PRINCETON
OPTRONICS

Laser without a RIN Peak!

Lowest Noise High Power Solid State Laser for the 1550 nm Wavelength Band

Introduction

Low noise high power lasers are needed for a number of analog and digital communications systems as well as for sensors and analog signal processing applications. At Princeton Optronics we have developed a low noise, high power diode pumped Er:Yb glass laser technology[1]. A major breakthrough has been achieved in this laser by using a non-linear absorbing material in the cavity. This technique has delivered the most effective noise reduction ever reported in a laser so far. Further optimization of materials and their characteristics will be able to reduce the noise by an additional 50dB more. Current laser output powers up to 100mW are available with **RIN of <-140dBc/Hz above 100kHz and –145dBc/Hz @1MHz and higher frequencies and shot noise limited above 100MHz** (see fig 3 in this white paper). This is enclosed in a **small, 1.1x1.1x0.5"(12cc), 16 pin butterfly package**.

The laser wavelength can be selected over the band 1528-1565nm and also tuned across this band. We have developed a wavelength locker using low finesse ULE glass air spaced etalons for standard laser operation to lock any wavelength. For ultra-stable frequency locking new lockers have been developed that use high finesse etalon and have a separate temperature control from the laser. Both lockers have a laser power monitors for normalization and power control. **Laser linewidths of 1.1kHz over 1ms** and a **frequency control of 250kHz for periods up to 1 hour** have been achieved.

Laser Design

Erbium doped phosphate glass permits high co-doping with ytterbium ions that strongly absorb at 976 nm and efficiently transfer their energy to the active erbium material. Therefore co-doping the erbium doped phosphate glass with ytterbium drastically decreases the absorption length at the 976 nm pump wavelength so that small solid-state lasers can be built. Aside from the obvious advantage for packaging a short cavity length results in a large longitudinal mode-spacing (>40 GHz). A single longitudinal mode can be obtained by inserting a low-finesse etalon. By using either an air-spaced etalon with a piezo controlled air gap or a temperature controlled solid etalon consisting of a material with high dn/dT different modes in the 1550 nm telecom wavelength band can be selected. Fine tuning of the lasing wavelength is achieved by controlling the cavity length using a piezoelectric moveable output coupler. Figure 1 shows the optical configuration of the low noise laser.

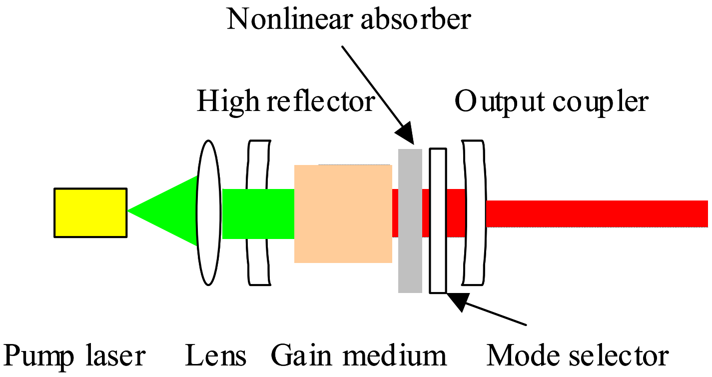

Figure 1. Laser design optical layout.

The singlemode edge emitter pump laser is collimated and directed into the glass. A slight angle is used to prevent back-reflections de-stabilizing the pump laser chip. The gain medium of high phosphate glass doped with Yb and Er ions is Brewster angle wedged to provide a linearly polarized laser output. Both the tunable etalon, for mode selection, and the output coupler, for frequency tuning, use piezo elements.

Noise Reduction

Due to the energy transfer between the co-dopant and the active material the laser shows a strongly reduced sensitivity to fluctuations in pump power. Hence the RIN spectrum is mainly determined by cavity loss perturbations[1]. The RIN spectrum of Er:Yb lasers is close to shot-noise limited at higher frequencies (>10 MHz) but shows a strong peak at the relaxation oscillating frequency, which is in the 100 kHz to 1 MHz range, depending on the cavity layout and laser power. Without active stabilization of the laser cavity the typical observed RIN peak is approximately -70dB/Hz. We have developed a noise reduction technology that is based on intra-cavity non-linear absorption. Figure 1 shows measured RIN spectra for Er:Yb laser with and without noise reduction. With noise reduction the RIN at the relaxation oscillation frequency is reduced by more than 50dB with no relaxation peak.

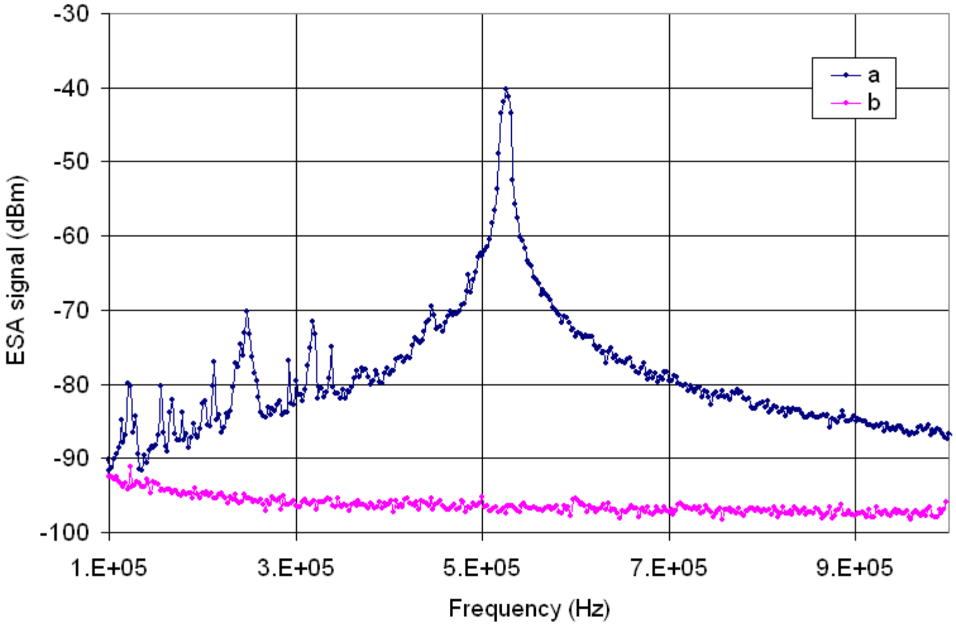

Figure 2 RIN spectrum of laser with noise reduction (a) and without noise reduction (b).

Figure 3 shows a recent measurement by the Naval Research Laboratory of one of our low noise lasers showing a RIN of –145dBc/Hz at 1 MHz when operated at 95mW output power. The shot noise limit is –168dBc/Hz and the laser reaches this above 200MHz.

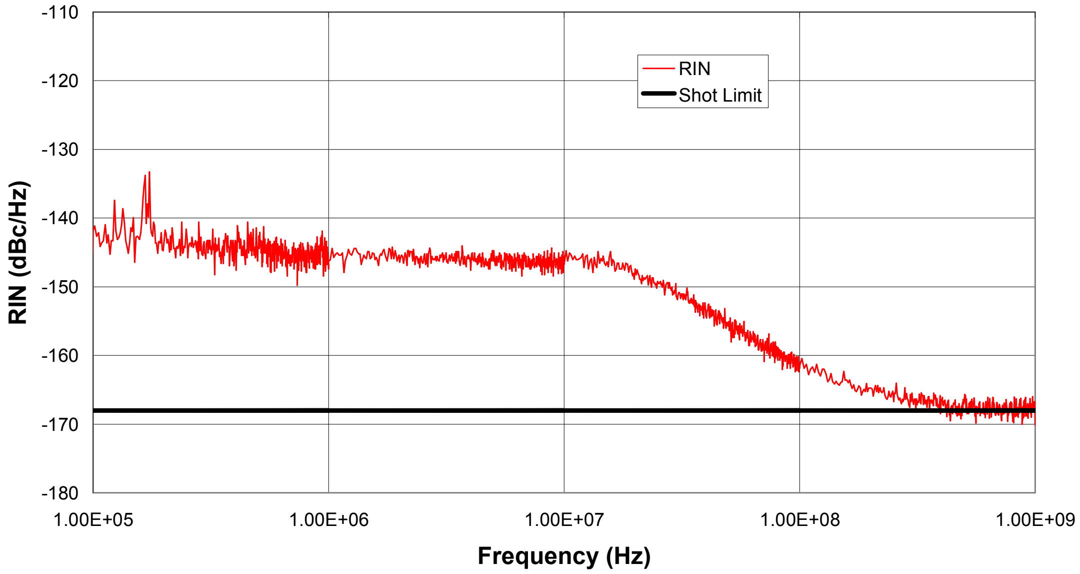

Figure 3. RIN measurement of low noise laser operating at 1535nm with output power of 95mW.

Sidemode Suppression

The laser technology uses a high finesse laser cavity and this coupled with the solid-state gain medium gives a very high sidemode suppression ratio. There is a strong mode selector in the laser cavity and the result is very good single frequency characteristics. Figure 4 shows the OSA plot indicating >70dB sidemode suppression. The shape of the laser line is limited by the resolution of the Optical Spectrum Analyzer.

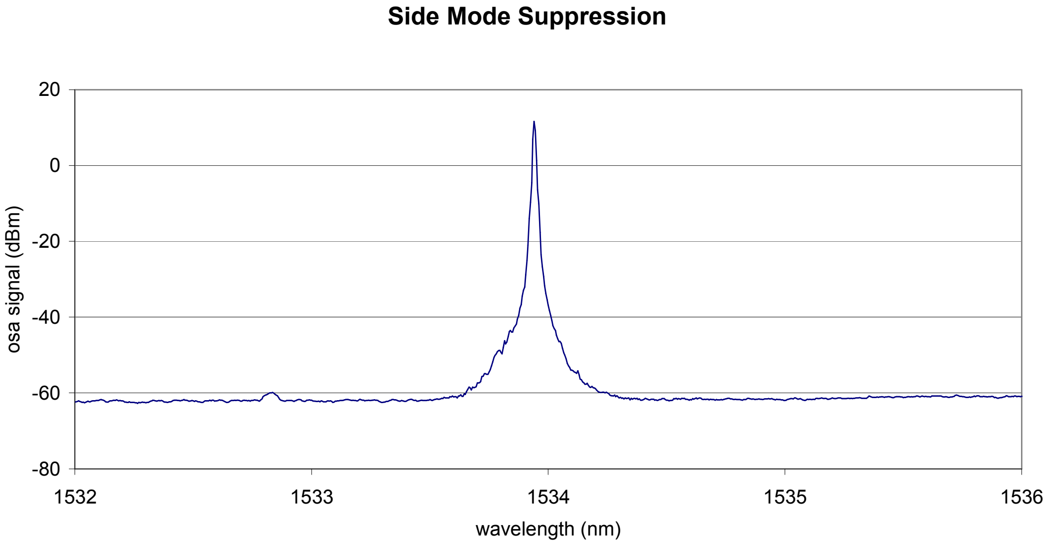

Figure 4. Optical spectrum analyzer chart showing >70dB SMSR

Frequency Stability and Linewidth

The instantaneous linewidth of the laser is ~10Hz or less. The linewidth of the laser is thus primarily governed by mechanical noise. The uncontrolled linewidth is ~1.1kHz over 1ms and this can be reduced by laser frequency control systems. The piezo frequency control systems are limited to a control bandwidth of tens of kHz and this will not significantly reduce the linewidth. There are two developments that we are actively pursuing to reduce the linewidth further. One is to improve the laser packaging to reduce the mechanical noise and increase the piezo tuning bandwith. This is expected to reduce the linewidth by x 4.

The second development is to use electro-optic tuning. This has been demonstrated in our research experiments and now is being developed further. Experiments at NIST laboratories using their combination of piezo control and acousto-optic control demonstrated a linewidth of 10Hz using the Princeton Optronics laser. This is shown in Figure 5 and required a control bandwidth of >300kHz in the acousto-optic control.

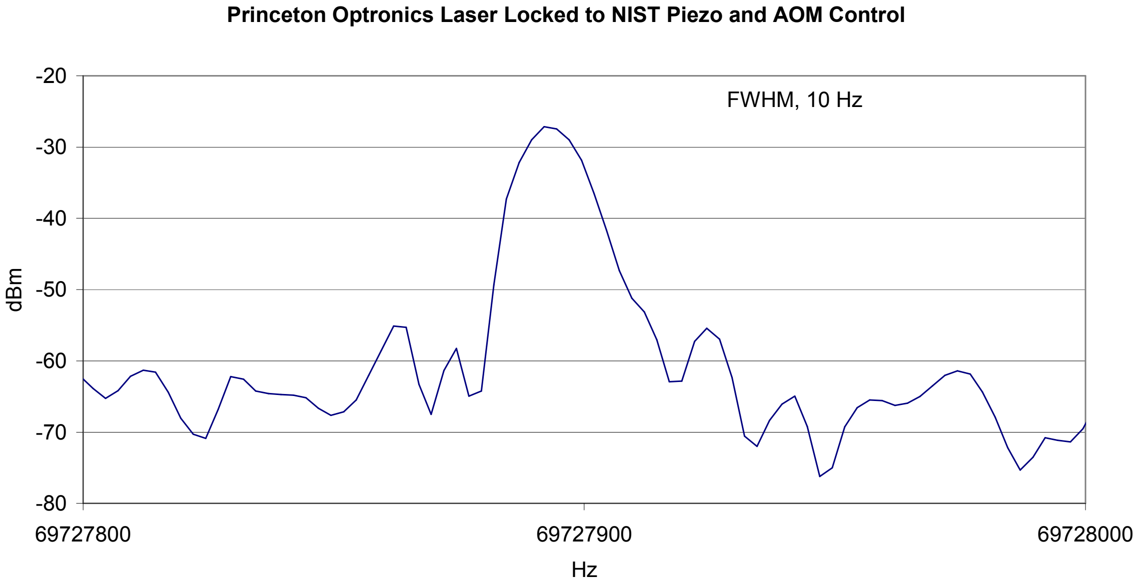

Figure 5. Frequency Spectrum of laser when locked using NIST piezo and acousto-optic controls. Shows linewidth of 10Hz FWHM.

The use of the electro-optic tuning will enable the implementation of laser tuning bandwith of up to 300kHz or more. In this way the linewidth of the laser will be significantly improved, and 10-100Hz linewidths should be possible.

Wavelength stability:

Using the standard locker a wavelength stability of a few hundred kHz for an hour is achieved. We have developed a high finesse ultralocker to more accurately control the laser wavelength. The current performance is +/-250kHz over a 1 hour period. This is shown in Figure 6.

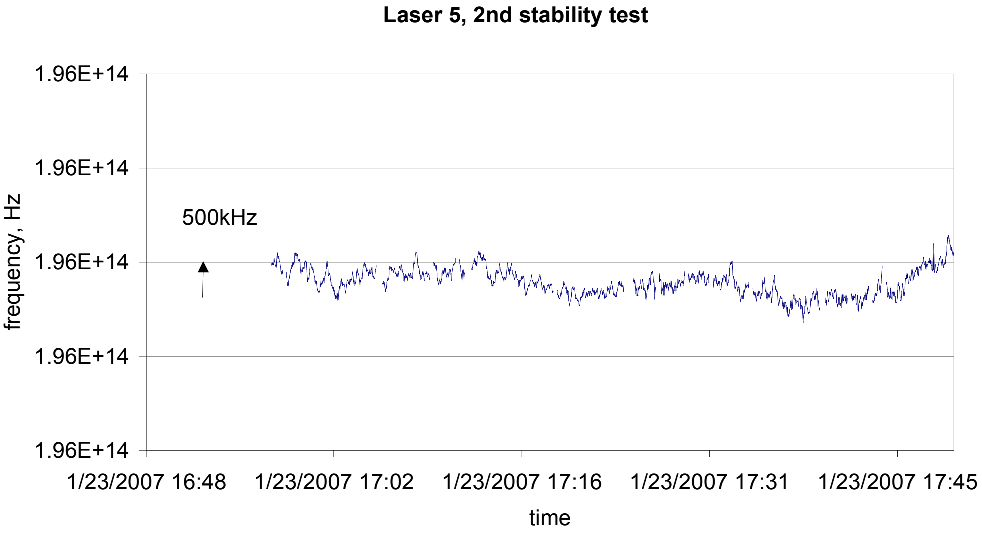

Figure 6. Wavelength stability test performed at NIST. Show wavelength stability of +/-250kHz over a 1 hour period.

Work is continuing to improve the locker stability and the control electronics and a stability of a few kHz is expected.

Phase Noise

The line width of the laser is very low, below 300Hz. This translates into low The phase noise of the laser Fig 7 shows the phase noise plot of the laser.

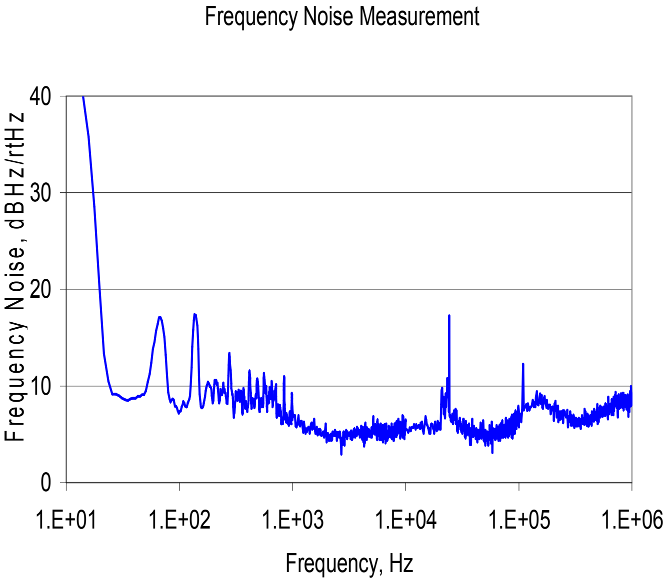

Fig 7: A plot of the frequency noise vs frequency of the laser.

References

[1] S. Taccheo, P. LaPorta, O. Svelto, and G. De Geronimo, “Theoretical and experimental analysis of intensity noise in a codoped erbium-ytterbium glass laser”, Appl. Phys. B, 19-26 (1998)

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