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基于周期性畴极化反转掺镁铌酸锂晶体的脉冲光纤激光器抽运的高功率光参量振荡器

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摘要 报道了研制高功率全光纤化线偏振掺铌脉冲激光器,并用其抽运光参量振荡器(OPO)的研究工作。激光器以光纤化的声光调 Q 掺铌光纤激光器作为种子源,用大直径双包层保偏光纤作为增益放大介质。在 40 kHz 重复频率下,得到 1064.2 nm 处最大 23.5 W 的线偏振脉冲激光输出,脉冲宽度约 46 ns,偏振消光比(PER)优于 10 dB,光束质量因子(M^2)约为 1.3。利用该全光纤激光器抽运基于周期性畴极化反转掺镁铌酸锂(PPMgLN)晶体的宽带可调谐 OPO,在信号光 1602 nm 通道,获得 11.05 W 最大光参量输出,其中 3168 nm 处闲散光功率为 3.01 W。OPO 能量转换效率为 56%,斜率效率为 63%。在信号光 1508 nm 通道,获得 9.87 W 最大光参量输出,其中 3614 nm 波长功率为 2.75 W。

关键词 激光器; 脉冲光纤激光器; 光参量振荡器; 周期性畴极化反转掺镁铌酸锂晶体

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PPMgLN-Based High Power Optical Parametric Oscillator Pumped by a Pulsed Fiber Laser

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Abstract This paper reports the development of our recent work on an all-fiberized high power linearly polarized pulsed Yb fiber laser and using the fiber laser to pump a PPMgLN-based optical parametric oscillator (OPO). The pulsed fiber laser used a fiberized acousto-optic (AO) Q-switched Yb doped fiber laser as a seed and a large mode area double cladding polarization-maintaining fiber as the gain medium. It delivered a linearly polarized pulsed laser output working at 1064.2 nm with an average power of 23.5 W at a repetition rate of 40 kHz. The polarization extinction ratio (PER) of the emission was better than 10 dB. The pulse duration was about 46 ns and the beam quality factor (M^2) was about 1.3. Using this all-fiberized laser as a pump source to pump a PPMgLN-based OPO, we obtained a maximum parametric output power of 11.05 W at signal wavelength of 1602 nm with 3.01 W of idler power at 3168 nm. The total conversion efficiency and the slope efficiency was 56% and 63% respectively. At signal wavelength of 1508 nm, a maximum parametric output power of 9.87 W was obtained with 2.75 W idler power at 3614 nm.

Key words lasers; pulsed fiber laser; optical parametric oscillator; PPMgLN crystal

1 引 言

中红外波段的激光光源在医学、生物、工业以及国防领域都有重要的作用,基于非线性光学转换的光

参量振荡器(OPO)可以实现大功率中红外波段的激光输出。实现非线性光学转换的晶体主要有周期性畴极化的铌酸锂(PPLN)^[1]晶体、磷酸钛氧钾

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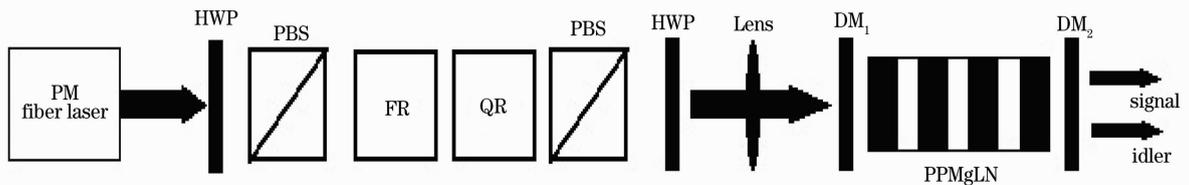


图2 光纤激光器抽运的光参量振荡器原理图

Fig. 2 Schematic diagram of the fiber laser pumped optical parametric oscillator

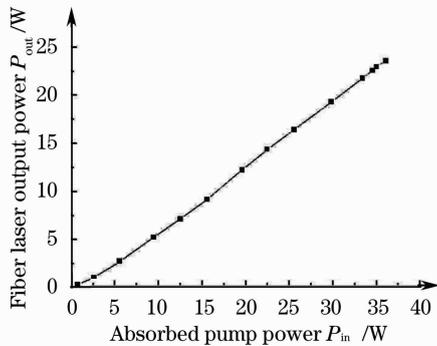


图3 在40 kHz重复频率下,全光纤线偏振激光输出功率与吸收抽运功率的关系

Fig. 3 Output power of the all fiberized linearly polarized fiber laser as a function of absorbed pump power at repetition rate of 40 kHz

在放大级,合束器将经过保偏光纤隔离器导入的线偏振激光种子源和作为抽运源的半导体激光耦合到大直径保偏掺镱双包层增益光纤中。合束器需进行有效的风冷,以避免损坏。图3所示为在40 kHz重复频率下,种子源激光经过放大后,在1064 nm处线偏振激光输出功率与所吸收的抽运功率之间的关系。在吸收的抽运功率为36 W时,得到最大线偏振激光输出功率为23.5 W,斜率效率为67.6%,偏振消光比优于10 dB。测得的光束质量因子 M^2 约为1.3,接近基模。

图4(a)为用光谱分析仪(OSA, Ando 6317C)测量的线偏振激光输出的光谱,波长为1064.2 nm,光谱半峰全宽(FWHM)为1.1 nm,与种子源相比光谱有所展宽。从光谱图中可以看出输出激光无受激拉曼散射(SRS)现象。图4(b)为用快速铟镓砷(InGaAs)光电探测器和500 MHz示波器测量的激光脉冲形状图,激光脉冲宽度为46 ns。与种子源相比,放大后的脉冲宽度亦有所展宽。

光纤激光器输出的线偏振激光经过隔离器后,得到最大功率为19.7 W线偏振激光。用该激光抽运PPMgLN晶体,成功获得了多个通道的光参量振荡输出。选择了信号光波长在1602 nm和1508 nm这两

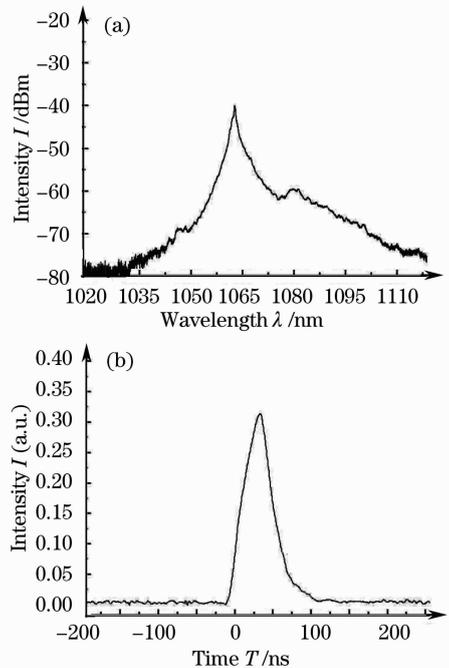


图4 抽运吸收功率为36 W,重复频率为40 kHz时,全光纤线偏振激光器输出的激光光谱(a)和激光脉冲波形(b)

Fig. 4 Emission spectrum (a) and pulse shape (b) of the fiber laser output at repetition rate of 40 kHz under absorbed pump power of 36 W

个通道,对应闲散光的波长分别为3168 nm和3614 nm。图5为光参量振荡器输出功率与作为抽运源的光纤激光器输入功率之间的关系图。图5(a)为在1602 nm信号光通道,光参量振荡器输出功率(包括总输出功率、信号光功率以及闲散光功率)与抽运源光纤激光器输入功率的关系图,在19.7 W抽运下,获得最大光参量输出功率为11.05 W,其中3168 nm波长处闲散光的功率为3.01 W,OPO能量转换效率为56%,斜率效率为63%。图5(b)为在1508 nm信号光通道,光参量振荡器输出功率与抽运源光纤激光器输入功率的关系图。在19.7 W抽运下,获得最大光参量输出为9.87 W,其中3614 nm波长处闲散光的功率为2.75 W。

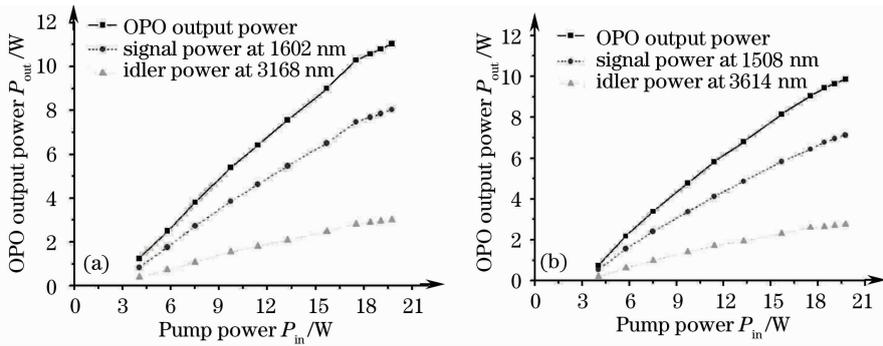


图5 光参量振荡器输出功率与抽运源光纤激光器功率的关系。(a)1602nm通道;(b)1508 nm通道

Fig.5 Output power of the OPO via fiber laser power (a) for 1602 nm channel;(b) for 1508 nm channel

4 结 论

介绍了研制全光纤化的线偏振高功率掺铽脉冲光纤激光器,以及用其抽运光参量振荡器的研究工作。光纤激光器最大输出线偏振功率达到 23.5 W,偏振消光比优于 10 dB,重复频率 40 kHz,脉冲宽度为 46 ns,光束质量因子 M^2 约为 1.3,接近基模。用该光纤激光器抽运基于 PPMgLN 晶体的宽带可调谐 OPO,实现了高效的参量转换输出。在 19.7 W 线偏振激光抽运下,在信号光 1602 nm 通道,获得最大光参量输出功率为 11.05 W,其中 3168 nm 处闲散光功率为 3.01 W,OPO 能量转换效率为 56%,斜率效率为 63%。在信号光 1508 nm 通道,获得最大光参量输出为 9.87 W,其中 3614 nm 处闲散光功率为 2.75 W。

参 考 文 献

- Elder, D. Legge, J. Beedell *et al.*. Nd:YVO₄ pumped degenerate PPLN OPO [C]. *Advanced Solid-State Photonics*, 2006, MB: Page MB20
- Y. Isyanova, E. Slobodtchikov, J. H. Flint. High repetition rate, rapidly tunable KTA OPO [C]. *Advanced Solid-State Photonics*, 2005, MB: Page MB407
- Zhu Yachen, Lan Ge, Li Tong *et al.*. 2 μ m KTiOAsO₄ optical parametric oscillator[J]. *Acta Optica Sinica*, 2007, **27**(11): 2059~2063
朱雅琛,兰戈,李彤等. 脉冲式 2 μ m KTiOAsO₄ 光参变振荡器[J]. *光学学报*, 2007, **27**(11): 2059~2063
- Y. Wang, D. Xu, Y. Yu *et al.*. High-peak-power, high-repetition-rate intracavity optical parametric oscillator at 1.57 μ m [J]. *Chin. Opt. Lett.*, 2007, **5**(2): 93~95
- Fu Weijia, Yu Jian, Kang Yuzhuo *et al.*. 13 mW-continuous-wave green light output by quasi-phase-matched frequency doubling in periodically poled KTP [J]. *Acta Optica Sinica*, 2007, **27**(6): 1063~1066
付伟佳,于建,康玉琢等. 准相位匹配 PPKTP 晶体连续倍频 13 mW 绿光输出[J]. *光学学报*, 2007, **27**(6): 1063~1066
- K. Miyamoto, K. Suizu, J. Shikata *et al.*. Wavelength-agile 5~10 μ m generation by galvano-controlled double crystal KTP-OPO [C]. *Conference on Lasers and Electro-Optics (CLEO)*, 2006, CTuZ: Page CTuZ2
- Yao Jianghong, Liu Zhiwei, Xue Liangping *et al.*. Low threshold and wide tunable optical parametric oscillator based on periodically poled MgO:LiNbO₃ (PPMgLN) crystal [J].

Infrared Millim. Waves, 2008, **27**(2): 105~108
姚江宏,刘志伟,薛亮平等. 基于 PPMgLN 晶体低阈值宽调谐红外光参量振荡研究 [J]. *红外与毫米波学报*, 2008, **27**(2): 105~108

- Kong Yongfa, Li Bing, Chen Yunlin *et al.*. Study on the micro-mechanism of Mg-doped lithium niobate crystals against photorefractive [J]. *Infrared Millim. Waves*, 2003, **22**(1): 40~44
孔勇发,李兵,陈云琳等. 掺镁铌酸锂晶体抗光折变微观机理研究 [J]. *红外与毫米波学报*, 2003, **22**(1): 40~44
- Yao Jianghong, Yan Boxia, Chen Yahui *et al.*. Periodically poled second harmonic green light generation in near-stoichiometric MgO-doped LiNbO₃ crystal [J]. *Laser Technology*, 2004, **28**(2): 141~143
姚江宏,颜博霞,陈亚辉等. 周期极化近化学计量比掺镁铌酸锂晶体倍频研究 [J]. *激光技术*, 2004, **28**(2): 141~143
- B. Wu, Y. Shen, S. Cai *et al.*. Widely tunable high power OPO based on a periodically poled MgO doped lithium niobate crystal [J]. *Optics & Laser Technology*, 2007, **39**(6): 1115~1119
- Xingbao Zhang, Baoquan Yao, Yuezu Wang *et al.*. Middle-infrared intracavity periodically poled MgO:LiNbO₃ optical parametric oscillator [J]. *Chin. Opt. Lett.*, 2007, **5**(7): 426~427
- D. W. Chen, K. Masters. Continuous-wave 4.3- μ m intracavity difference frequency generation in an optical parametric oscillator [J]. *Opt. Lett.*, 2001, **26**(1): 25~27
- Yao Jianghong, Xue Liangping, Yan Boxia *et al.*. Optical parametric oscillator based on periodically poled MgO:LiNbO₃ crystal [J]. *Chinese J. Lasers*, 2007, **34**(2): 209~213
姚江宏,薛亮平,颜博霞等. 周期极化掺镁铌酸锂晶体的光学参量振荡 [J]. *中国激光*, 2007, **34**(2): 209~213
- C. Kieleck, M. Eichhorn, A. Hirth *et al.*. High-efficiency 20-50 kHz mid-infrared orientation-patterned GaAs optical parametric oscillator pumped by a 2 μ m holmium laser [J]. *Opt. Lett.*, 2009, **34**(3): 262~264
- Zhu Guoli, Ju Youlun, Wang Tianheng *et al.*. A mid-IR 14.1 W ZnGeP₂ optical parametric oscillator pumped by a Tm, Ho:GdVO₄ laser [J]. *Chin. Phys. Lett.*, 2009, **26**(3): 034208
- D. Creeden, P. A. Ketteridge, P. A. Budni *et al.*. Mid-infrared ZnGeP₂ parametric oscillator directly pumped by a pulsed 2 μ m Tm-doped fiber laser [J]. *Opt. Lett.*, 2008, **33**(4): 315~317
- D. Creeden, P. A. Ketteridge, P. A. Budni *et al.*. Multi-watt mid-IR fiber-pumped OPO [C]. *Conference on Lasers and Electro-Optics (CLEO)*, 2008, CTuII: Page CTuII2
- A. Henderson, R. Stafford. Low threshold, singly-resonant CW OPO pumped by an all-fiber pump source [J]. *Opt. Express.*, 2006, **14**(2): 767~772
- D. Chen, T. S. Rose. Low noise 10-W cw OPO generation near 3 μ m with MgO doped PPLN [C]. *Conference on Lasers and Electro-Optics (CLEO)*, 2005, CThQ: Page CThQ2
- Jiang Peipei, Cai Shuangshuang, Shen Yongchang *et al.*. PPMgLN based high power optical parametric oscillator pumped by a pulsed Yb fiber laser [J]. *Chinese J. Lasers*, 2008, **35**(s2): 168~171
姜培培,蔡双双,沈永行等. 掺铽脉冲光纤激光器抽运的高功率 PPMgLN 光参变振荡器 [J]. *中国激光*, 2008, **35**(s2): 168~171