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First indirectly diode pumped Yb:SFAP laser, Reaching the watt level at 985 nm

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Abstract: We present the first demonstration of the three-level-laser transition at 985nm in an Yb:S-FAP crystal intracavity pumped at 914nm. We obtained 940mW output power at 985nm for 20W incident pump power at 808nm.

Introduction:

Laser oscillation around 980 nm has been investigated for a few years for many applications. For example, pumping of erbium-doped fiber amplifiers needs laser sources emitting at a few watts at this wavelength with good spatial beam quality. Moreover by using nonlinear crystals, the blue range around 490 nm is then achievable. This is close to the argon laser line at 488 nm, which is widely used in fluorescence spectroscopy and biological applications. The main problems relative to argon lasers are their size, low efficiency and their very restrictive maintenance. Solid state lasers are a good alternative thanks to their compactness and efficiency. Several architectures, based on optically pumped semiconductor lasers [1] or sum frequency mixing of two Neodymium lines [2, 3], are already in use. However, the large emission cross section around 980 nm in ytterbium doped crystals has never been exploited for this kind of applications.

Indeed, the laser beam undergoes strong reabsorption losses due to the three level nature of the transition, and very high pump intensity is needed to reach the laser medium transparency. In this case direct diode pumping won't be efficient enough. An alternative is to use the very high intensity available into a laser cavity combined with diffraction limited beam for pumping the ytterbium crystal. This concept has already been demonstrated in mid-IR [4], with the case of a Ho:YAG laser at 2.09 µm intracavity pumped by a Tm:YAG laser at 2.01 µm, but never in the near IR.

Our goal is to indirectly pump an Yb doped crystal with a diode, by inserting it in an efficient diode-pumped Nd doped laser. As Yb doped materials generally present absorption in the 900-950 range, we will use an Nd doped laser operating on the $^4F_{3/2} - ^4I_{9/2}$ transition.

We choose the Yb:S-FAP crystal [5] (Yb^{3+}:$Sr_5(PO_4)_3F$) among all commonly used Yb doped crystals, because its emission spectrum has an unusual narrow emission line at 985 (Fig. 1). This property allows an easier spectral selection of the three-level transition at 985 nm with dichroic mirrors being highly reflective at 985 nm and highly transmissive at 1047 nm to prevent the laser emission on the high gain quasi-four-level transition at around 1047 nm.

According to the absorption spectrum, the maximum is centered at 899 nm and one way to pump this crystal would be the use of a 899 nm resonating cavity performed with an Nd:YAG crystal [6]. However, simple calculations can show that in order to maintain laser oscillation in the Nd doped crystal, losses induced by absorption in the Yb:S-FAP crystal need to be low (in the range of a few percents). This would lead to very thin Yb:S-FAP crystal if we used a standard concentration . Hence we decided to pump in the edge of its absorption band, at 914 nm and so use a simple Nd:YVO_4 laser. In that case, standard concentrations for several mm thick Yb:S-FAP crystals can be used. Thus the energy level diagram of the system is presented in the figure 2.

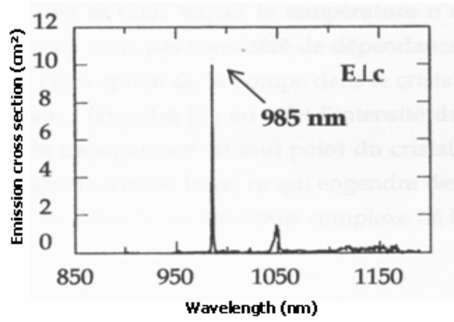

Fig. 1: Emission spectrum of Yb:S-FAP

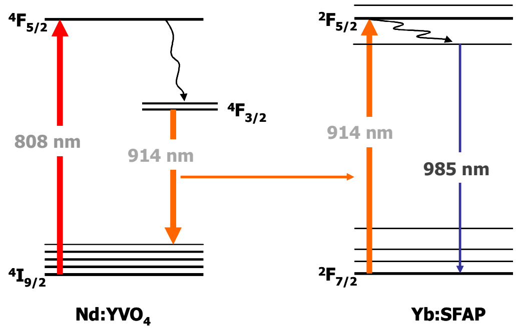

Fig. 2: Energy level diagrams for the Nd:YVO_4 / Yb:S-FAP system

Experimental setup and results:

The pump source is a laser diode emitting at 808 nm coupled into a 100 µm core diameter fiber with a numerical aperture of 0.22. This diode provides up to 25 W of an unpolarized emission. The fiber output is imaged with two identical doublets (60 mm focal length) into the Nd:YVO_4 crystal with a waist (radius) of 50 µm.

The first three mirrors of the cavity are highly reflective at 914 and 985 nm and highly transmissive at 1047 and 1064 nm. M_4 is the output coupler at 985 nm (still highly reflective at 914 nm) with a transmission of 33%.

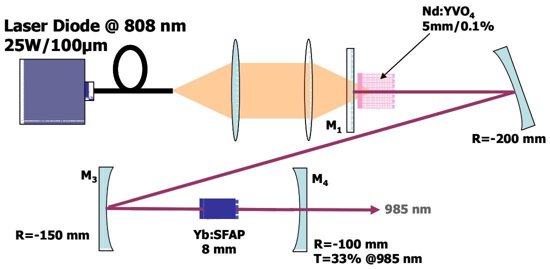

Fig. 3: Experimental setup

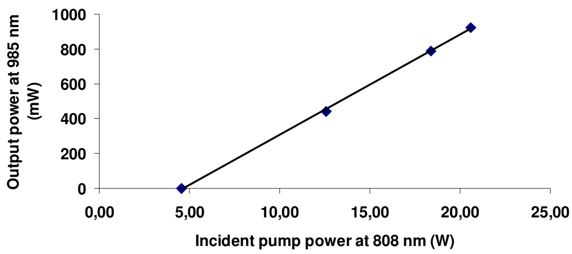

Fig.4: Output power at 985 nm versus incident pump power at 808 nm

In the second waist of the cavity, we introduced the AR coated Yb:S-FAP crystal. We investigated laser performance with different S-FAP crystal length. The maximum output power at 985 nm was obtained for the longest one (8 mm long) with 940 mW for 20 W incident pump power at 808 nm (corresponding to 60 W of intracavity power at 914 nm), for a threshold around 4.5 W at 808 nm (Fig. 4). Moreover, we obtained 500 mW at 985 nm with a higher output coupler whose transmission was around 75% (still highly reflecting at 914 nm), demonstrating the huge gain available with this kind of pumping.

Conclusion and prospects:

Thus, in this paper we have demonstrated the first indirectly diode-pumped Yb:S-FAP laser emitting at 985 nm with a maximum output power of 940 mW for 20 W of incident pump power at 808 nm. Possible optimizations on the output coupler can be achieved (Indeed, the coupler used was not the optimal one at 985 nm, and amelioration of the reflectivity at 914 nm could increase the intracavity power at this wavelength)

Moreover, the very high gain which seems available in this architecture promises good performance for future intracavity second harmonic generation experiments. Indeed with a first non-optimized configuration, more than 70 mW at 492.5 nm has been obtained with a $KNbO_3$ crystal placed close to the Yb:SFAP crystal.

References:

[1] A.Caprara et al (Coherent Inc.), "Intracavity frequency-converted optically-pumped semiconductor laser", US patent 179022, (1999)

[2] E. Herault, F. Balembois, and P. Georges, "491 nm generation by sum-frequency mixing of diode pumped neodymium lasers," Opt. Express **13**, 5653-5661 (2005)

[3] Cobolt, http://www.cobolt.se

[4] R. C. Stoneman, L. Esterowitz, "Intracavity-pumped 2.09 µm Ho:YAG laser", Opt. Lett. **17**, 736-738 (1992)

[5] S.A. Payne et al, "Ytterbium-doped apatite-structure crystals: A new class of laser materials", J. Appl. Phys. **76**, 497-503 (1994)

[6] M. Castaing, E. Herault, F. Balembois, and P. Georges, "Diode-pumped Nd:YAG laser at 899 nm and below," Opt. Lett. **32**, 799-801 (2007)