

2 μm 波段多波长可调谐光纤激光器研究

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摘要:设计了一种基于马赫-曾德(M-Z)光纤干涉滤波器的可调谐多波长掺铥环形光纤激光器, M-Z光纤滤波器由两个3 dB耦合器级联构成, 通过光纤耦合器接入环形腔中, 并利用Sagnac光纤反射镜实现反射式滤波。实验利用一个发射功率为250 mW的1573 nm光纤激光器作为泵浦源, 通过一个1570/2000 nm波分复用器(WDM)注入一段4 m长单模掺铥光纤(TDF)中获得2 μm 波段光增益。环形腔内加入偏振控制器(PC)调节腔内损耗, 实现了2 μm 波段可调谐多波长输出, 观测到最多3个波长激光。

关键词:光纤激光器; 掺铥光纤(TDF); 2 μm 波段; 马赫-曾德干涉仪; 多波长

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Multi-wavelength tunable fiber laser operating at 2 μm band

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Abstract: A tunable multi-wavelength Tm^{3+} -doped ring fiber laser based on all-fiber Mach-Zehnder (M-Z) interferometer was designed. The Mach-Zehnder fiber filter consisted of two cascaded 2×2 3 dB couplers, and it connected to the ring cavity through a fiber coupler and reflecting filter was realized by a Sagnac fiber mirror. In experiment, a fiber laser at 1573 nm with a output power of 250 mW was used as pump source, and the pump laser was injected into a segment of 4 m single-mode Tm^{3+} -doped fiber through a 1570/2000 nm wavelength division multiplexer (WDM), and then optical gain at 2 μm band was obtained. A polarization controller (PC) was used for adjusting laser polarization loss in the cavity. By observing tunable multi-wavelength laser around 2 μm band, 3 wavelengths were obtained by adjusting the PC.

Key words: fiber laser; Tm^{3+} -doped fiber; 2 μm band; Mach-Zehnder interferometer; multi-wavelength

1 引言

2 μm 波段掺铥光纤激光器工作在人眼安全波段、效率高、光束质量好^[1-3], 可广泛应用于激光医疗、传感、雷达和空间通信等领域^[4-5], 也可作为3~5 μm 中红外光参量振荡的泵浦源^[6-7]。近十年, 掺铥光纤激光技术在高功率^[8-10]、宽调谐范围^[11-12]及脉冲激光^[13-14]领域已取得了快速的进

展。多波长光纤激光器结构简单、成本低、稳定性好, 在波分复用系统、分布式光纤传感系统、微波光子技术等方面具有很好的应用价值。获得多波长的方法主要有非线性偏振旋转效应和四波混频效应的多波长掺铥光纤激光器^[15], 非线性光纤环形镜的多波长掺铥光纤激光器^[16-17]。

本文提出了一种利用光纤马赫-曾德(M-Z)干

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涉仪滤波的多波长掺铥光纤激光器, 并采用 1573 nm 光纤激光泵浦一段 4 m 长单模掺铥光纤的环形腔结构。实现了 2 μm 波段 1~3 个波长的多波长激光输出, 输出的单波长激光 3 dB 线宽为 0.048 nm, 边模抑制比为 53 dB。

2 实验结构与工作原理

基于光纤 M-Z 干涉仪滤波的多波长掺铥光纤激光器结构如图 1 所示, 两个级联的 2 × 2 耦合器 (3 dB) 构成的 M-Z 干涉仪, 通过一个 3 dB 耦合器接入激光环形腔, 另一个 3 dB 耦合器两端光纤连接作为 Sagnac 全反射镜, 该结构构成了反射式滤波器。中心波长为 1573 nm 光纤激光泵浦源通过一个 1570/2000 nm 波分复用器 (WDM) 注入一段 4 m 长单模掺铥光纤 (TDF) 中, 掺铥光纤的数值孔径、1570 nm 处吸收、2000 nm 模场直径分别为 0.15、15 dB/m、10.5 μm。掺铥光纤中 Tm^{3+} 粒子受激辐射产生的背向增益经 M-Z 干涉仪滤波后, 在输出耦合器 90% 端口反馈, 在环形腔内不断放大而形成激光振荡, 在 10% 端口输出, 采用光谱分析仪 (AQ6375) 观测光谱。利用偏振控制器 (PC) 改变腔内激光偏振态, 光隔离器保证环形腔内单方向通光。

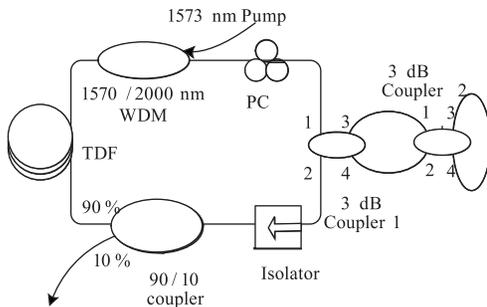


图 1 多波长掺铥光纤激光器结构

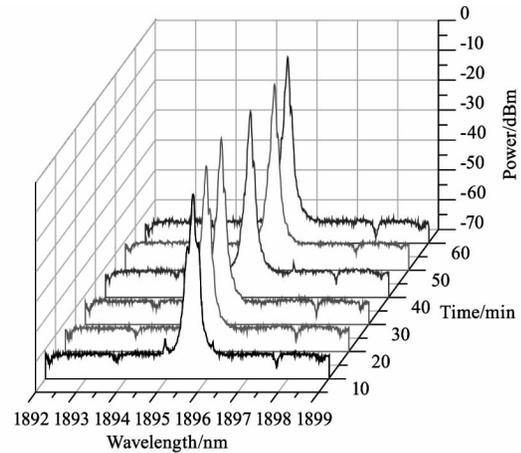
Fig. 1 Configuration of multi-wavelength Tm^{3+} -doped fiber laser

光纤 M-Z 干涉滤波器由两个 3 dB 光纤耦合器组成, 初始输入光被耦合器 1 分为强度相等的两束光, 在耦合器 2 的 3、4 端口干涉, 耦合器 2 的 3、4 端口相连形成环路, 干涉光沿环路返回耦合器 1 中再次干涉并输出。光纤 M-Z 干涉仪的滤波特性由耦合器的分光比和干涉仪两臂的臂长差共同决定^[18]。

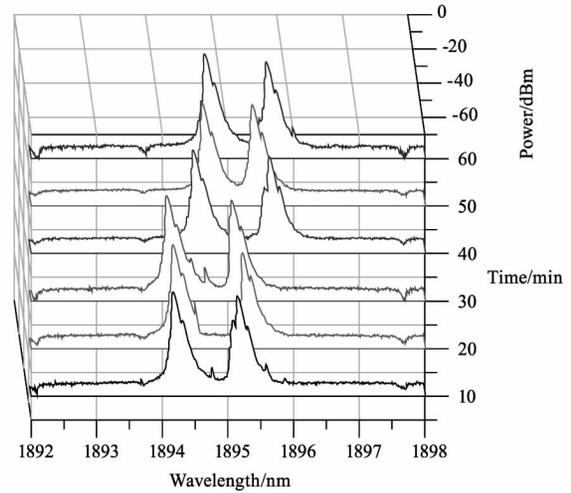
3 实验结果与讨论

1573 nm 光纤激光器的输出功率为 250 mW, 2 μm 波段的 1895 nm 附近形成了多波长激光振荡, 由于 M-Z 的梳状滤波周期较小, 相近模式激光之间存在模式竞争。调节 PC 改变腔内激光偏振态来抑制一些波长振荡, 1.9 μm 波段得到 1~3 个波长数的多波长激光输出。图 2 为 1 h 内不同波长数的多

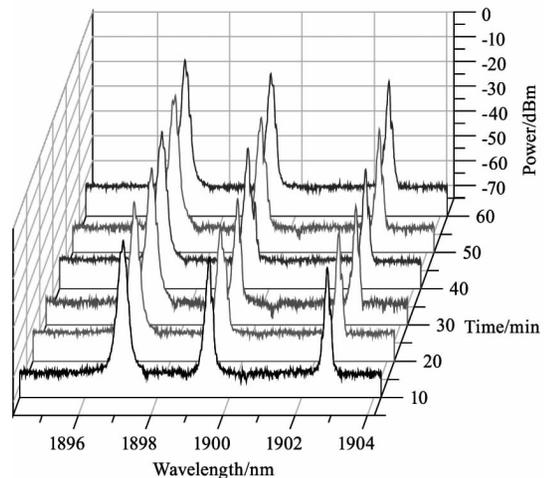
波长激光输出光谱。其中, 单波长激光中心波长为 1895.5 nm, 3 dB 线宽约为 0.048 nm, 边模抑制比为 53 dB; 双波长激光波长间隔约为 1 nm, 边模抑制比为 50 dB。可以看出, 在 60 min 内, 单波长和三波长输出比较稳定, 双波长在 0.5 nm 范围内产生了漂移。



(a) 单波长光谱



(b) 双波长光谱



(c) 三波长光谱

图 2 60 min 内不同波长数的多波长激光输出光谱

Fig. 3 Output spectrum of multi-wavelength laser in 60 minutes with different number of wavelength

图3为60 min内该多波长掺铥光纤激光器的功率稳定性,详细记录了输出波长数分别为1~3个时单个波长的功率变化,时间间隔为10 min。可以看出,该多波长掺铥光纤激光器具有较好的功率稳定性。

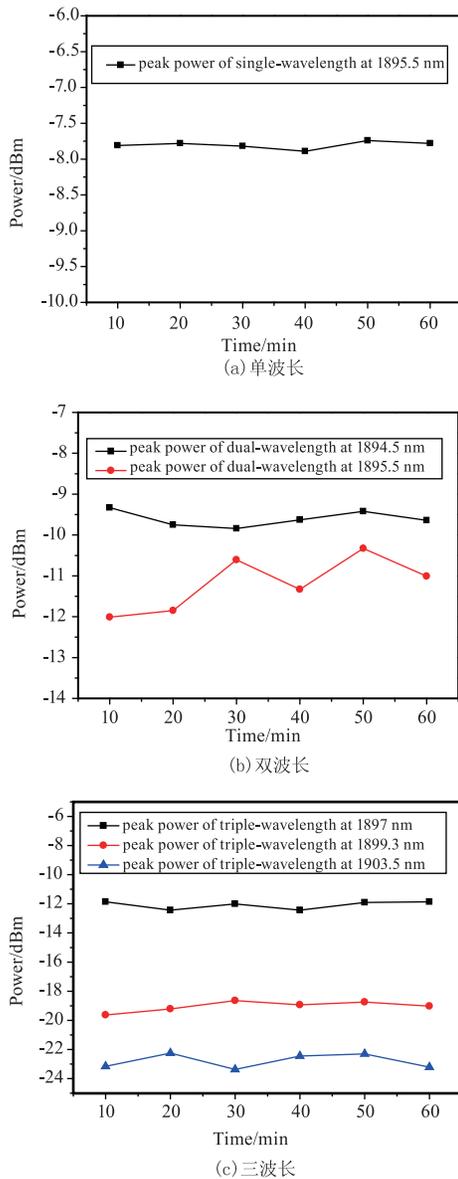


图3 60 min内多波长激光输出功率变化情况

Fig. 3 Power variation of multi-wavelength laser in 60 minutes

4 结论

提出并实验研究了一种光纤马赫-曾德干涉仪滤波的环形腔多波长掺铥光纤激光器,1573 nm 光纤激光器泵浦一段4 m长单模掺铥光纤。泵浦功率为250 mW时,通过调节PC实现了2 μm 波段波长数为1~3的多波长激光输出。该多波长激光器具有窄线宽、高信噪比、较好的功率稳定性等特点。

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