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SBS Q-switched Nd:YAG laser

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Abstract. The construction and characterization of operation of a reliable SBS Q-switched Nd:YAG laser was done. The Q-switching was realized by SBS phase congugation in SF_6 gas. The conditions for stable operation are discused.

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1. Introduction

Since 1972, when the phenomenon of optical phase conjugation (PC) was discovered by Zel'dovich *et al.* [1], many theoretical and experimental works dealing with several aspects of it have been published. The two most commonly used methods to produce PC are based on degenerate four-wave mixing (DFWM) or stimulated Brillouin scattering (SBS) [2,3]. In particular PC by SBS has attracted much attention in recent years [4]. In addition to well-known properties of PC such as correction of spatial aberrations, PC by SBS has been shown capable of producing high reflectivities and high phase-congugate fidelities [5,6]. Unlike PC by DFWM where good quality pump beams and critical alignment is required, PC by SBS is a rather simple experimental technique. One of the most interesting application of PC by SBS is the construction of full or half resonant PC laser cavities (*i.e.* cavities where both or one of the mirrors is a PC mirror), where phenomena such as pulse compression or Q-switching can occur [7–9].

In this paper we report the construction and characterization of a reliable Q-Switched Nd:YAG laser where the Q-switching is achived by an intracavity SBS mirror using SF_6 gas as PC medium. We belive that an additional advantage of this way of obtaining Q-switching in relation to conventional ones using electro and acousto optical devices is its experimental simplicity and low cost.

2. Laser

The laser was build-up using a Nd:YAG rod of diameter 9.5 mm and length 65 mm pumped by a Xenon flash lamp inside a water cooled eliptical cavity. The pulsed electrical input energy for the lamp was 60 J. Two flat mirrors M_1 and M_2 of reflectivities 16% and 100% at 1.06 μm separated by an optical distance L of 120 cm were placed as it is shown in Fig. 1. The 150 mm long stainles steel SBS cell was

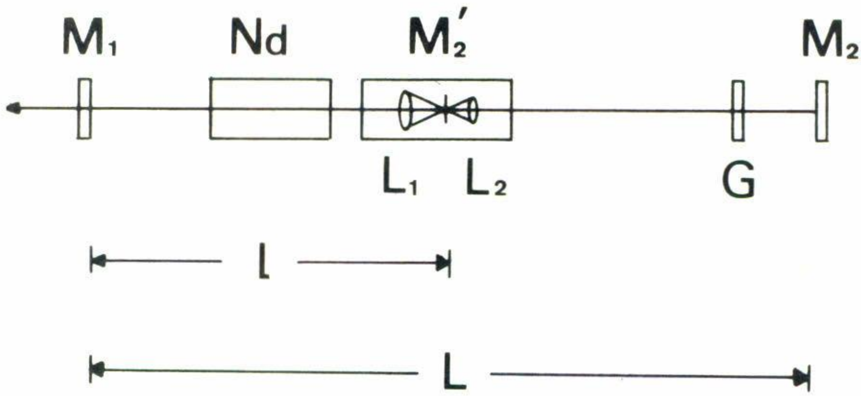

FIGURE 1. Set up of the Laser with an SBS phase conjugation mirror.

filled out with SF_6 gas at 20 bar and two lenses L_1 and L_2 of focal lengths 30 and 20 mm were placed inside the cell separated each other by 60 mm. Lenses L_1 and L_2 form a telescope with real focus and this focus defines the position M_2' of the SBS PC mirror. The SBS cell was placed inside the resonator formed by M_1 and M_2 dividing it into two parts of optical lenght $l = L/2 = 60$ cm. The length l between mirror M_1 and M_2' define the PC resonator. G is an attenuation glass plate with 30% transmition.

When pumping of the Nd:YAG rod just starts the laser is in free-running regime between mirrors M_1 and M_2. In this situation the SBS gas cell and the G plate are losses inside the cavity causing a low Q cavity value. The interference of the counterpropagating fields in the focus of the SBS cell causes the excitation of acoustic waves. Since the longitudinal mode frequency separation of the resonator with length L is $\pi c/L$, a pair of modes with frequencies v_i and v_{i-m} will resonantly build up an interference acoustic grating if

$$v_i - v_{i-m} = m(c/2L) = v_B \tag{1}$$

where v_B is the ultrasound frequency (Brillouin shift) of the medium (Fig. 2). For SF_6 v_B is 250MHz. This accoustic wave reflects the forward propagating wave of frequency v_i into its Stokes wave of frequency $v_i - v_B$ (Fig. 2). In this way the reflectivity of the SBS cell increases exponentially with the incident wave intensity and a new high Q resonator is formed between mirrors M_1 and M_2'.

From expresion (1) we can see that for $v_B = 250$ MHz L can be chosen as 60 cm, 120 cm, 180 cm, etc. In our experiment the tolerance to this value was ± 5 cm and we assume that the higher the gain of the laser the less rigourous this requeriment is.

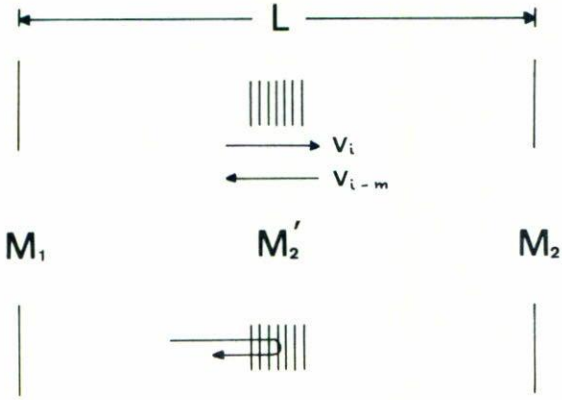

FIGURE 2. Generation mechanism of a SBS phase conjugation mirror.

3. Characterization

The temporal structure of the laser pulse was detected using a fast-PIN photodiode and a Tektronix transient digitizer Mod. R7912. When the laser was operated without the SBS Cell showed in Fig. 1, the laser pulse obtained was a 200 μmsec FWHM pulse. Once the SBS Cell was placed as showed in Fig. 1, the laser pulse obtained was a 15nsec FWHM pulse (Fig. 3). When the laser was operated without the attenuation glass plate G the temporal structure of the output pulse was spiking as it is shown in Fig. 4. This is probably due to the fact that in this situation SBS PC starts too early when there is not enough population inversion in the active medium, therefore, only a weak Q-switching occurs and several pulses are emitted. In order to ensure that only one single Q-switched laser pulse is emitted we must retard the operation of the SBS PC mirror (*i.e.* retard the time when the SBS thereshold is reached) by increasing the losses of the resonator formed between mirrors M_1 and M_2. In this way, when the SBS PC mirror reaches a high reflectivity value the active medium is fully populated and a single laser pulse is emited.

The laser constructed was able to operate in TEM_{00} mode with 100 mJ output energy (measured with a Laser Precision energy radiometer Mod. Rk 3232) at a repetition rate of 5 Hz with an energy stability of $\pm 5\%$. The beam divergence was estimated to be smaller than 3×10^{-4} rad. Fig. 5 shows the transversal modes TEM_{00} and TEM_{01}. By missalignement of the mirrors M_1, M_2 and the SBS cell the laser can operate at higher order TEM modes.

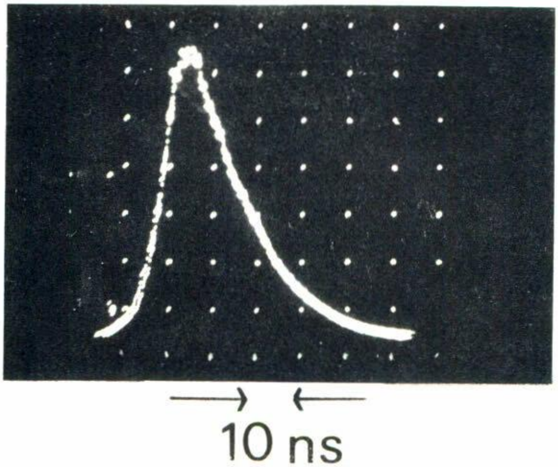

FIGURE 3. Temporal profile of a single Q-switched laser pulse obtained when the attenuator G is present.

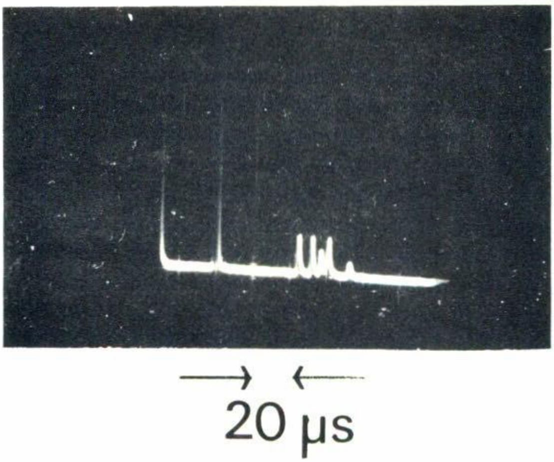

FIGURE 4. Temporal profile of multiple Q-switched pulses obtained when the atenuaton G was absent.

4. Conclusion

The construction and characterization of operation of a SBS Q-switched Nd:YAG laser was done. The Q-switching was realized by PC in an SBS SF_6 cell obtaining stable operation at TEM_{00} with 100 mJ and 10–20 nsec pulses at a repetition rate up to 5 Hz.

It was found that the primary resonator must satisfy a length matching condition depending on the Brillouin shift of the SBS medium.

FIGURE 5. Transverse structure of the laser beam for the TEM_{00} and TEM_{01} modes.

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Resumen. Fue realizada la construcción y caracterización en operación de un láser de Nd:YAG Q-switcheado por SBS confiable fue realizada. El Q-switcheo se realiza por medio de conjugación de fase por SBS en gas SF_6. Se discuten las condiciones para operación estable.