Single stable axial mode operation of a high power Nd: YAG oscillator by injection locking

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We have successfully operated a Q-switch high power unstable resonator Nd: YAG oscillator in a Fourier Transform limited bandwidth single axial mode. The measured optical bandwidth was 50 MHz at 1.064 μm for a 150 mJ, 9 nsec pulse at 10 pps. The key to successful stable single axial mode operation was the use of injection locking in place of the more usual application of spectral selective elements within the resonator.

Our studies have shown that two effects are present in the high gain unstable resonator Nd: YAG source which inhibit stable single axial mode operation by usual techniques. The first is the diverging wavefront of the unstable resonator cavity results in loss due to the spectral selecting element and also limits the spectral resolution. The second is that under high gain operation Nd: YAG 1.064 μm transition is not homogeneously saturated. Thus a greater degree of spectral selection is required if the laser is to maintain a stable single axial mode.

Injection locking with a low power single frequency 1.064 μm input provides adequate spectral selectivity to insure stable single mode operation. Figure 1 shows the pulse power of 200 consecuetive Q-switched pulses, its Fourier transform, and the measured optical spectrum using a scanning confocal interferometer. The Fourier transform limited linewidth was further verified by measurements at other Q-switched pulses lengths.

Our studies of the injection locking theory led to an understanding of transient injection locking of a high gain laser source. The theory predicts that the slave oscillator (unstable resonator oscillator) will not oscillate at the master oscillator frequency as in steady state injection locking, but will oscillate at a frequency determined by the slave oscillator cavity length. Experimental measurements confirmed the theory.

We are applying the single mode unstable resonator laser to spectroscopic studies of Stimulated Raman Scattering and to Molecular Beam Coherent Anti-Stokes Raman Scattering (CARS). The single axial mode unstable resonator Nd: YAG source is useful for a wide variety of high resolution spectroscopy studies due to its peak power stability, frequency stability and ease of frequency conversion via nonlinear optical methods.

注入锁定高功率 Nd: YAG 振荡器的稳定单纵模运转

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我们成功地使Q开关高功率非稳定谐振腔 Nd:YAG 振荡器以傅里叶变换极限带宽单纵模来工作。在每秒 10 个脉冲数目下,对于 150 毫焦耳、9 毫微秒的脉冲测得 1.064 微米时光学带宽为 50 兆赫。成功进行稳定单纵模工作的关键是采用注入锁定来代替谐振腔内通常使用的谱选择元件。

我们的研究表明,高增益非稳定谐振腔 Nd:YAG 激光源中呈现的两种效应阻碍了以通常的技术来进行稳定单纵模工作。第一个效应是非稳定谐振腔的发散波前致使谱选择元件造成损耗而且限制了谱分辨率。第二个效应是高增益工作下 Nd:YAG1.064 微米跃迁不是均匀饱和。于是如果要激光器维持稳定单纵模,就要求有较大程度的谱选择。

以低功率单频注入锁定 1.064 微米输入提供足够的谱选择性保证稳定单模工作,图 1 表明 200 次Q开关脉冲得到的脉冲功率,它的傅里叶变换,和采用扫描共焦干涉仪测得的光谱。经在其它Q开关脉冲长度下测量,进一步证实了傅里叶变换极限线宽。

我们就注入锁定理论的研究导致对高增益激光源瞬时注入锁定的理解。理论预言从属振荡器(非稳定谐振腔振荡器)不象稳态注入锁定以主振荡频率振荡,而是以从属振荡器腔长所确定的频率来振荡,实验测量进一步证实了理论。

我们把单模非稳定谐振腔激光器应用于受激喇曼散射和分子束相干反斯托克斯喇曼散射(CARS)作光谱研究。对于种种高分辨光谱学研究,由于单纵模非稳定谐振腔 Nd:YAG 激光源峰值功率稳定性、频率稳定性以及容易通过非线性光学方法来进行频率转换,故该种激光源是有用的。