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Gain stability in fluorine polymer modified PbS Quantum dot fiber amplifier

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Abstract. The fluorescence intensity drop rate of PbS quantum dot with fluorine-containing polymer is 9.76% and the gain drop rate of quantum dot fiber amplifier (QDFA) with fluorine-containing polymer is 57.66% separately with temperature, which is more stable than no fluorine polymer QDFA.

1. Introduction

A fiber amplifier is a key component for optical fiber communication systems featuring direct in-line amplification. The erbium-doped fiber amplifier (EDFA) is one of the most dominating commercial products in the fiber amplifier market[1] and has been applied in various fiber communication systems. However, the gain bandwidth of EDFA only covers the C band (1525nm-1560nm) due to the limited band width of erbium[2]. Therefore, there is a need to find alternative new gain media to improve the performance of fiber amplifiers. In recent years, the quantum dot fiber amplifier (QDFA) has drawn great attention on account of its broad band, tunable bandwidth, compact size, simple fabrication process and compatibility with standard optical fiber communication systems[3-7].

In this paper, a novel optical amplifier having a fused bi-conical single mode fiber (SMF) coupler is demonstrated, as shown in Fig. 1[5], on which PbS QDs capped with fluorine-containing polymers (FCPs) were coated. The multifunctional copolymers were designed to realize simultaneous QDs ligand exchange, encapsulation, dispersion, and protection. A QDFA modified by such FCPs exhibits exceptional gain stability.

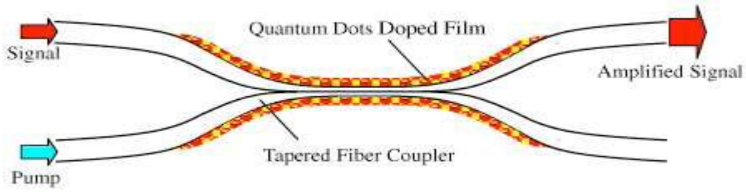

Fig. 1. Schematic device structure of the semiconductor quantum dots fiber amplifier (SQDFA)[5].

2. Fluorescence thermal stability of PbS quantum dot

Adopting 980 nm laser as pump source, we research fluorescence thermal stability of PbS QDs with temperature increasing. Fluorescent variety of PbS QDs modified by three fluorine content polymer takes on different downtrend. As Fig. 2 shown, fixed pump power and other experimental factors, the

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fluorescence intensity at 1550 nm of PbS QDs modified by 0%, 15% and 30% fluorine-containing polymer drop by 26.27%, 11.13% and 9.76% respectively from 25℃ to 65℃. It is obvious that the growing of fluorine content contributes to improving surrounding invulnerability. The reason why consistent trend of QDs with 15% and 30% fluorine-containing polymer coincides by and large is weakening binding affinity of QDs and polymer.

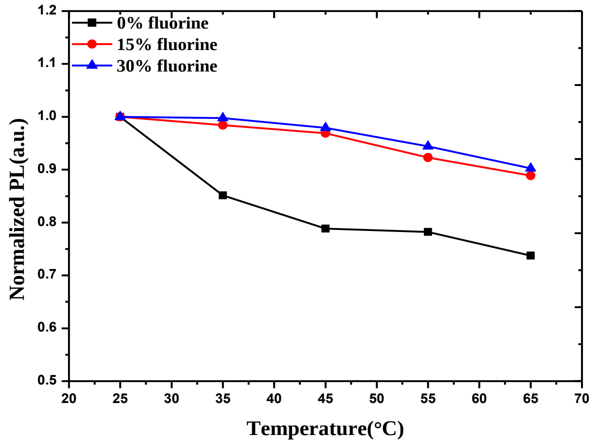

Fig. 2. The curve of fluorescence at 1550 nm of PbS QDs modified by different fluorine content polymers with temperature

3. Gain stability of quantum dot fiber amplifier with temperature

The PbS QDs were synthesized according to the Cademartiri method[8]. They were then modified by FCPs to improve surface characteristics and enhance their gain stability. We adopted a SiO2 sol-gel method to form PbS QDs doped films on the surface of a fused bi-conical SMFs coupler which is coated with QDs doped films. As Fig. 3 shown, a 1550 nm semiconductor light emitting diode (SLED) and a 980 nm laser diode (LD) are used as the signal and pump respectively. The signal and pump sources are injected into the tapered region simultaneously. The 980 nm pump excites the doped PbS QDs at the tapered region through an evanescent wave. The 1550 nm signal interacts with excited QDs through the evanescent wave and then can be amplified. A 1550nm/980nm wavelength division multiplex (WDM) is connected to an output of the QDFA. The amplified signal is analyzed by an optical spectrum analyzer (QSA).

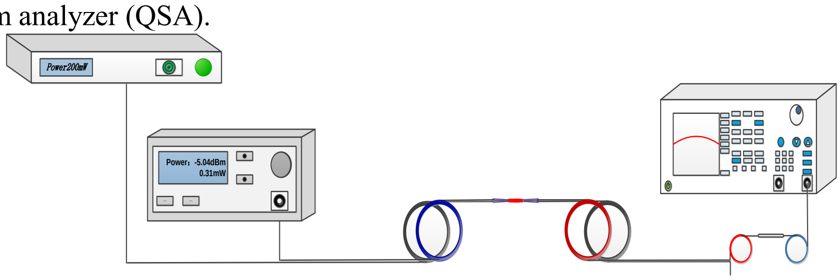

Fig. 3. The characterization system for PbS QDs optical fiber amplifier.

In this paper, we studied temperature-dependent stabilities of QDFA's gains on different fluorine contents. Fig. 4 shows the gain at 1550 nm at different temperature. The gain dropped by 93%, 57.66% and 74.68%, respectively, for QDFA modified with FCPs having 0, 15% and 30% fluorine. The gain declination is caused by vigorous internal electron thermal motion of QDs with rising temperature, leading to easier formation of spontaneous emission.

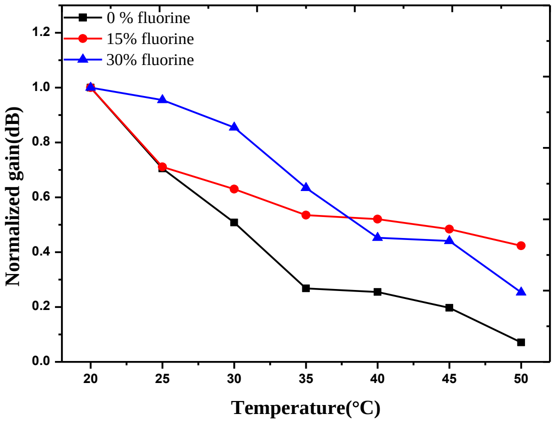

Fig. 4. temperature-dependent stability of gain of optical fiber amplifiers based on PbS QDs

Previously, we used an amphiphilic copolymer to encapsulate hydrophobic PbS QDs that were capped with either oleylamine or oleic acid ligands[6-7]. In this work, the FCPs we designed have the oligo (ethylene glycol) side chain that is hydrophilic and servers to maintain colloidal stability of QDs in silica sol. The carboxylic acid side group is used to ligand-exchange with oleylamine on the surface of PbS QDs that were synthesized in organic solution. Ligand exchange using these multifunctional copolymers not only results in polymer coating of QDs but also renders PbS QDs more stable because carboxylic acid is a stronger ligand than oleylamine.

4. Conclusion

The properties of PbS QDs and QDFAs which were modified by polymers with different fluorine content were investigated. The fluorescence intensity drop rate of QDs with no fluorine-containing polymer was about 3 times than QDs with 30% fluorine-containing polymer. Similarly, thermal stability of QDFA with fluorine-containing polymer exhibited more excellent constancy than QDFA with no fluorine-containing polymer. Due to the good fluorescence performance of the PbS QDs and improved gain stability of QDFA, the proposed fiber amplifier will find potential applications in broadband and high speed fiber-optic communication.

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