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Fluctuation of colliding-enhanced YAG phase-conjugate ring cavity in primary resonator stability

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In this paper, we report on a colliding-enhanced cavity. The fluctuation of output energy and divergence angle are in accordance with primary resonator. The results of output energy and fluctuation under different conditions are given.

Keywords: SBS, colliding-enhanced cavity, fluctuation, primary resonator.

1. Introduction

For many years, phase conjugation has been demonstrated to be a useful technique for the correction of wavefront aberrations in optical and laser systems. Stimulated Brillouin scattering (SBS) is widely used as a convenient method for phase conjugating pulsed laser radiation [1]–[4]. The process can be efficient at moderate powers, and high-fidelity phase conjugation can be achieved using a focused geometry or by propagating through a waveguide containing a Brillouin active medium [5]. In order to obtain steady output in phase conjugation cavity, wasting of primary cavity should be higher and wasting of phase conjugation cavity should be lower [6]. There are two ways to enlarge the wasting of primary cavity, one is to choose appropriate parameter and collocation of optical element of primary cavity so that the latter becomes unstable, and the diffraction wasting is large for high-order transverse modes and small for low-order transverse modes. The other way is to place an attenuator between SBS-cell and back cavity mirror, while this way is of no benefit to low-order transverse models [7]. So, we can see that unstable cavity is superior to using attenuator, it can ameliorate the effect of Q-switch and improve the quality of output beam [8].

2. Experiment

The experimental arrangement is shown in Fig. 1. The center wavelength of coating of high reflecting mirror M_1, M_2, M_3 is 1.064 μm, the bandwidth of which is 100 nm. F is a thin lens, and the SBS-cell is filled with liquid medium. The length of Nd:YAG rod is 100 mm, and its diameter is 7 mm. The beam splitter BS_1 has the splitting ratio 1:1 at an angle of $\pi/4$. There are two resonance paths of static laser in the colliding resonator under free operating condition, which are $M_1 \rightarrow$ YAG $\rightarrow$ BS_1 (transmission) $\rightarrow M_3 \rightarrow$ SBS-cell $\rightarrow M_2 \rightarrow BS_1$ (reflection) $\rightarrow$ YAG $\rightarrow M_1$ and $M_1 \rightarrow$ YAG $\rightarrow BS_1$ (reflection) $\rightarrow M_2 \rightarrow$ SBS-cell $\rightarrow M_3 \rightarrow BS_1$ (transmission) $\rightarrow$ YAG $\rightarrow M_1$. Parts of transmission and reflection beam when pass through the BS_1 for the second time act as the coupling output of the original colliding resonator. In Fig. 1, mirror M_2 and mirror M_3 are placed symmetrically to BS_1, and the SBS-cell is located at the midpoint between M_2 and M_3, at the same time the optical lengths of two resonance beams are equal, so they arrive at the SBS-cell simultaneously to collide. The focus of the lens is located at the midpoint of the SBS-cell. As the intensity of static cavity laser reaches the threshold, the two static beams interact in the SBS-cell to produce forward and backward phase conjugation light, and the SBS-cell turn into double reflection phase conjugate mirror. At this time, the colliding origination cavity changes into colliding phase conjugate resonator immediately, which also has two PCRs (phase conjugation resonators). The optical paths of PCRs are $M_1 \rightarrow$ YAG $\rightarrow BS_1$ (transmission) $\rightarrow M_3 \rightarrow M_{pc}$ (conjugate reflection) $\rightarrow$ $M_3 \rightarrow BS_1$ (transmission) $\rightarrow$ YAG $\rightarrow M_1$ and $M_1 \rightarrow$ YAG $\rightarrow BS_1$ (reflection) $\rightarrow M_2$ $\rightarrow M_{pc}$ (conjugate reflection) $\rightarrow M_2 \rightarrow BS_1$ (reflection) $\rightarrow$ YAG $\rightarrow M_1$. Part of transmission and reflection beam when pass through the BS_1 for the second time act as the coupling output of the origination colliding phase conjugate resonator.

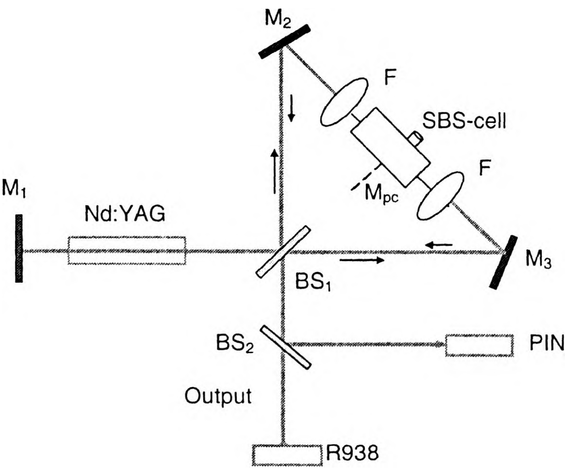

Fig. 1. Experimental scheme (BS – beam splitter, R938 – energy meter, PIN – photodiode detector, M – mirror, F – lens).

The Q-value of cavity is much lower at initial stages because of diffraction of intracavity and other deteriorations. While light intensity grows up to exceeding SBS threshold, intracavity Q-value will have mutation owing to reflectivity's rush and reduction of cavity length as well as phase distortion. Here the SBS-cell acts as both a back cavity mirror and a Q-switch. We measured the output impulse laser with Tektronix oscilloscope and the energy output with energy meter.

In the experiment, the center wavelength of coating of high reflecting plano -concave mirror M_1 (the curvature radius is 5 m, the length of ring cavity is 3.5 m) is 1.064 μm at first, that is the primary cavity is stable. The results of a single pulse the width of which is about 25 ns appear steady when the pump voltage is 750 V, and

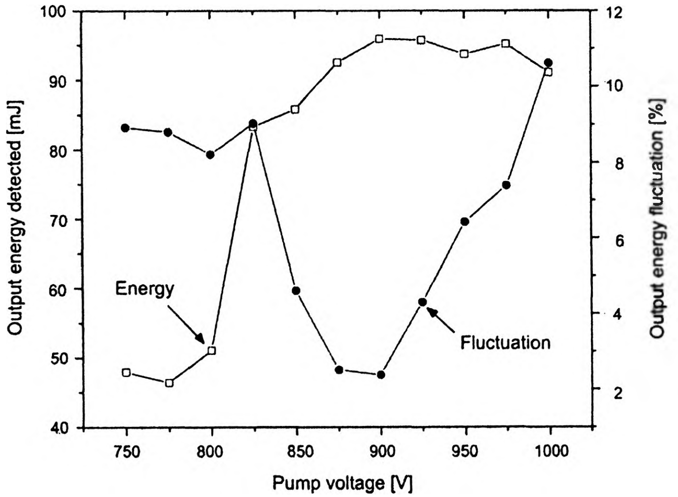

Fig. 2. Relationship between energy and its fluctuation with pump voltage of stable primary cavity.

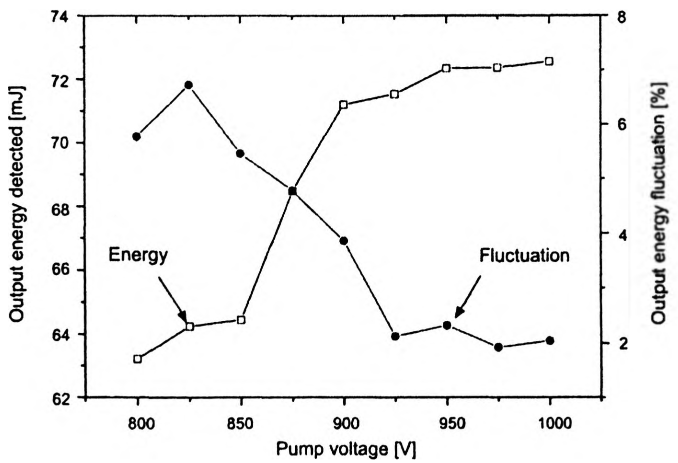

Fig. 3. Relationship between energy and its fluctuation with pump voltage of unstable primary cavity.

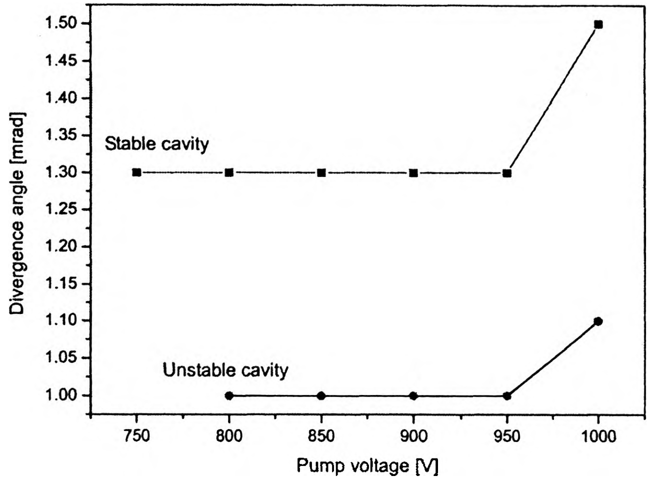

Fig. 4. Relationship between the divergence angles and pump voltages of two cavities.

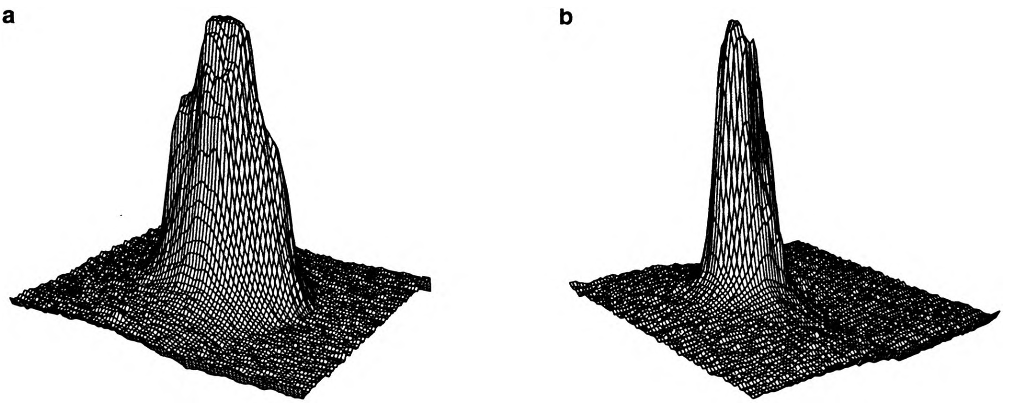

Fig. 5. Three-dimensional intensity profile of sports of far field corresponding to different primary cavities: stable cavity (**a**), unstable cavity (**b**).

output pulse width decreases with the higher pump voltage, the output energy and its fluctuations being shown in Fig. 2.

The output energies wave obviously at higher and lower pump voltage, which is because the grating formed is unstable at lower pump voltage and at high laser powers the onset of competing nonlinearities such as optical breakdown, thermal heating can also lead to energy fluctuation. As the mirror M_1 changed to plano-convex mirror (the curvature radius is –3 m, the length of ring cavity is 3.5 m) is 1.064 μm, the primary cavity is unstable. The results of a single pulse whose width is about 25 ns appear steady when the pump voltage is 800 V, and output pulse width decreases with the higher pump voltage, the output energy and its fluctuations being shown in Fig. 3. And we can see the fluctuation of energy is lower, and the fluctuation of it is below 4%, which is because the high-order models diffract and the output is a low-order model. So, the fluctuation of output energy is down. The profile of sports of far field and divergence angles are also measured. We can also see that the divergence angles are small and the 3D intensity profile of sports of far field is improved as the primary cavity is unstable (Figs. 4 and 5).

3. Summary

Summing up, the colliding-enhanced resonator is a novel PCR that produces steady passive Q-switched pulse. The fluctuation of output energy and divergence angle is according to primary resonator, when the primary cavity is unstable, the fluctuation of energy is lower and the divergence angle is small, the output energy is improved obviously, and it offers reference to design phase conjugation cavity.

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