Q-switching of a Nd:YAG laser with a ring resonator using external stimulated Brillouin scattering

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1. Introduction

During the past fifteen years the interest in solid-state phase-conjugation lasers has been growing due to the increased demand of high quality beams for both scientific and technical applications [1].

The use of intracavity phase-conjugating mirrors (PCM) is very important because they will improve directly the output beam from resonators by compensating the internal phase distortions.

Phase conjugate laser resonators using stimulated Brillouin scattering (SBS) have been the subject of numerous investigations in recent years. PCM based on stimulated Brillouin scattering is easier to achieve in comparison with a PCM based on four-wave mixing which requires two references beams, thus an additional laser is needed. Beside potentially achieving a good beam quality, a further interesting feature provided by the SBS mirrors is self Q-switching.

The approach usually adopted is to include the SBS medium inside a laser cavity with a secondary mirror employed to provide feedback at the beginning of the laser action [2,3]. High intra-cavity intensities experienced by the SBS medium in this configuration can lead to poor spatial beam quality. This limits the repetition rate and peak power of the output. Recently there has been reported an alternative cavity configuration in which SBS medium resides outside the conventional cavity [4,5]. The output beam was found to have a TEM00 mode and efficient energy extraction at very high repetition rate using high purity SBS media.

The cavities used till now are linear and each round trip the laser beam travels within this cavity will generate a downshifted Stokes beam.

We have investigated experimentally the performance of a pulsed Nd:YAG laser system utilising stimulated Brillouin scattering for Q-switching and phase conjugation of the cavity radiation.

A novel feature of this system is the use of a ring cavity configuration that allows the potential of single frequency operation from the resonator.

2. Experimental set-up

The experimental set up is depicted schematically in Fig. 1. The four plane mirrors with reflectivity $R \approx 100\%$ and the Nd:YAG rod with a small signal single pass gain of about 100 define the ring cavity. The Nd:YAG rod with a 6 mm diameter and a 90 mm length is pumped by a flash lamp in a diffuse, liquid cooled cavity. The radiation at 1.06 μm is outcoupled by a half-wave plate – polarizer combination which provides an easy way to optimise the output energy by adjusting the coupling transmis-

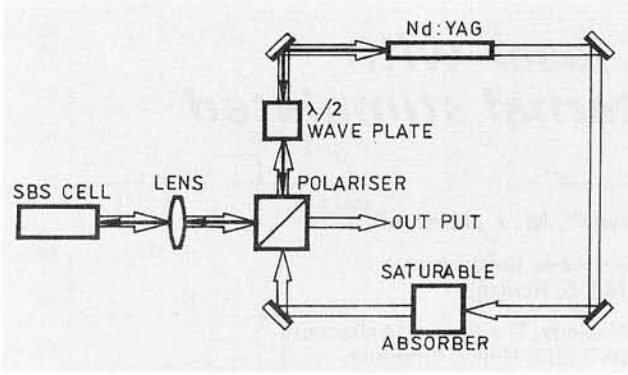

Fig. 1. Setup of the ring laser with external SBS

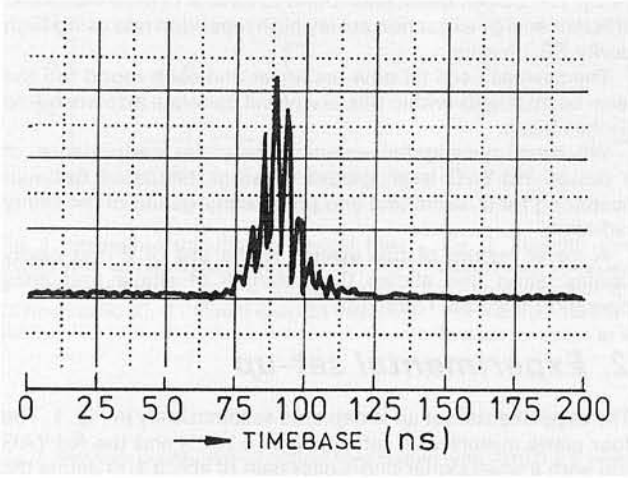

Fig. 2. Temporal structure of the laser pulse

sion, including the final Brillouin reflectivity. The Brillouin cell (L=10 cm) filled with CS_2 is placed behind a lens, which has a focal length of 10 cm, outside the ring cavity. We chose CS_2 as nonlinear medium because of its relatively large gain coefficient (about 0.04 cm/MW) for Brillouin scattering. This cell acts as both a phase conjugate mirror and as a Q-switch.

The Brillouin backscattering radiation returned to the ring resonator has been extracted through the polarizer cube to be analysed. A fast photodiode and a LeCroy digital oscilloscope have been used to monitor laser pulse durations. Mollectron detectors have been used to measure laser beam energies. The transversal structure of the output radiation was monitored by a CCD camera and a SPIRICON system.

3. Experimental results and discussion

The energy entering the Brillouin cell was about 120÷130 mJ in the form of relaxations oscillations pulses with duration of the order of 200÷300 ns. This output power proved not to be enough to onset the SBS process so we use a saturable absorber to start the Q-switching of the cavity.

A notable enhancement of the Q-switching effect was observed by increasing the side coupling to the Brillouin cell, through the half-wave plate rotation.

The laser visible in Fig. 1 starts in the free-running mode with a low Q factor determined by the losses of the cell and of the saturable absorber. The SBS reflectivity of the cell increases rapidly with the incident wave intensity and the ring resonator with the Brillouin mirror reaches a high Q factor.

The output beam with an energy of 40 mJ in a pulse of 15÷20 nsec duration was obtained at 2 Hz. At higher repetition rates Q-switching action become unreliable due to the fact that

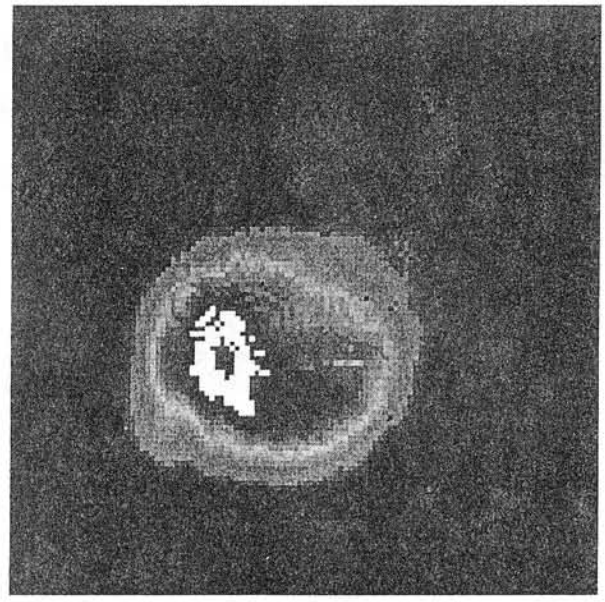

Fig. 3. Transverse structure of the laser beam in the near field

the saturable absorber was not circulated and excessive thermal loading may appear.

A typical output pulse with a width (FWHM) of 15 nsec is shown in Fig. 2. The Q-switched laser is partially modelocked indicating that there exist many longitudinal modes oscilating during the lasing process.

Under proper alignment of laser mirrors, and with an aperture of d=1,5 mm the laser can operate in the TEM00 mode, whose transverse structure, in the near field, is shown in Fig. 3. In this case the energy of the pulses diminishes to 5 mJ.

4. Conclusions

We demonstrated a SBS Q-switching of a ring resonator based on the gain material Nd:YAG. The power generated in the freerunning regime proved to be not enough to rich the threshold of the SBS process in the cell. However, we succeed to start operation of the laser in the Q-switching regime using a saturable absorber.

The repetition rate was set at 2 Hz. Higher repetition rates caused the beam quality to deteriorate and the Q-switching action become unreliable.

In this configuration just a single Brillouin shift occurs which shows the potential for operation of this phase conjugation cavity in a narrow frequency bandwidth.

Further work is required to exploit the full potential of this configuration.

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