DEVELOPMENT AND APPLICATION OF A NEW DEVICE FOR LIGHT CONTROL BY LIGHT (OPTICAL TRANSISTOR)

Margarita Angelova Deneva[1], Marin Nenchev Nenchev [1,2]

[1] Technical University – Sofia, Branch Plovdiv, 61 blvd. St.Peterburg, 4000 Plovdiv
[2] Institute of Electronics – Bulgarian Academy of Sciences, 72 blvd. Tzarigradsko Chausse, 1784 Sofia, Bulgaria, e-mail: mdeneva@yahoo.com

Keywords: light control by light , nanosecond rectangular laser pulses

We develop an original device for light control by light and describe its application to form a rectangular laser pulses with precisely varied duration in nanosecond scale. The device employs an idea that given volume near the limits of the gap in the Fabry-Perot Interferometer (FPI) wit high reflecting coatings (~ 92 - 97 %), can be illuminated by light in two essentially different ways – directly and through the mirrors. In combination with high sensitivity of the FPI transmission to the losses in the gap, this permits, using in the gap a saturable absorber,(SA), to obtain efficient control of the resonant beam that is incident through the mirror by the second beam, which directly illuminates the gap. We have shown that such devices can be successively created using as saturable absorber Cr^{4+} : YAG material. The variation of the controlled beam intensity with variation of the controlling beam increases more than of order of magnitude in comparison with a simple use only a saturable absorber.

1. INTRODUCTION

The development of simple methods and techniques for producing laser light in nano and subnanosecond pulses, especially with a rectangular shape and with precisely variable duration (~ 1 ns to few ten ns) is a question that is continuously under attention in the literature [e.g.1,2]. As it is well known, such pulses are of essential interest for use in testing systems in optics communications and in high speed optoelectronics as well as in the scientific investigations.

Here we describe an original and very simple for realization new approach for solving this question. On the base of our patent [3] we develop a simple original device, where the light is controlled very efficiently by light. We show especially the possibility to use for create such device in attractive way the relatively new saturable absorber Cr^{4+}:YAG with its typical production's parameters . Such absorber works at the wavelength (1.06 μm) of one of the most common lasers – Nd:YAG , what increases the practical importance of such study. Note that the light control by light, except the simplicity, presents the important advantage to avoid the influences of external magnetic and electric fields. In the work

2. THE PRINCIPLE OF THE Cr^{4+}:YAG DEVICE FOR LIGHT CONTROL BY LIGHT AND ITS CHARACTERISTICS.

In Figure 1 are shown simultaneously the picture that gives the principle of a proposed new interferometer type device for light control by light (DLCL) and the scheme of its use to produce a controlled rectangular nanosecond pulses.

The DLCL uses of one hand the high sensitivity of the Fabry-Perot interferometer (FPI) to the losses in the interferometer's gap. Our original idea is to use the possibility to illuminate chosen volumes of the limits of interferometer's gap in two quite different manners: i. through the interferometer mirrors (beam A- as it is shown in the figure); ii. directly in the gap (beam B). If the gap is filed by the saturable absorption medium and the mirrors are with a high reflection – e.g. 0.92–0.99 the beam B will influenced the saturable absorber transmission and respectively the FPI transmission drastically high because it illuminate the working volume more efficiently that the beam B (the last through the mirror). Thus, with the low power beam B we can control in efficient manner (or to open and stop) the FPI transmissivity for the beam A as we will sown below.

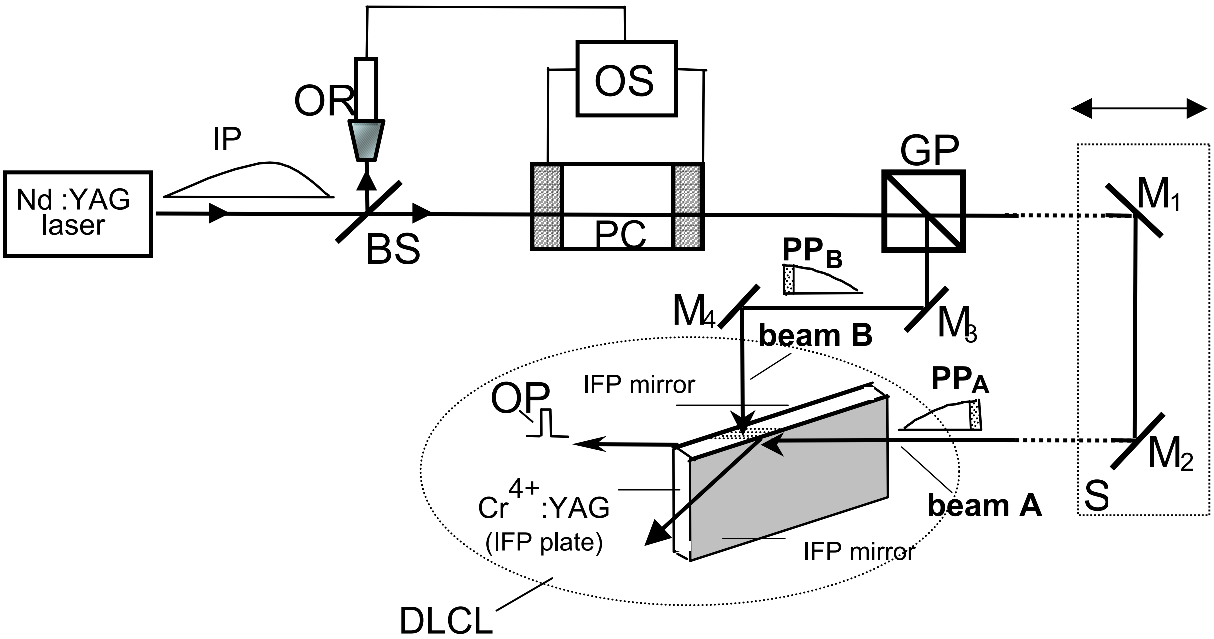

Fig.1. Schematic diagram of a Cr^{4+}:YAG interferometer device for light control by light (DLCL) and of the experimental set-up for forming controlled duration rectangular laser light pulse.

When the interferometer's gap is made of materials with a transmissivity a, the intensity I of the transmitted beam through the FPI is given by the expression [e.g.4]:

$$I = \frac{I_o \tau^2 a}{(1 - ar)^2 + 4ar\sin^2(\delta/2)}$$

where *Io* is the intensity of the incident beam , *r* is the reflectivity of the interferometer's mirrors, $\tau = 1 - r$, *a* is the coefficient of decreasing of the light intensity for one pass of the light thought the interferometer gap and δ is the faze difference [4] .

For the considered saturable absorber Cr^{4+}:YAG we have taken the typical its initial absorption dependences versus illuminating power from Ref. 5. For simplicity we will use directly in our calculation the experimental data for the dependences of the absorption of the sample of Cr^{4+}:YAG from the incident energy density (in J/ cm2 ; the pulse length is 20 ns at the wavelength 1.06 μm), given in the noted work in Fig.2.

The length of the sample is 0.265 cm. The non-saturated transmissivity for energy density of 0.01- 0.1 J/ cm2 is ~ 0.55 and the saturated transmissivity for high energy density than 0.5 J/ cm2 is ~ 0.85 . of used A well known calculation made by us from this dates gives for the value of nonsaturable coefficient of absorption α = 2.23 cm-1 for the energy of the illuminating light less than 0.1 J in 20 ns pulse (i.e. less than 5 MW). For high pump energy the absorption decreases and for 0.4 - 0.6 J in the same length pulses it is α = 0.61 cm-1. Thus the transmissivity of the saturated sample is high of this one of ~ 1.5 times. This will be the effect if we use in conventional manner the sample to control of light by light wit maximal controlled light variation intensity of ~ 1.5 times for any controlling intensities. Using our devices this effect can be increased to be of order of magnitude high ~ 15-17 times increase in for saturated and nonsaturated cases. As examples, some calculated transmissivities of DLCL T_{DLCL} are given in the TABLE .

TABLE

TRANSMISIVITY OF THE LIGHT CONTROLLED NEW Cr^{4+}:YAG DEVICE(T_{DLCL})

α (0,0 J/cm^2) = 2,36 cm$^{'1}$ α (0,1 J/cm^2) = 2,26 cm^4 α (0,5 J/cm^2) = 0,6 cm^4

Reflectivity of the mirror	Interferometer Thickness, mm	Illuminating beam energy density J/cm^2	Controlling beam energy density J/cm^2	Transmission %
0.99	0.4	0.5	0	1
		0.5	0.1	8.54
:				
0.99	0.2	0.5	0	3
		0.5	0.1	21
0.99	0.1	0.5	0	9
		0.5	0.1	40
0.92	2.65	0.5	0	1. 4
		0.5	0.5	12
0.5	20	0.5	0	1
		0.5	0.1	10

A few cases are considered – of different reflectivity of the FPI mirrors and different thickness of the FPI gap, made as a plate of Cr^{4+}:YAG. The calculation for each case are made for absence and for the presence of illumination by the beam B.

In Fig. 2 are plotted the calculated curves of the transmissivity T_{DLCL} for different energy densities and for few reflectivity R of the interferometer's mirrors as a parameter. The desired effect of strongly increased dependence of the transmissivity (~ 12 –15 times) from illuminating energy density is proved , taken into account the noted maximal its relative variation of ~ 1.5 for conventional use of the saturation effect.

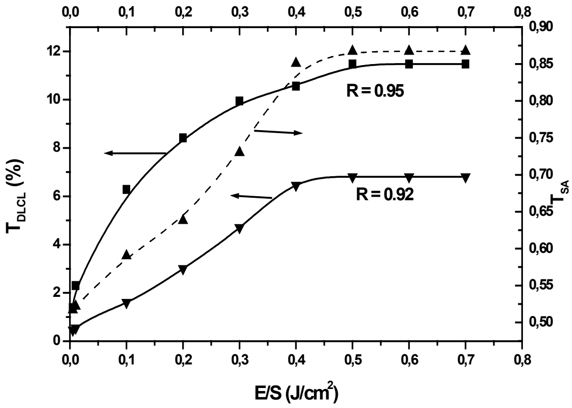

Fig.2 Transmissivity of DLCL as a function of illuminating energy density – solid lines, left scale. The same dependence for a SA – right scale

3. RECTANGULAR LASER PULSE FORMATION USING DLCL DEVICE

As an application of our device we have developed a promising technique (Fig.1) for producing rectangular pulses with precisely controlled length (~1 to 20 ns). The incident 20 – 50 ns pulse from conventional Q-switched Nd:YAG laser is spatially divided at two partial pulses PPA and PPB with a quick (~0.5 ns) fall front the first pulse and quick (~5 ns) start front the second one. This is achieved using the high speed Pockel's cell PC with a rise time of the polarization switching of ~ 0.5 ns and Glan Prism The input pulse energy and the focusing of the partial pulses in DLCL (not shown in Fig.1) are conveniently chosen, following the TABLE and Fig.2 to assure the high transmissivity during the illumination of FPI gap in DLCL by PPB . After passing the appropriate optical delay lines PPB bleaching the gap in the moment of the end of the FPI illumination by PPA and thus a rectangular part passes through FPI. By varying the length of the optical line we can vary the pulse length. This variation is with high precision due to the strong dependences of the delay from the easily and precisely controlled length of the delay line (1 cm correspond of 0.3 ns variation of the pulse length). The start and fall fronts of the formed pulse are given by the time of the polarization switching by the PC (~ 0.5 ns). The formed rectangular pulse can be amplified to very high powers with shape conservation using our injection-locking amplifier technique [6].

4. CONCLUSION

In the present work we have described and investigated en original and simple interferometer devices for attractive control of light by light that uses a Cr4+:YAG saturable absorber. We have shown that the original idea to exploit the possibility to illuminate a chosen volume in the Fabry_Perot interferometer's gap in two different manner in combination with use of noted absorption medium, permits to increases a variation of the saturable absorber transmission of more than of order of magnitude. As a one application we have presented a system with the new element that permits to produce a rectangular nanosecond pulses with high precisely controlled duration.

5. ACKNOWLEDGMENTS

The work is partially supported by the contract Ph.1305 NFNI.and partially by TU-Sofia – Br.Plovdiv.

6. REFERENCES

[1]. Delev A., M.Deneva, M.Nenchev, E.Stoykova, D.Slavov, *Tunable subnanosecond pulse generationin a dye laser using overlapped pump pulses,* Rev.Sci.Instrum., 2001, vol.72, pp.1253-1259 ;

[2]. Delev A., M.Nenchev, *Square nanosecond pulse generation in a tunable dye laser using two step laser pumping,* Proc.SPIE, 2000, vol.4397, pp. 74-78, and the literature sited therein

[3]. Nenchev M.,A.Gizbrekht, V.Tzanev.,*Dye laser pumped by compressed pulses,* Opt.Communications, 1987, 24, pp. 1957-1959

[4]. M.Nenchev, *Devices for laser light control,* Bulg. Patent No 90903/1990

[5]. Demtreder W., Laser Spectroscopy, 2-th edition, Springer, 1996

[6]. Mony A., *Cr4+:YAG as passive Q-switch and brewster plate, IEEE Journal Quantum Electronics, 1995, Vol. 31, pp. 1738-1741*

[7]. A.Boyadjieva, M.Deneva, M.Nenchev et al, Proc. SPIE , 2004, Vol. 5449, pp. 329-335