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Experimental Evidence of an Optical Bistability Based on Self - Focusing

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Abstract:

Optical bistability based on Self – Focusing of low power CW He-Ne laser radiation ,at the wavelength of 0.632µm ,has been experimentally evidence in liquid CS_2 using a new simple and effective technique. New experimental results supporting the hypothesis that optical bistability based on self –focusing of laser radiation occurs in liquid are present in this article. Mirrorless limiting mode is observed too.

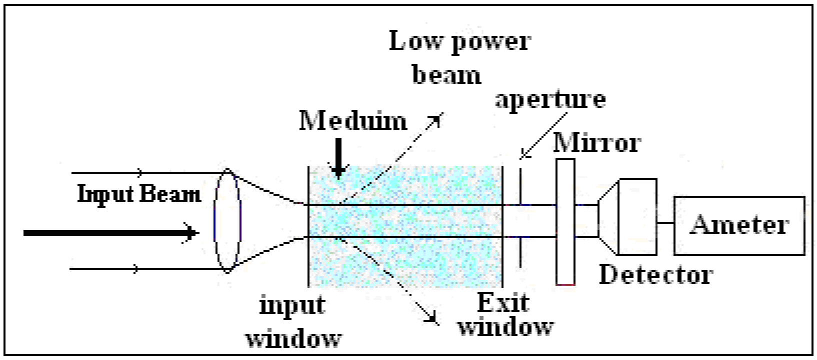
Keyword: Optical bistability; Self – Focusing; CS_2 liquid; Mirrorless limiting

Introduction:

Optical bistability (OB) in a system arises as a result of the nonlinear dependence of the response (transmission, reflection ...etc.) on the input power .The basic mechanisms responsible for the nonlinearity are numerous, as reviewed by Chang [1]. Almost all studies involve a resonant medium or a resonant cavity (a Fabry-Perot).The first reports on optical bistability were due to Sedil [2] and Szoke [3] in 1969 and 1974 respectively. Optical bistability can be displayed by a number of techniques: using a Fabry Perot resonator cavity filled with various media[4], in a microwave cavity[5], using a nonlinear interface[6] , in lasers with intracavity saturable absorbers[7] and incoherent mirrorless optical devices[8] ,These methods were studied extensively but the method of optical bistability based on self focusing is rarely mentioned[9,10].

The purpose of the present work is to present experimental evidences of observing optical bistability in CS_2 liquid based on the effect of self-focusing [11-18].

Principles of operation: self focusing occurs when a light beam having a uniform spatial profile (such as a Gaussian laser beam) and sufficient intensity propagates through a nonlinear medium having an intensity dependent index of refraction. Previously proposed devices that exhibited intrinsic bistability are operable in principle with light beams having uniform intensity profiles. The new class of devices used in the present work (Fig.1) differs from previous intrinsic devices in that the earlier devices have all required resonant optical cavities[4] ; no such cavity is required for this class of devices. In principle, eliminating the resonant cavity removes restrictions on tuning the light frequency and offers the potential for broad – band operation.



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The basic principles on which the new class of devices operates can be understood from a simplified discussion based on the schematic diagram of Fig. (1). A laser beam of power P_{in}, assumed to have a Gaussian intensity profile, is focused inside a medium having an intensity dependent index of refraction. For self-focusing to be possible the refractive index must increase with increasing light intensity. A measure of the strength of this nonlinearity is called the critical power(4), P_{cr}. When $P_{in}=P_{cr}$ the input laser beam passes through the medium with no change in spot size, this situation is referred to a self – trapping(18). For $P_{in}< P_{cr}$, the laser beam diverges less rapidly than it would in the absence of the nonlinearity(dash trajectory in Fig.(1)) ,and for $P_{in}>P_{cr}$ the beam converges(continuous trajectory). Essentially, for $P_{in}<< P_{cr}$, there is no self – focusing.

Experimental:

He-Ne laser used in the present work emits 6328A^0 red light (Coherent C325) .The output power was focused using 5 cm focal length converging lens 1 cm inside the cell (10 cm in length and 5 cm diameter).The aperture and the 90% reflectivity mirror were aligned behind the exit window perpendicular to the device axis 1 cm and 4 cm respectively with respect to exit window. The output of the laser was varied using a variac to vary the input voltage to the laser. The output of the laser was normalized with respect to input voltage. A photo diode and a kyoritsu digital multimeter model 1001 (200 μamp) were used for normalization procedure and for the measurements of the output power transmitting from the aperture (<2 mm diameter)

Results and discussion:

The diameter of the laser spot size at the focal point is 1 mm and 8 mm on the aperture in the absence of CS_2 while it is <3mm on the aperture in the presence of CS_2 .Fig.(2a) shows the result of P_{out} versus P_{in} without the mirror but Fig.(2b) shows the relation between P_{out} and P_{in} using the mirror .The aperture diameter was chosen for two reasons, firstly, it must be small enough so that in the absence of self focusing the fraction of the incident beam fed back into the medium by the mirror is small . Secondly, it is large enough that under self-focusing most of the beam passes through and back reflected by mirror. This feedback reinforces the self- focusing in the nonlinear medium even though the input power is below P_{cr} .This is the mechanism that gives rise to the optical bistability (hysterices). As the input power was increased upward switching from a low transmission state to a high transmission state occurred at an input power of about 0.28 mWatt. At the switching, the transmission level increased by 3.5 times .The reduction of the input power resulted in a downward switch at about 0.2 mWatt (Fig.2b).

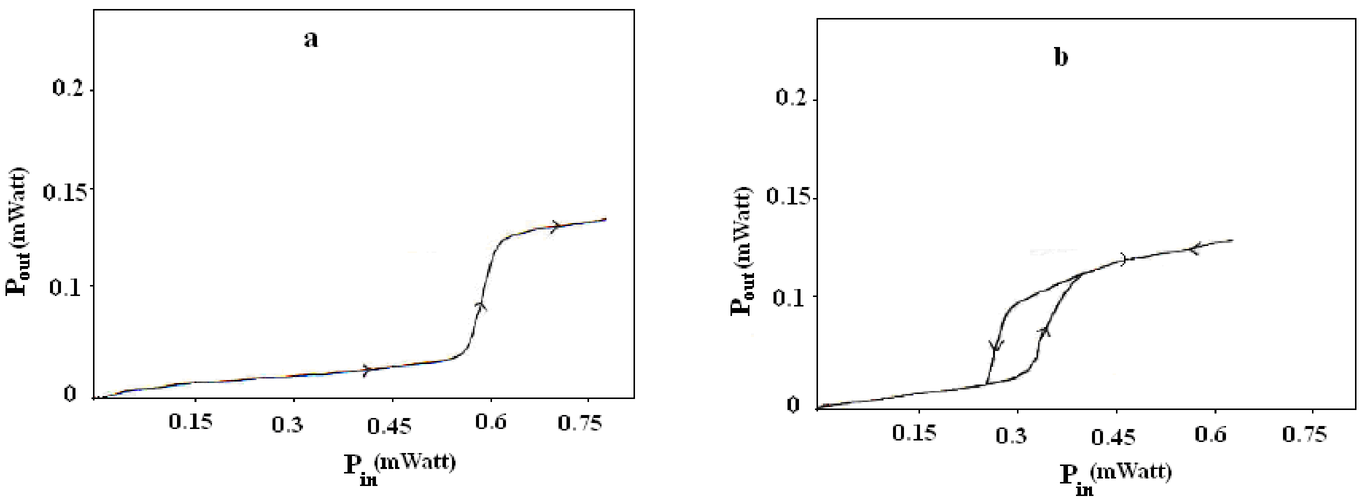

Figure (2): Experimental curve of P_{out} versus P_{in} (a) without the mirror showing the optical limiting mode of the mirroless situation. (b) With the mirror in place so that the deviceexhibits bistable operation.

In the absence of the mirror, the optical limiting mode of the mirrorless situation is shown in Fig.(2a).The switching upward or downward time cannot be measured unless the input amplitude is modulated at certain frequency, devices such as the one we have discussed above are of particular interest because of their potential for ultrafast switching. Given a suitable medium having a sufficiently strong nonlinearity, these devices would be scalable to short lengths giving the potential for fast response time.

Conclusion:

Optical bistability in CS_2, liquid is observed based on self- focusing effect with mirrorless limiting mode of operation.

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شاهد عملي على ثنائية الاستقرار البصري الناتجة عن التبؤر الذاتي

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الخلاصة:

أثبت عمليا حصول تاثير ثنائية الاستقرار البصري الناتج عن التبؤر الذاتي لطاقة أشعاع واطئه من ليزر الهليوم نيون ذو طول الموجي 0.632 مايكرومتر في سائل ثنائي كبريتيد الكاربون بأستخدام طريقة بسيطة مؤثره .النتائج العملية الجديدة في هذا البحث دعمت وأثبتت فرضية امكانية حصول ثنائية ألاستقرار البصري على اساس التبؤر الذاتي لأشعاع الليزر الحاصل في السائل . لوحظ كذلك العمل بالنمط المحدد بدون أستعمال المرايا.