FQ5 Coupled cavity mode locking of a Nd:YAG laser using second harmonic generation

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Recently it has been demonstrated that intracavity second harmonic generation (SHG) in a Nd:YAG laser can lead to mode locking with pulse durations of $\simeq$100 ps at 532 nm.[1,2] Ohter work has shown that nonlinear processes in an external coupled cavity can effectively mode lock a laser.[3,4] These two mechanisms are combined to mode lock a Nd:YAG laser using SHG as the nonlinearity.

The experiment uses a long pulse Nd:YAG laser with a pulse duration of 5 ms and peak power of 100 W. The coupled cavity is formed by placing a retroreflecting mirror a distance equal to the length of the laser beyond the output coupler. This ensures that pulses injected back into the laser are synchronous with the circulating pulses. The retroreflecting mirror is a high reflector for 532 nm and has a reflectivity of $\simeq$10% for 1.064 μm. An intracavity lens ensures that there is a waist on this mirror which provides good coupling back into the main laser. The SHG crystal (3- × 3- × 5-mm^3 KTP crystal cut for type II doubling) is positioned near this mirror to give good SHG conversion efficiency.

Adjustment of the crystal–mirror separation over the 2–6-cm range provides intermittent mode locking of the Nd:YAG laser. Mode locking occurs when the coupled cavities have the correct phase relationship. This feature has been observed experimentally in solitonlike lasers[4] and has been predicted for coupled cavity mode locking incorporating a nonlinear element.[3] The phase varies due to mechanical vibration and thermal loading of the Nd:YAG rod, and this enables mode locking to occur at one or more points during the 5-ms pulse. Mode locking is accompanied by self-*Q*-switching and results in a pulse with a FWHM of 700 ns, which is 100% modulated by the laser round trip time (7.6 ns). This behavior may be the manifestation of a fundamental instability characteristic of passively mode-locked solid state lasers.

The cw power required to induce mode locking is ~16 W, which could be reduced by a factor of 4 or more in an optimized setup. This places this technique of coupled cavity SHG mode locking within reach of cw Nd:YAG lasers.

The pulse length, averaged over the pulse train, has been measured using autocorrelation techniques to be 70 ± 15 ps (assuming a Gaussian pulse shape). Since the pulse energy and pulse duration are varying throughout the pulse train further experiments are planned to measure the pulse duration throughout the train. The influence of varying the length of the external cavity by small amounts from the synchronous case ($\simeq\pm$ 1 mm) will be studied because this can prevent the laser from mode locking.

Further work on the dynamics of the mode-locking process, the importance of the relative phase, and the correct crystal–mirror separation, and the ultimate pulse length limitations is in progress and is reported. **(12 min)**

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4. P. N. Kean, R. S. Grant, X. Zhu, D. W. Crust, D. Burns, and W. Sibbett, in *Postdeadline Papers, Conference On Lasers and Electro-Optics* (Optical Society of America, Washington, DC, 1988).