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利用飞秒光梳获得正交压缩态

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摘 要

介绍了利用周期性极化KTP晶体的参量下转换过程制备飞秒光场压缩态的实验研究. 实验使用运转于阈值以下的同步泵浦光学参量振荡器获得了压缩度为2.9 dB、中心波长为795 nm、重复频率为76 MHz的飞秒正交振幅压缩态光场. 考虑到系统传输测量过程中的损耗,实际输出压缩度应该为3.8 dB.

关键词: 压缩态,飞秒光梳,参量振荡.
中图分类号: O431.2

0 引 言

压缩态[1]是量子光学中的一种非经典态,具有很好的量子关联性. 其可以将某一测量分量的起伏降低到散粒噪声极限以下,在亚散粒噪声的测量[2],量子离物传态[3]及量子秘钥[4]等方面都有很好的应用. 在1985年,Bell实验室的R. E. Slusher等人首次得到光场压缩态[6]后,产生压缩态的主要实验光源大多为连续光. 由于脉冲光具备高峰值功率和较宽的光谱范围,所以用脉冲光场产生压缩态,也会有很好的应用前景. 1987年,同样是Slusher研究组首次用锁模Nd:YAG脉冲激光器获得低于量子噪声极限12%的脉冲压缩态光场[7],压缩光脉宽为100ps. Slusher研究组并没有采用OPO腔,而是让脉冲光单次穿过非线性晶体. 并且在后续的研究中一直延续这个方法,直到近几年才开始关注脉冲光的OPO腔的性质. SPOPO腔[8](synchronously pumped optical parametric oscillator)可让脉冲光在OPO腔中振荡一周后恰好与下一个脉冲相遇,提高功率的同时,又不破坏其光学频率梳. 飞秒光梳技术在近几年受到了很大的关注,在精确测量[9],显微成像[10]及微加工[11]等方面有很好的应用. 2005年,格劳伯教授(R. J. Glauber),霍尔教授(J. L. Hall)和亨施教授(T. W. Hansch),由于对超精细激光光谱学,主要是光学频率梳技术的贡献分享了当年的诺贝尔物理学奖[12].

本实验是用飞秒脉冲激光器,通过参量下转换来产生压缩态光场. 飞秒激光本身已经具备较好的测量精度,对其进行压缩后,测量精度将进一步得到提高. 实验中的模式清洁器和OPO腔均采用的是两镜驻波腔. 这种腔形相对于行波腔而言,腔内能量的损失较小,容易控制. 在产生压缩态的实验中用的较多的是四镜蝴蝶型腔,与两镜腔相比,经历的镜面多了一倍,必然损耗较大. 而驻波的特点波腹与波节位置固定,波节位置的非线性晶体不参与参量作用,能量集中在波腹处,这导致对于晶体的利用率不足,而且容易造成空间烧孔现象.

1 实验装置和实验结果

实验装置如图1所示。

实验中使用全固态激光器(Verdi-V18)输出18W的532 nm连续光,用以泵浦掺钛蓝宝石激光器(Mira HP). Mira锁模后输出波长为795 nm的红外脉冲光,脉宽为150 fs,重复频率76 MHz,输出功率3.6 W. 输出的红外脉冲光穿过LBO(三硼酸锂晶体,尺寸为5×5×3 mm^3,温度精确控制在25 ℃)后,倍频产生1.5 W的397.5 nm紫外光. 由LBO输出的红外光和紫外光经一个对795 nm光高透、397.5 nm光高反的双色镜(D1)分开,紫外光作为泵浦光进入OPO;透射的红外光,经偏振分束棱镜

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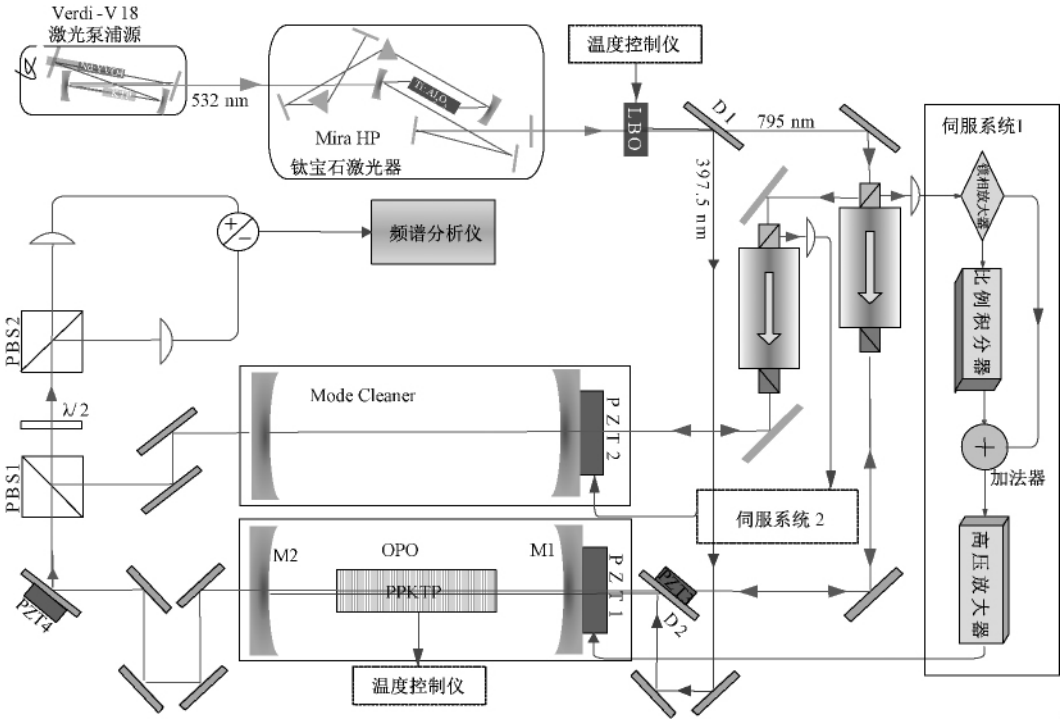


图 1

分成两束,一束经过模式清洁器(Mode Cleaner)作为本振光参与探测,另一束经过隔离器后作为基频光进入 OPO 腔. OPO 输出的压缩红外光与从模式清洁器中出射的本振光在 PBS1 上混合为一束,此时两束光的偏振方向相互垂直,经半波片旋转 45°后用 PBS2 分开(如图 2). 这样 PBS2 两个端口输出的两束光为相互干涉的本振光和压缩光,注入平衡零拍探测系统.

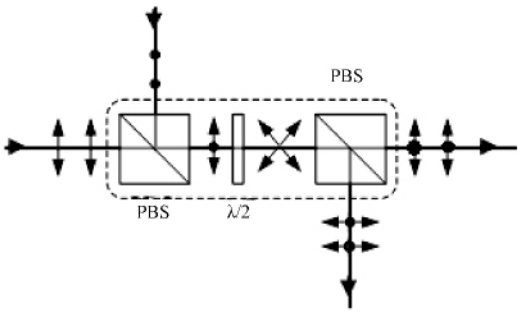


图 2　偏转方向示意图

实验中 OPO 与模式清洁器采用的都是两镜驻波腔,为了实现同步泵浦 OPO 的腔长与 Mira 内的驻波腔长保持一致,约为 1.97 m. 我们将 OPO 与模式清洁器设置为相同的腔型,这样使得 OPO 输出的压缩光和模式清洁器输出的本振光之间更加容易实现干涉. 腔前镜 M1 的凹面对 397.5 nm 的反射率为 40%,对 795 nm 的反射率为 97%;后镜对 397.5 的反射率为 95%,对 795 nm 的反射率为 96%. 让红外光形成驻波,紫外光双次穿过. OPO 对红外光的精细度为 26,下转换阈值 90 mW. OPO 中使用的晶体为 I 类共线相位匹配周期极化的 KTP 晶体(PPKTP),晶体厚为 300 μm,匹配温度为 23.5 ℃.

OPO 以及模式清洁器分别由伺服系统 1 和伺服系统 2 将腔长锁定在共振位置. 两伺服系统组成完全相同,都是从光隔离器提取腔的反射信号转化为电信号后,由锁相放大器检波放大再经过比例积分器积分放大,最后加载在腔镜后边的压电陶瓷(PZT1、PZT2)上将腔长锁定. 锁相放大器的调制信号(2 KHz)也加载在同一压电陶瓷上.

实验结果如图 3 所示。

在 397.5 nm 注入功率为 35 mW、795 nm 注入功率为 18.6 mW 时,OPO 运转于参量缩小状态下(由 PZT3 控制),在 4 M 处测量得到低于散粒噪声极限 2.9 dB 的正交振幅压缩态,放大状态高于散粒噪声极限 10 dB. 图中红线为散粒噪声极限;蓝色曲线为正交振幅压缩态噪声;紫色曲线为被放大的正交位相噪声;黑色曲线为以 1.6Hz 的固定频率扫描本振光与压缩光场的相对相位(PZT4)所测量到的由正交振幅(缩小)到正交位相(放大)周期变化的噪声曲线.

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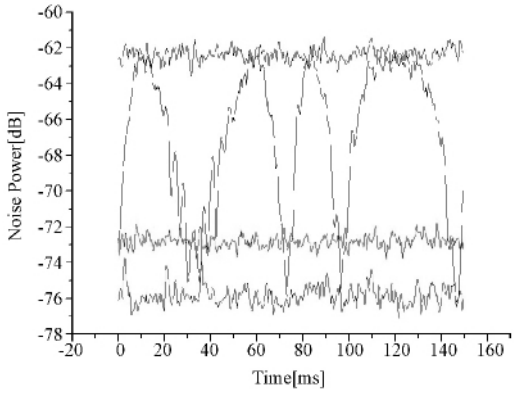


图3

考虑到光路传输损耗和探测器量子效率,由公式 $V_{sq}=\frac{V_{sq,\det}-1+\eta}{\eta}$ [13] 可以计算出 OPO 实际输出的压缩应为 3.8 dB. 式中 $V_{sq,\det}$ 为探测器测量的实测噪声,η 为系统的探测效率.

2 总 结

我们使用内置 PPKTP 晶体的 SPOPO 获得了正交振幅压缩光,压缩度为 2.9 dB,考虑到传输效率、探测器量子效率、平衡零拍干涉效率等因素 OPO 的直接输出压缩度应为 3.8 dB. 由图 3 易知,噪声幅度的起伏较大以及系统的探测效率是影响最后测量结果的主要因素,改善以上因素可以得到质量更高的正交振幅压缩态.

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Generation of Quadrature Squeezed States by Using Femtosecond Optical Comb

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Abstract

Squeezed states is an important non-classical states in quantum optics. It has been generated in the experiment

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Recalculate the Position of the Viewfinder Gridlines

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Abstract

In order to facilitate photographers while framing reference to determine the location and range of motion picture fun center in camera and video camera viewfinder are designed thirds screen grid lines, they are positioned to the side length of one-third of the picture that the "Rule of Thirds." Many scholars say that its source is the golden section on the specific application of the principle of split screen, because 0.382≈1 \ 3; however, there are nearly 0.05 gaps between 0.382 and 0.333, do so from a mathematical perspective it is not enough rigorous. If the golden section principle of the most popular "perfect triangle Rule of Thirds" in the picture and the Fibonacci spiral contraction point of the curve is introduced into the split screen, we assume that the center of gravity of the human eye binocular vision is the center of the screen visual interest, error correction by experimental observation may bring; can be calculated by mathematical mean they are no longer distributed in the ratio of 28∶44∶28 by the picture but to distribution. The new division will provide a more convenient way and quick reference picture composition digital imaging device when switching between different frame shooting.

Key words: composition of camera picture, focus of binocular vision, fun center of the screen, the position of the gridlines, the style box with golden section.

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by using different methods. Due to the uncertainty principle of quantum mechanics, no matter how better the light is,there will be noise. A quadrature component fluctuations of the squeezed light can be reduced at the cost of the increase of the other quadrature component. Our paper investigates the generation of squeezed light field by using parametric down conversion process pumped by femtosecond pulses laser. Femtosecond laser has high Accuracy by itself. Moreover, with squeezed states, it will have lower noise. The measurement accuracy can be further increased by improving the detection and transmission efficiency. The investigation can be applied in weak signals measurememt, quantum communication and quantum information processing.

Key words: Squeezed states, femtosecond comb, OPO.

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