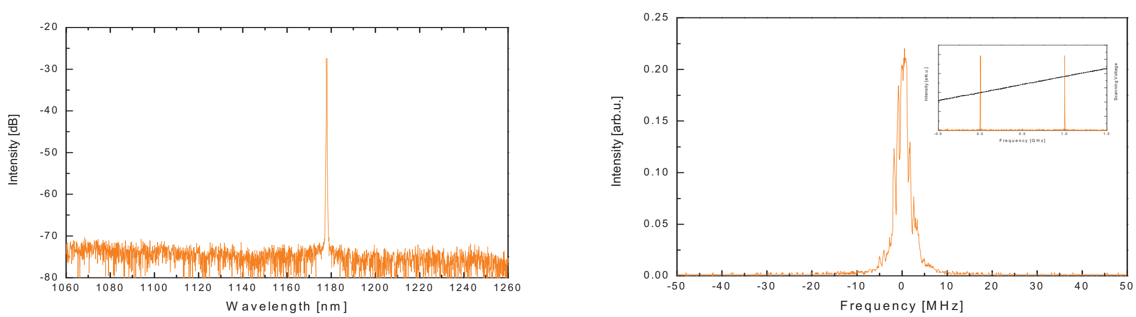

Fig. 2 Spectrum of the amplifier output. left) a broad range spectrum taken with an Ando spectral analyzer showing 40 dB contrast; right) a detailed spectrum of the 3.5MHz line taken with a Fabry-Perot interferometer (1 GHz FSR).

The spikes on the emitted spectrum are due to the well known fast frequency jitter of our DFB diode seed. The temporal separation of these spikes depends on jitter frequency, so one can see fewer spikes in the spectrum when scanning faster. The inset figure shows a full free spectral range scanning, indicating that no other frequency exists around the 1178nm line. The 1178nm signal power variation RMS as measured is <1% at full power.