https://doi.org/10.1051/epjconf/202226702044

Fiber based high power low noise single frequency lasers and applications

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With the advances in fundamental science such as gravitational wave detection (GWD) [1], cold atom physics [2] and quantum computing [3], the need for single frequency (SF) high-power fiber lasers has been increasing over the last decade. The ability to maintain an excellent modal quality, the wide tuning range in the Ytterbium (Yb) band, the linear polarization and the optical low-noise operation is driving this technology as an excellent replacement for more established high-power bulk systems in the 1 µm region. We will present several very low noise high power laser sources at different wavelengths and the potential applications.
Although very high-power fiber lasers have been demonstrated in a master oscillator power amplifier (MOPA) configuration, SF operation faces some physical limitations, stimulated Brillouin scattering (SBS) being the principal one. This well-known non-linear effect has an impact on amplifier intensity noise and will eventually lead to catastrophic system damage at high enough power.
Several groups have already demonstrated SF operation up to hundreds of watts of continuous power. However, very few of these studies have focused on the noise characteristics of the amplifiers or the long-term stability of these systems. In this framework we have demonstrated a robust and efficient 365W MOPA laser with low intensity noise laser with excellent modal quality based on LMA fiber without SBS management (see Fig. 1 (a)). We have implemented full wide bandwidth intensity control able to pin down intensity noise close to 160dBc/Hz. The scaled down (130W) version of this laser is used in the Virgo GWD, with more than 5000h of operation. Beyond GWD this type of high power laser find applications in the generation of optical lattices and traps for modern atomic physics.

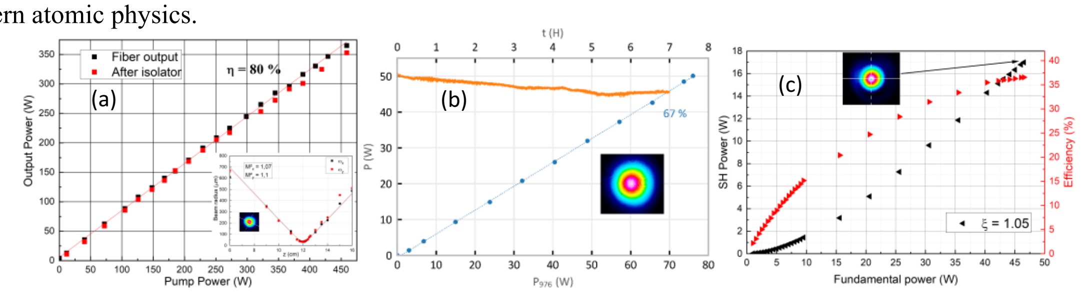

Fig. 1. (a): high power 1064nm MOPA, output power versus pump power at the fiber output (black) and after the isolator (red), M^2 (inset)(b): 1013 nm laser power vs pump power and slope efficiency (blue), 7-hour stability (orange) and mode profile (inset) (c) 1064/532 Second harmonic single pass generation SH power (black) and efficiency (red) versus fundamental power and mode profile (inset).

Another interesting case laying in the lower side of the Yb doped fiber operation window is 1013nm. This emission wavelength is critical for modern quantum processing units using neutral Rb atoms where tens of Watts are required, and no other available technology can compete with Yb fibers. The emission at such short wavelength is quite challenging due the strong signal re-absorption. This has two perverse effects: first, ASE around 1030 nm sees a much higher gain triggering parasitic lasing. Second, a strong pump intensity is needed to prevent signal reabsorption. The solution is to use short fibers, to limit ASE gain and ensure strong pump intensity all along the fiber but this impairs the efficiency and leaves a strong residual pump. Despite those problems we have demonstrated an efficient laser (67%) around 1013nm able to deliver up to 50W before photodarkening with low noise and good modal quality [5] (see fig 1 (b)). The industrial version of this lasers (10W) is currently used in the quantum processing unit under development in several laboratories and start-ups. By using Second Harmonic Generation (SHG) is also possible to produce high power visible sources in the green domain starting from Yb doped fiber laser. Again, low noise sources are necessary in modern physics, laser pumping and industrial applications. We have been able to demonstrate up to 17 W of low noise green radiation at 532nm by efficient single pass doubling (see Fig 1 (c)) and develop a model of the SHG intensity noise transfer in the saturation regime [6]

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