Self-pulsing in Erbium-doped Fiber Laser

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Abstract —**We report the study of self-pulsing behavior in erbium-doped fiber laser due to the ion-pair formation and scattered feedback. We observed the high doping concentration of the laser to be the main cause of the pulsing phenomenon. We also demonstrate that the self pulsing can be suppressed by resonance pumping.**

Keywords – Self-pulsing; Fiber laser

I. Introduction

In solid state lasers, the self-pulsing behavior has been investigated theoretically and experimentally [1, 2]. The cause of such behavior is ion-pair formation in gain medium, under the condition that ion pair concentration is more than 5% [1]. Besides, by introducing incoherent feedback outside the laser resonance cavity [3, 4], the pulses can also be generated. Erbium doped laser, either in fiber or on-chip, are extremely useful due to its emission wavelength. The on-chip erbium doped laser is promising for light source in silicon photonics, as has been shown high power [5] and wafer scale [6]. While the pulsing has also been observed in these on-chip lasers, which might have detrimental effect for applications. In this paper we want to study the cause of such un-stability by looking into ion pair and feedback due to scattered light. A fiber laser system is setup as analogy to integrated laser system.

II. Experimental Setup

The setup is illustrated in figure 1. The purpose of two isolators is to eliminate the optical feedback in laser system. The reflectivity of two DBRs is 99% and 76% on left and right respectively. The WDM on the right side split the lasing signal and residue pump. In order to confirm the cause of self-pulsing, three EDFs are used: (1) Er-16, with $6.8 \times 10^{18}\ ions/cm^3$ doping concentration, 3% ion-pair concentration, and 0.16 dB/cm absorption at 1530 nm; (2) Er-80, with $3.7 \times 10^{19}\ ions/cm^3$ doping concentration, 14% ion-pair concentration, and 0.80 dB/cm absorption at 1530 nm; (3) Er-110, with $6.6 \times 10^{19}\ ions/cm^3$ doping concentration, 16% ion-pair concentration, and 1.10 dB/cm absorption at 1530 nm. It is worth to mention that the integrated CW laser reported in [5] has a doping concentration of $9.0 \times 10^{19}\ ions/cm^3$.

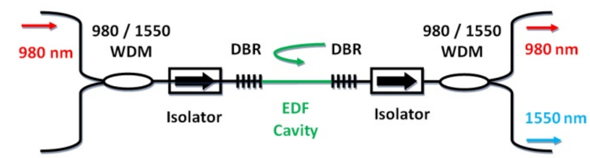

Fig.1 Schematic diagram of Erbium doped fiber laser. WDM: Wavelength Division Multiplexing; DBR: Distribute Bragg Reflector; EDF: Erbium Doped Fiber

III. Results and Discussion

The time domain of 1550 nm signal has been measured for three doping levels, as shown in figure 2 (a)-(c). (a) is the case for low doping: as pump increases near the lasing threshold, the laser keeps working in CW; while (b) and (c) show the cases for high doping (>5% ion-pair concentration): the laser operates in self-pulsing regime near the lasing threshold. Both (b) and (c) shows that as pump goes further from threshold, the repetition rate increases and eventually the CW regime dominates the self-pulsing. Besides, the observation proves that the self-pulsing effect in this fiber laser, with proper optical isolation, is caused by ion pair in high doping concentration instead of feedback.

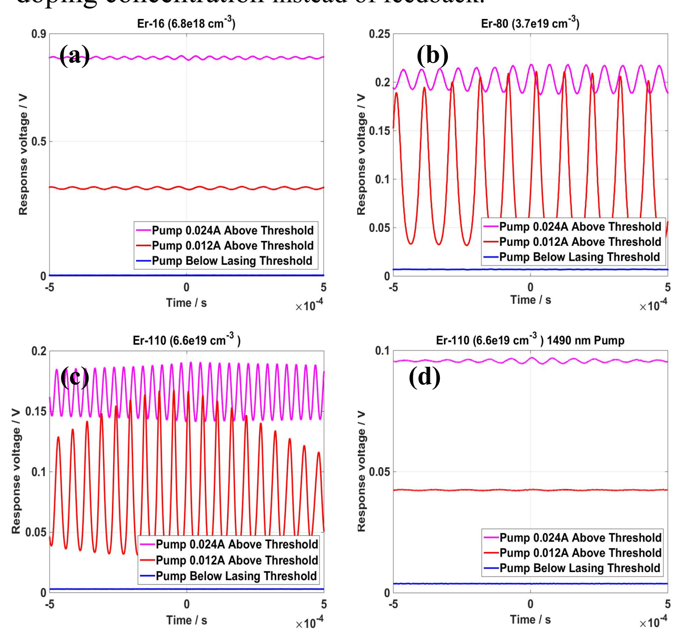

Fig.2 Stability measurement near the lasing threshold under different doping concentrations (a) Er-16 (b) Er-80 (c) Er-110. As the doping concentration becomes higher, the laser becomes more unstable (d) Er-110 under resonant pumping, the laser becomes stable

With the aim of investigating how optical feedback will affect the pulsing, the setup in figure 1 has been modified to the setup shown in figure 3. Er-80 is used in laser cavity. The reflectivity of the additional DBR is 93%. A tunable attenuator, ranging from 0 dB to 60 dB, is used together with DBR to provide variable feedback. Figure 4 shows the pulsing trend under different attenuation value: (a) is the case under the condition of high feedback, the pulse peak value becomes higher, which means that the feedback has constructive interaction with self-pulsing. When the attenuation is increased to 20 dB, the feedback is decreased, and the peak value of the pulse decreases. In this case, the feedback has destructive interaction with self-pulsing. When the attenuation is further increased to 40 dB and even 60 dB, the measurement result tends to be the same as figure 2(b), which means the feedback has been shut off by such amount of attenuation. In order to further verify that the cause of pulsing is due to ion pair formation rather than optical feedback, the EDF in Figure 3 has been replaced with lowly doped Er-16. Stable curves are observed near the lasing threshold under various feedback conditions. Figure 4(c) shows the case under 0dB attenuation.

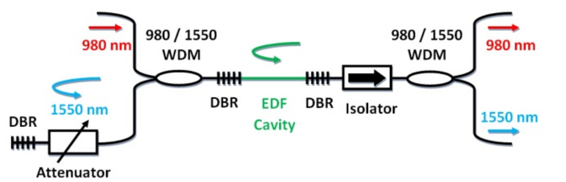

Fig.3 Erbium doped fiber laser with feedback

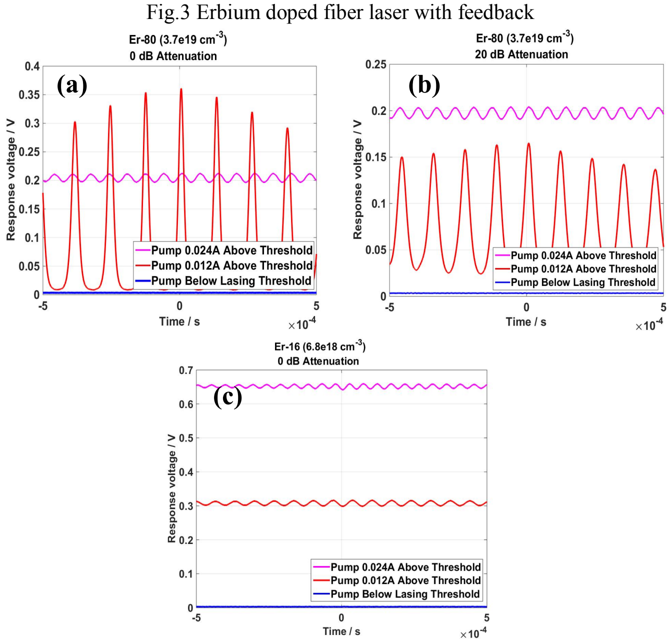

Fig.4 Stability measurement near the lasing threshold with feedback (a) Er-80, 0 dB attenuation (b) Er-80, 20 dB attenuation (c) Er-16, 0 dB attenuation

Several ways have been reported to stabilize the laser against self-pulsing [7-9]. Among them, an effective one is resonant pumping [7]. The idea is that when pump wavelength is close to signal, the pump will also serve as gain limiter, which damps out the oscillations in population inversion. Hence the pulsing can be suppressed. This method is also implemented in our setup, with 980 nm pump replaced by 1490 nm one. The two WDMs in figure 1 also need to be replaced by the ones work with 1490 nm. The time domain measurement for Er-110 fiber is illustrated in figure 2(d). Comparing the figure 2(c) and (d), the self-pulsing has been significantly suppressed, while the output power becomes relatively lower.

IV. Conclusion

To sum up, we report the self-pulsing in DBR based erbium doped fiber laser under different doping level, and verified that the pulsing is mainly caused by ion pair in highly doped gain instead of feedback. A controlled feedback is created by an additional DBR and it is varied quantitatively by a tunable attenuator. Such feedback is found to either constructive or destructive interact with laser beam. By using 1490 nm pump instead of 980 nm, the self-pulsing is suppressed significantly.

References

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This work was supported in part by the Defense Advanced Research Projects Agency (DARPA) E-PHI program. Nanxi Li acknowledges a fellowship from the Agency of Science, Technology and Research (A*STAR), Singapore